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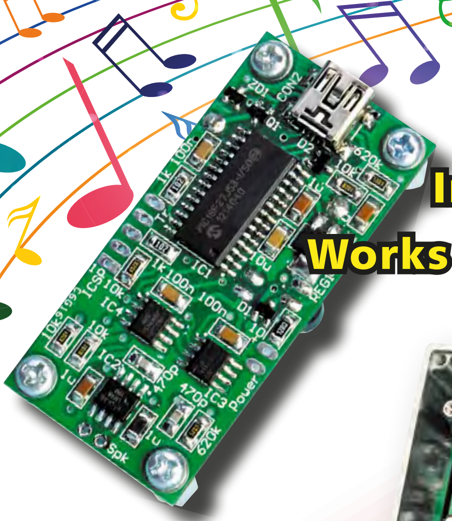

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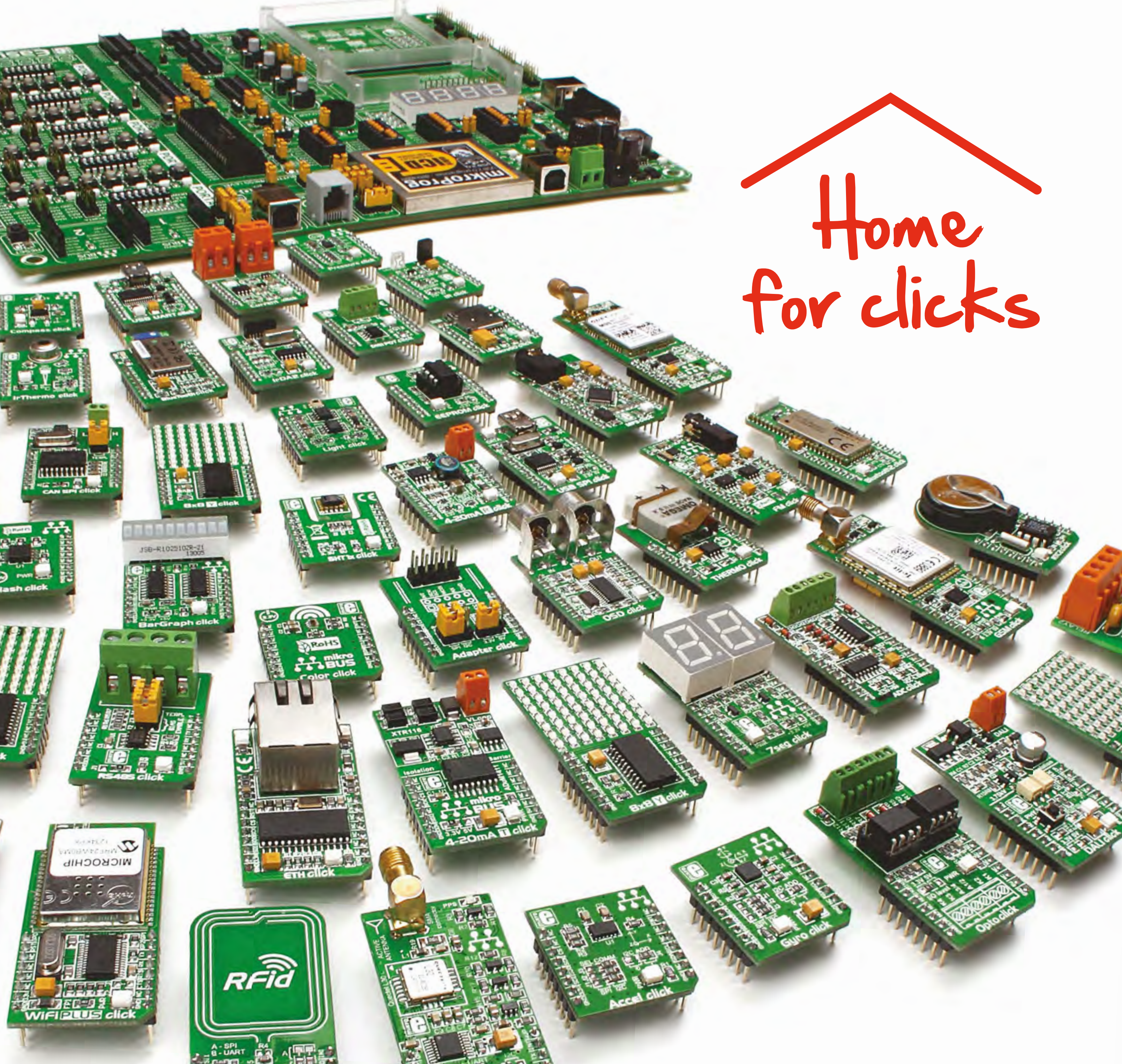

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ISSN 0262 3617

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● NEWS ● COMMENT ●
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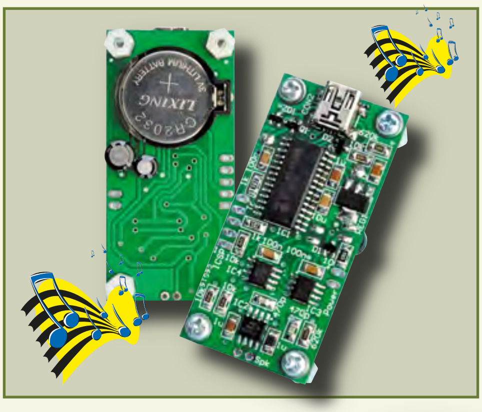

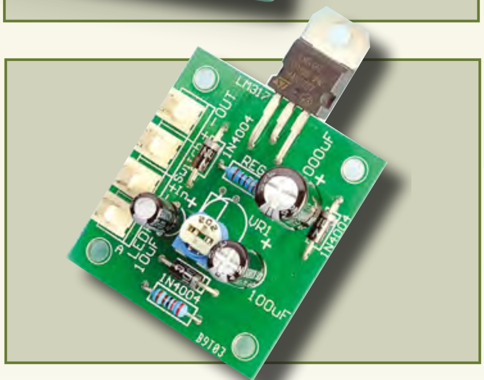

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Our October 2013 issue will be published on Thursday 05 September 2013, see page 72 for details.

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40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £22.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer

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

USB Flash PIC Programmer

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

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board

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

PIC Programmer & Experimenter Board

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

Controllers & Loggers

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 £10.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055NKT - **£27.95**
Assembled Order Code: VM110N - **£40.95**

Rolling Code 4-Channel UHF Remote

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

Computer Temperature Data Logger

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

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£10.72**

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

4-Ch DTMF Telephone Relay Switcher

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

8-Ch Serial Port Isolated I/O Relay Module

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

Infrared RC 12–Channel Relay Board

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

Audio DTMF Decoder and Display

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

3x5Amp RGB LED Controller with RS232

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

Hot New Products!

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.

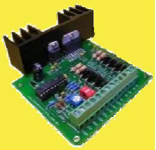
4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller. Four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay outputs are independent of sensor channels allowing flexibility to setup the linkage in any way you choose. Simple text string commands for reading temperature and relay control via RS232 using a comms program like Windows HyperTerminal or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

40 Second Message Recorder

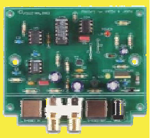
Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24Vdc powered. Change a resistor for different recording duration/sound quality. Sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver



Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner



Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£24.70**
Assembled Order Code: VM106 - **£36.53**

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

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

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.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more DC, AC and Stepper motor drivers

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Order Code EPL500 - **£179.95**
Also available: 30-in-1 **£17.95**, 50-in-1 **£29.95**, 75-in-1 **£39.95**, 130-in-1 **£49.95** & 300-in-1 **£79.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~£374.95~~ **£324.95**

Handheld Personal Scope with USB

Designed by electronics enthusiasts for electronics enthusiasts! Powerful, compact and USB connectivity, this sums up the features of this oscilloscope. 40 MHz sampling rate, 12 MHz analog bandwith, 0.1 mV sensitivity, 5mV to 20V/div in 12 steps, 50ns to 1 hour/div time base in 34 steps, ultra fast full auto set up option, adjustable trigger level, X and Y position signal shift, DVM readout and more...
Order Code: HPS50 - ~~£289.95~~ **£204.00**

See website for more super deals!

No.1 FOR KITS

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DIY KITS FOR ELECTRONICS ENTHUSIASTS

TEST & TIMER KITS

Transistor Tester Kit

Have you ever unsoldered a suspect transistor only to find that it checks OK? Troubleshooting exercises are often hindered by this type of false alarm. You can avoid these hassles with the In-Circuit Transistor, SCR and Diode Tester. The kit does just that, test drives WITHOUT the need to unsolder them from the circuit! VERY HANDY!

- PCB: 70 x 57mm

KA-1119 £10.25*

The 'Flexitimer' Kit

Now in it's 3rd revision by Jaycar, the flexitimer remains one of our most versatile short form projects. The flexitimer runs on 12-15V DC and switches the on-board relay once or repeatedly when the switching time is reached. Switching time can be set between 7 seconds and 2 hours in fixed steps.

- PCB size: 74 x 47mm

KA-1732 £7.25*

Garbage and Recycling Reminder Kit

Easy to build kit that reminds you when to put which bin out by flashing the corresponding brightly coloured LED. Up to four bins can be individually set to weekly, fortnightly or alternate week or fortnight cycle. Kit supplied with silk-screened PCB, black enclosure (83 x 54 x 31mm), pre-programmed PIC, battery and PCB mount components.

- PCB: 75 x 47mm

KC-5518 £11.00*

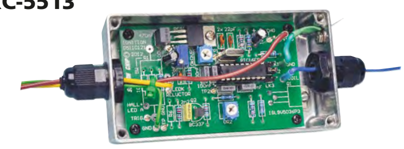
AUTOMOTIVE KITS

High Energy Ignition Kit for Cars

Use this kit to replace a failed ignition module or to upgrade a mechanical ignition system when restoring a vehicle. Also use with any ignition system that uses a single coil with points, hall effect/lumenition, reluctor or optical sensors (Crane and Piranha) and ECU.

- Kit supplied with silk-screened PCB, diecast enclosure (111 x 60 x 30mm), pre-programmed PIC and PCB mount components for four trigger/pickup options

KC-5513 £18.25*



Frequency Switch Kit

This is a great module which can be adapted to suit a range of different applications. It uses a standard tacho, road speed, or many other pulse outputs to switch a relay. The switch frequency can be set to trip when it is rising or falling, and it features adjustable hysteresis (the difference between trigger on/off frequency). Kit supplied with PCB, and all electronic components.

- PCB: 105 x 60mm

KC-5378 £14.00*

Car Battery Monitor Kit

Don't get caught with a flat battery! This simple electronic voltmeter lets you monitor the condition of your car's battery so you can act before getting stranded. 10 rectangular LEDs tell you your battery's condition.

- Kit includes PC board and all components.
- PCB: 62 x 39mm

KA-1683 £8.50*

Digital Fuel Mixture Display Kit

This brilliant dashboard-mounting unit monitors and displays your car's air-fuel ratio in real time on a three-digit display, as well as a bargraph for readings at a glance.

- Kit includes case with silk-screened panel, PCBs, pre-programmed PIC micro, 7-segment displays, red acrylic, hook-up wire and all electronic components.

KC-5300 £24.75*

Mixture Display Kit For Fuel Injected Cars

THOUSANDS SOLD!

This very simple kit will allow you to monitor the fuel mixtures being run by your car. This type of sensor is also known as an E.G.O. (exhaust, gas, oxygen) monitor. The circuit connects to the EGO sensor mounted in the exhaust manifold and the cars battery. PCB, LEDs and components supplied.

- PCB: 74 x 36mm

KC-5195 £6.25*

ROBOTICS KITS

3 in 1 All Terrain Tracked Robot

A robust all terrain tracked robot kit with very detailed instructions included to help you put this kit together. Comes with 6 terrestrial tracks/crawlers. Can be reconfigured to operate as a gripper, rover or forklift type mechanism. Electric motors included.

- 50 page instruction manual included
- Suitable for ages 13+
- Requires 4 x AA batteries
- Size of gripper robot: 90(H) x 160(W) x 270(L)mm

WATCH VIDEO ONLINE

KJ-8918 £18.25*

Robot Arm Kit with Controller

A great gift for a robot enthusiast. The arm is capable of 5 separate movements and can easily perform complex tasks. An excellent project for anyone interested in robotic construction and basic electrical connections.

- Arm is supplied as a kit of parts
- 100g lift capacity
- Suitable for ages 12+
- Base size: 225(L) x 160(W) x 40(H)mm

WATCH VIDEO ONLINE

KJ-8916 £18.25*

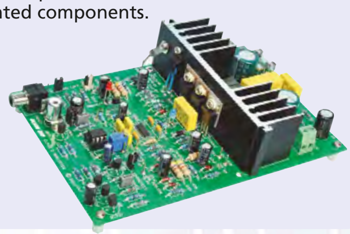
Add computer control via USB to your robotic arm with its matching interface kit.
KJ-8917
£12.75

High-Power Class-D Audio Amplifier Kit

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

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

KC-5514 £32.75*



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

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VOL. 42 No. 09 SEPTEMBER 2013

EVERYDAY PRACTICAL ELECTRONICS

How to kick start your electronics business

By its nature, *EPE* is about having fun with electronics as a hobby, or perhaps as a fascinating adjunct to another interest – building the best amplifier you can because of a passion for high-end hi-fi and listening to music. We rarely comment on pursuing electronics as a career – although we definitely recommend it, or engineering in general as a most fulfilling and rewarding way to pay the mortgage. (Contrary to many of the doomsayers in the popular media, there is still quite a lot of engineering in this country. True, not as much as there should be, but all those Naim amps and Rolls Royce gas turbines don't grow on trees or get imported from China; they're made here, in Britain.)

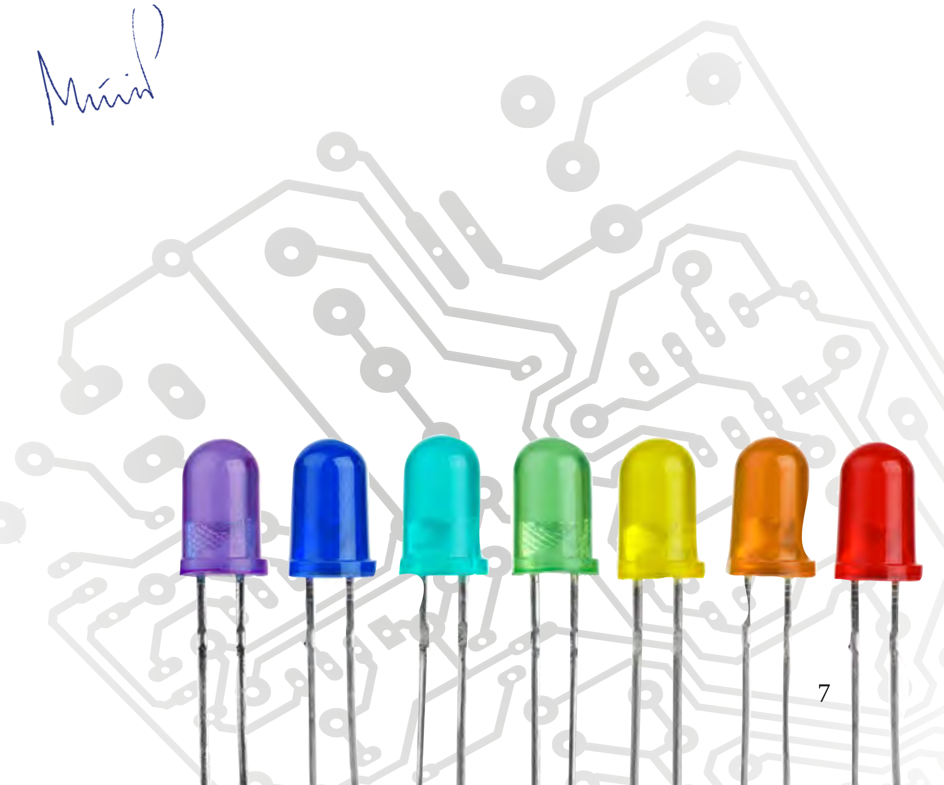
What if you don't just want a 'job' in electronics, what if you actually have some ideas for products and a potential roadmap for manufacturing – but not a lot of money to get started? There are banks and venture capitalists, but that route can be a long haul if you have little or no track record making money by making things. However, recently, a new option has become popular and successful – kickstarter.com

You may have noticed this referenced in last month's (and this month's) news, where a couple of add-on boards for the popular British computer board Raspberry Pi have been featured.

So what is kickstarter.com? Put simply, it's a US company that helps to 'crowd fund' projects. These project can be anything from getting your autobiography published or funding a film to producing a great piece of technology. This rather begs the question, what is 'crowd funding'. kickstarter.com provide an online platform for your project where you can offer anyone the opportunity to provide a little money in return for rewards. For a dollar you might just get a friendly 'thank you', but as your donation rises you may get the product in question, or a healthy discount.

This might sound all a bit vague and naively optimistic, but one project has attracted 10,000 backers and $10 million dollars in pledges, so it can work for the right project.

If you have a great idea, but little money, why not have a look at kickstarter.com – *EPE* would certainly like to hear from readers who have any experience backing or launching via this innovative website.



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NEWS

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

The right use for 'white spaces' – report by Barry Fox

Microsoft is in the news with plans for a new Xbox, which at last will have a Blu-ray disc drive. Microsoft is also in the news for admitting that Windows 8 needs a redesign to recapture the familiar look and feel of Windows, for instance by reinstating the Start button, which some bright spark at Microsoft HQ decided to remove.

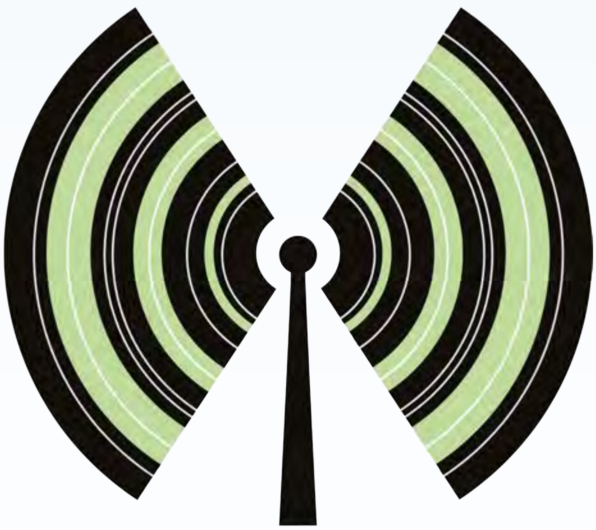
There has been a lot less news cover of another project, which could have far wider implications. The company wants EU legislators in Brussels to harmonise Europe's telecommunications laws so that anyone in Europe can use a white spaces radio device to send data in the TV bands, without the need for a licence. The term 'white spaces' refers to parts of the electromagnetic spectrum which are nominally allocated/reserved for broadcasting, but which in reality are usually left unused or have been abandoned. Sometimes white spaces exist between radio and TV channels. The global switch from analogue to digital TV is a good example of how spectrum use can change and space be created.

Demonstration at UK digital TV summit

Microsoft literally set out its stall on this at the UK's Digital TV Group (DTG) Summit in London, with a demonstration of white spaces transmission and a live link to the Spectrum Observatory, which Microsoft has tactically built in Brussels – right next door to the European Parliament building.

The DTG, the industry association for digital TV in the UK, hopes to become gatekeeper for the geo-location database of spectrum activity, which will control the way white spaces devices work in Europe.

'Why build more car parks, when you can use existing white spaces more efficiently?' said Jim Beveridge, director of international technology affairs at Microsoft, as he used a feed from the Brussels observatory to show radio spectrum activity across the frequency range 30MHz – 6GHz. 'You can see the many gaps between the spikes of activity in the TV band – like gaps between words' said Beveridge, who was previously with UK set-top box maker Pace. 'They could all be used to carry data – but a live geo-location database in the cloud is critical to make sure the data devices work only in the gaps.' See this effect at: **http://spectrum-observatory.cloudapp.net/Chart?activeTab=charts**



The cloud database will update every few seconds, and business-to-business and consumer transceivers will continually check it for authorisation to use free frequencies.

'Finland has now changed its regulations to permit white spaces use without licensing. We want the regulations changed throughout Europe so that devices are licence-exempt', said Beveridge.

At the London demonstration, Microsoft was using terminal hardware made by Neul of Cambridge, UK, and operating under a temporary licence from UK regulator Ofcom, to send data in UHF TV channel 33. Microsoft is also running similar 'non-operational' trials in Cambridge, Munich, and Brussels.

The raw data rate in a European 8MHz TV channel is around 16Mbps, with a payload of around 10-12Mbps when TCP/IP Internet coding is used. With transmission powers of around 1W, the link can reach up to 10km. 'bonding' several channels increases the data rate.

Elsewhere in the world, Microsoft is using white spaces in North Carolina, Silicon Valley and South Africa.

Government action

On the conference floor, UK government minister for Culture, Communications and Creative Industries, Ed Vaizey, said regulator Ofcom would be tasked to 'facilitate and manage white spaces use', with the DTG in charge of testing equipment to safeguard against data interference to TV.

'It is now legislation rather than technology that is holding us back' Vaizey said. 'We can have the best of both worlds. But if we get it wrong we could damage a successful ecosystem'.

SSDs to account for 33% of computer storage market in 2017

Research firm IHS has predicted that SSDs (solid-state drives) will account for more than a third of the computer storage market by 2017, almost seven times the level recorded in 2012. Total worldwide shipments is expected to increase from 31 million units to 227 million units in the space of just five years, forcing down the percentage of the market devoted to hard disk drives (HDD); from 94% in 2012, to 64%.

SSDs carry out the same function as a conventional HDD, but with one vital difference: they have no moving parts. Where HDDs function by using magnetic fields and spinning parts, an SSD uses Flash memory chips (as in a USB drive). This can drastically reduce read and write times, and has the added advantage of not wearing out.

It's not all bad news for the traditional hard drive. They are still cheaper in price than their high-tech competitors, and they have much higher storage density.

More change on the horizon?

However, nothing stands still in electronics; researchers at MIT (Massachusetts Institute of Technology) have discovered a magnetic breakthrough that might revolutionise the computer storage industry.

Storage media such as HDDs are based entirely on arrangements of magnets. Positive and negative alignments of magnetics within a magnetic domain help to create the ones and zeros which feature in every piece of data stored on every HDD. The MIT researchers have discovered that when a film of ferromagnetic material is placed onto platinum and exposed to a current, it presents the reverse magnetic pole. Switching the platinum for tantalum changes the poles back to normal. With most materials, the direction of pole changes is random and can change over an extended period of time. With thin, film-like materials like the ones used in this experiment, the pole can be changed by force, using currents and certain other materials, including platinum and tantalum.

The discovery means that small amounts of power can now be applied to change spin orientation of magnets very efficiently; if it is manufactured into a viable computer storage solution, it will be around 10,000 times more energy-efficient than current HDDs.

Sense, actuate and control from Parallax

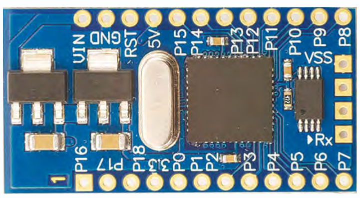
Parallax has announced a trio of new products.

The SCP1000 pressure sensor module is an absolute pressure sensor that can detect atmospheric pressure from 30-120kPa. The pressure data is internally calibrated and temperature compensated. The SCP1000 also provides temperature data and has four measurement modes as well as standby and power down mode. Communication is via an SPI bus, which also provides additional control lines such as an interrupt line and trigger input. (Part No. 29135, US$24.99)

Their new single relay board allows experimenters to control high-power devices (up to 10A) via its on-board relay. It can be used to turn lights, fans and other devices on/off while keeping them isolated from a microcontroller. Control of the relay is provided via a 1 × 3 header – friendly to servo cables and convenient to connect to many development boards. (Part No. 27115, US$9.99)

The Propeller Mini is a low-cost solution for embedding a multi-core microcontroller system in hard-to-reach places or small-sized projects where a full-sized development board is not practical. The board is small in size and component count, all while having the necessary features that are expected from a control board. (Part No. 32150, US$24.99)

Further details on these new products at: **www.Parallax.com**

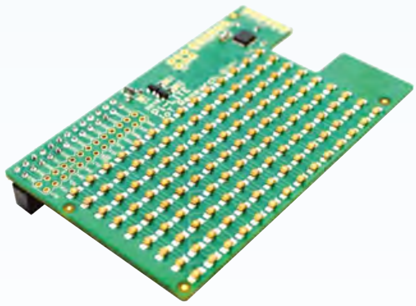


L-R: Parallax's new SCP1000 pressure sensor, single relay control board and Propeller Mini

Brit Kickstarter projects

It's nice to see a couple of classy British projects making the rounds on kickstarter.com, the crowd-funding website (see this month's *Editorial*).

You wouldn't think a novel variation on the humble loudspeaker amp would be possible, but Paul Cocksedge has produced 'The Vamp', which neatly combines stylish design, Bluetooth technology, a rechargeable speaker drive, all in a sculpted, portable little package. It will stick magnetically to your speaker of choice, can be controlled by an iPhone or Android mobile phone and has a 10+ hours battery life. Altogether a nice product; see **www.kickstarter.com** and search for 'vamp'.

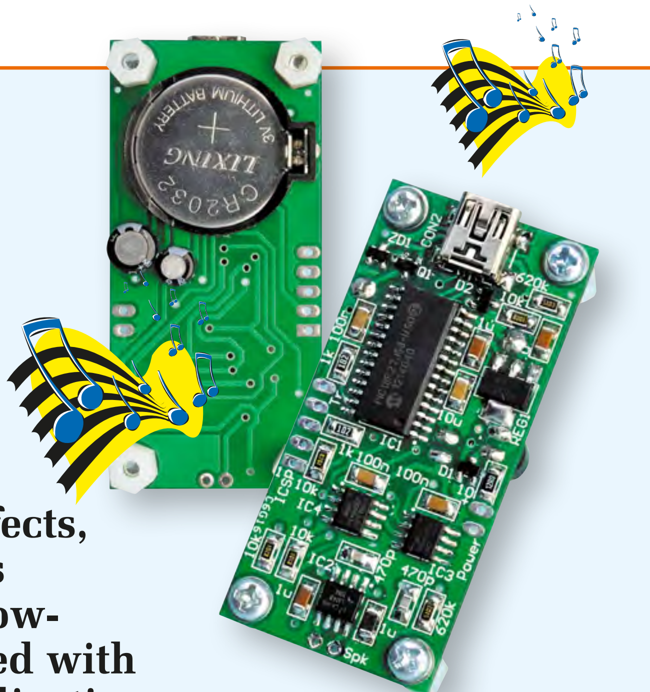


Also doing well on kickstarter.com is the Pi Lite from Ciseco in Nottingham. It's a large LED matrix display for scrolling text and graphics and an interesting way to get a Raspberry Pi to do something physical and fun.

Using standard serial communications (9600bps), it's really simple to send rolling text and graphics to the 9×14 (126) LEDs.

The matrix is powered from an ATMega328p processor, which means all the processing of driving the 126 LEDs is off loaded from the Pi's processor. This frees the Pi's processor and GPIO for other functions. Search for 'Pi Lite' at: **www.kickstarter.com**

Digital Sound Effects Module



This inexpensive, compact module can play back up to eight different sound effects, lasting a total of 60 seconds or more. It's powered from a lithium cell or from a low-voltage AC or DC supply, and can be used with model railway layouts or any other application requiring sound effects.

By NICHOLAS VINEN

THIS LITTLE MODULE is quite simple, but we've packed a host of features into it. You can upload a variety of sounds from a computer via its USB port, and it will then play back the sounds when triggered. It's small enough to be hidden away inside a vehicle or model, and it can be triggered by a microswitch, reed switch, pushbutton, sound or light detector...

The most obvious use is to hide it inside a model car or train, to produce an engine sound and a horn or whistle effect. Or you could build it into a door to play back a sound each time it's opened. You could even hook it up to a pet door so that it plays a sound to let you know when your pet enters or leaves the house.

Alternatively, you could fit it with a pushbutton for sound effects while playing a game or have it triggered whenever equipment is used or the fridge door is opened. In fact, the possibilities are endless.

In operation, the unit drives an 8Ω-ohm speaker and if the speaker is properly baffled and efficient enough, the playback volume level can be quite loud (more so with an AC/DC supply than a button cell). The playback time can be up to 60 seconds or more, depending on the sound quality used.

The module has two inputs to trigger different sets of sound effects; each one can be assigned to any set of the eight possible sound effect slots. When triggered, it can either randomly pick one sound from the selected set or cycle through them in sequence.

To keep the unit small and the cost low, it uses virtually all SMDs (surface mount devices). We've chosen the easiest SMDs to solder so that just about anyone can build it, given some patience. The circuit is based around two ICs, a PIC microcontroller and an LM4819 low-power audio amplifier. Up to 108KB of the PIC's internal Flash memory can be used for sound storage, but if that isn't enough, it can be expanded to over 1MB (more on this later).

PWM sound generation

We initially considered using a PIC microcontroller with an inbuilt DAC (digital-to-analogue converter) for sound playback. Unfortunately, few PICs contain an audio DAC and those that do require a regulated supply of 2.7-3.3V. This isn't really suitable for use with a lithium cell as they can drop below 2.7V under load or if a bit flat.

Rather than add the complexity of a boost regulator to maintain the voltage, we decided to use a standard PIC with two high-speed PWM outputs. These are used to drive low-pass filters, so that we effectively build our own simple DAC. In practice, this works quite well and gives performance comparable to a dedicated 10-bit or 12-bit DAC, with an acceptable level of distortion – typically less than 0.2%.

Block diagram Fig.1 shows the general arrangement. IC1 produces two PWM waveforms, each with a duty cycle variable from 0-100% in 64 steps (2^6). The output from pin 7 (RP2/PWM0) is determined by the six most-significant bits of the 12-bit sampled waveform being played back, while pin 2 (RP0/PWM1) has a duty cycle based on the six least-significant bits. This second output is used to provide smaller output voltage steps for better resolution.

These two square waves each pass through low-pass RC filters, to remove most of the high-frequency harmonics and produce voltages which are proportional to the input duty cycles. The 34kHz –3dB roll-off point ensures that there is little attenuation of audible frequencies.

After filtering, the signals are mixed with a ratio of 64:1, to reconstruct the 12-bit digitally-sampled voltage level. Refer to the panel later in this article (Using PWM to reproduce PCM audio) for a detailed explanation of how the two 6-bit PWM outputs are combined to give the equivalent of a 12-bit output.

We chose six bits per output for two reasons: 1) a total of 12 bits gives a good compromise between the memory

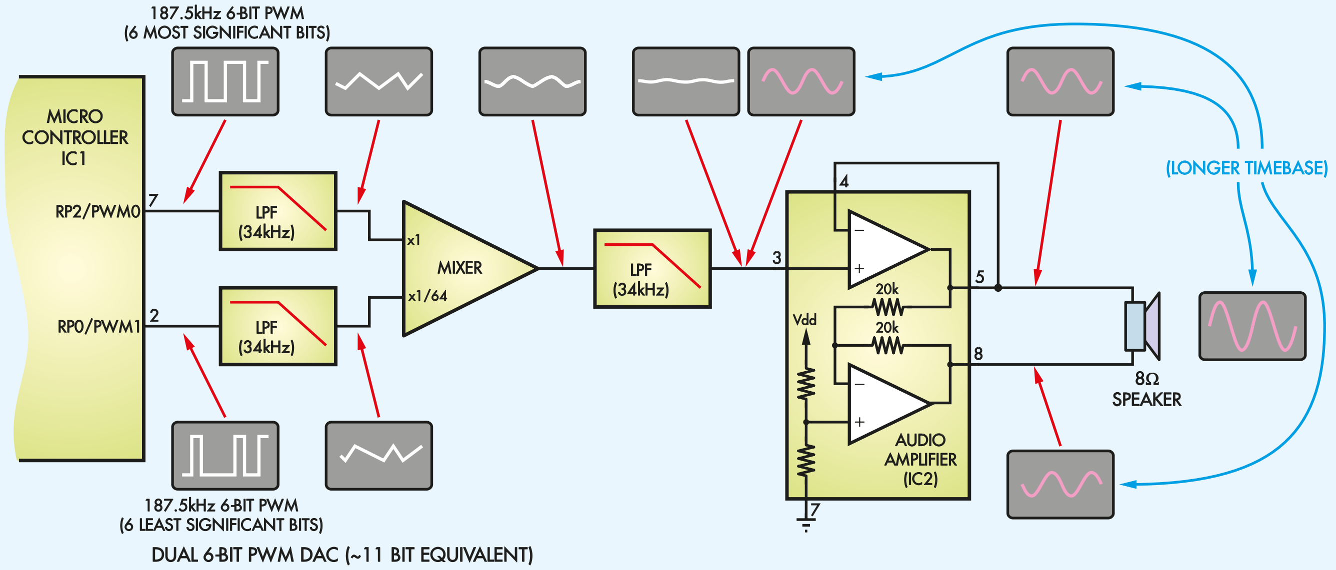


Fig.1: block diagram of the *Digital Sound Effects Module* showing how the PIC micro reproduces the audio. IC1 generates two PWM square waves based on stored audio data. These signals are fed through low-pass filters before being mixed with a 64:1 ratio. The output of the mixer is filtered further and then passed to IC2, a low-power audio amplifier that drives the 8Ω speaker in bridge mode.

required to store an audio file and the resulting playback quality; and 2) this allows us to have a PWM frequency well above the –3dB point of the required low-pass filters, so that the latter are reasonably effective.

The output from the mixer passes through another low-pass RC filter to further remove switching noise and is then fed to the non-inverting input of audio amplifier IC2. As shown, this stage drives the speaker in bridge mode. This not only maximises the audio output power (important given the low supply voltage of ~3V) but also avoids the need for a large output DC-blocking capacitor.

IC2 operates with a gain of +1 for the non-inverting output and a gain of –1 for the inverting output, giving an overall gain of 2. It's able to deliver about 100mW to the speaker, which produces quite a reasonable volume if the speaker is efficient. In practice, the available power is limited by the lithium cell.

Fig.2(a) shows a scope grab of the audio output when reproducing a sinewave. It's zoomed in far enough to show the remnants of the high-frequency PWM signal, but you can still see the curved sinewave shape. When we change the scope's time base to 'zoom out', we see from Fig.2(b) that the waveform is quite smooth (ignoring supersonic frequencies).

Table 1: Playback time vs sample rate and bit depth

Sampling rate and bit depth	No Flash chips	One Flash chip	Two Flash chips
8kHz, 8-bit	14s	80s	125s
11.025kHz, 8-bit	10s	58s	105s
8kHz, 12-bit	9.5s	53s	97s
11.025kHz, 12-bit	7s	38s	70s
22.05kHz, 12-bit	3.5s	19s	35s
32kHz, 12-bit	2.5s	13s	24s
44.1kHz, 12-bit	1.5s	9.5s	17.5s
48kHz, 12-bit	1.5s	8.5s	16s

Interpolation

While the PWM outputs operate at around 187.5kHz, the audio sampling rate is a lot lower. If we simply changed the PWM duty cycles at the sampling rate of the audio file being replayed (eg, 11,025Hz), the output would have visible steps – as shown in Figs.2(c) and 2(d).

This would result in extra harmonic content in the audio output, which would sound quite bad, especially at lower sampling rates due to the larger effective step size. In fact, the audio produced using this technique sounds rather 'crackly' – not good!

The simplest solution is linear interpolation. This involves changing the PWM cycle a little for each pulse, for the same total changeover time, but in smaller increments. In fact, Figs.2(a) and 2(b) show the identical waveform to Figs.2(c) and 2(d), but the former have the linear interpolation enabled. As you can see, the resulting waveform is much smoother and it sounds a lot better too.

This interpolation requires a lot more processing in the PIC. Each time a new sample value is loaded, it must calculate the required slope and given the low PWM resolution (six bits), this is often going to be a fractional value, so we need to do some fractional maths to generate a smooth ramp.

The PIC18F27J53 is (just) powerful enough to do this with some carefully written code. With a 187.5kHz PWM update rate and a maximum instruction clock rate of 12MHz, we have

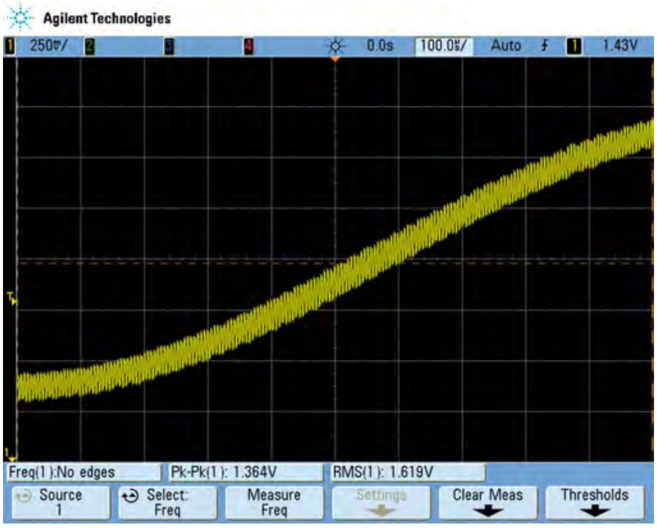


Fig.2(a): a close up of the audio output from the *Digital Sound Effects Module* (output of IC2), showing the residual PWM signal that isn't filtered out, plus the smoothly varying level of the sinewave which is being played back.

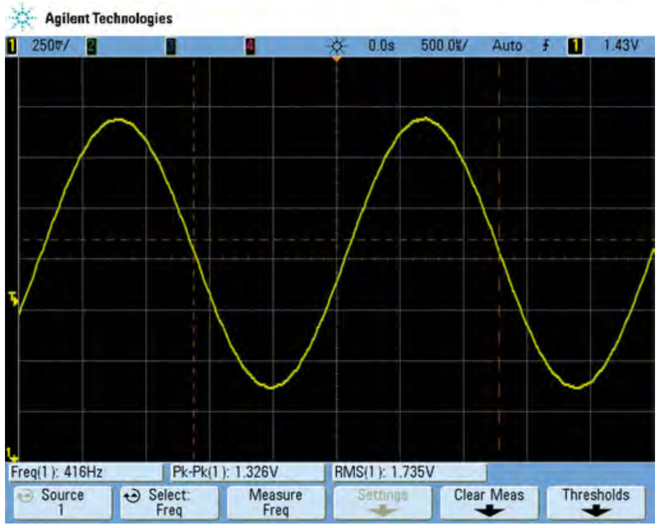


Fig.2(b): the same sinewave signal as Fig.2(a) but with a longer timebase. The low-pass filtering of the scope's input circuitry has rendered the switching residuals invisible, leaving just the smoothly varying output.

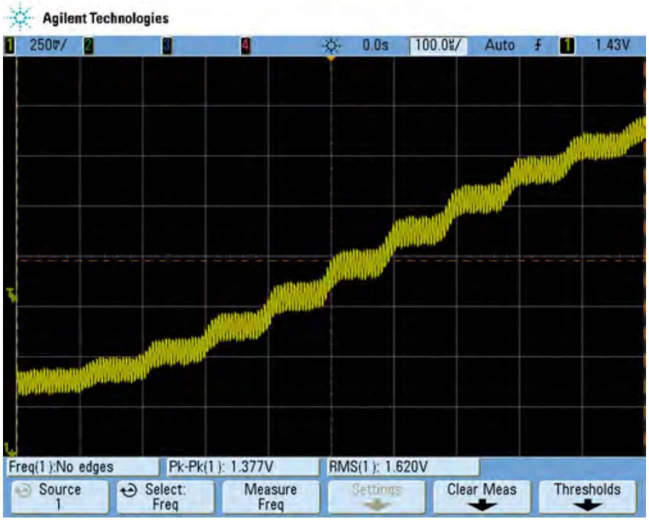


Fig.2(c): the same sinewave (11.025kHz sampling rate) being played back without the linear interpolation code active. The resulting steps cause audible artefacts, especially with lower sampling rates.

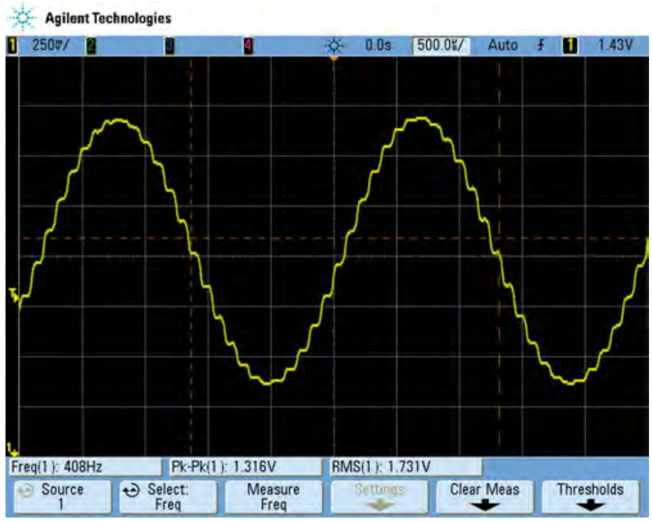


Fig.2(d): another view of the non-interpolated sinewave with a longer time base, clearly showing the steps which result from the limited time resolution available at low sampling rates.

just 12M/187.5k = 64 instructions to perform these calculations. In the end, we were able to make the code fast enough, using an 8-bit fractional sample-position counter and a hand-optimised 8 × 12-bit multiply/scale function to integrate the computed delta (ramp) value over time.

Circuit description

Now take a look at Fig.3, the complete circuit diagram. The three low-pass filters and mixer shown in Fig.1 are implemented using three resistors (two 10kΩ and one 620kΩ) and two 470pF capacitors. This is possible because the two first-stage low-pass filters and the mixer are combined. You can think of it as two low-pass RC filters with a common capacitor.

In addition, the different resistor values effectively form an attenuator between the two PWM outputs, to give the correct (approximate) mixing ratio.

The relatively small capacitor value (470pF) was chosen to minimise distortion due to loading on the microcontroller outputs, which have limited current capability. The second low-pass filter is similar to the first and is connected between the mixing node (ie, the junction of the 10kΩ and 620kΩ resistors) and the non-inverting input (pin 3) of amplifier IC2.

In this configuration, IC2 only needs two additional components to operate: a 1µF supply bypass capacitor and a 10nF capacitor to filter its internal half-supply voltage generator. This latter capacitor also determines how long it takes to go into and out of sleep mode, which is used to minimise power consumption when no sound is being played. We want to play back sounds immediately when triggered, so the 10nF capacitor gives a turn-on time of just 10ms.

Audio amplifier IC2 drives the speaker in bridge mode via CON4. The circuit is DC-coupled so IC1 is programmed to deliver an average modulated output of 50% to prevent a large DC voltage from appearing across the speaker.

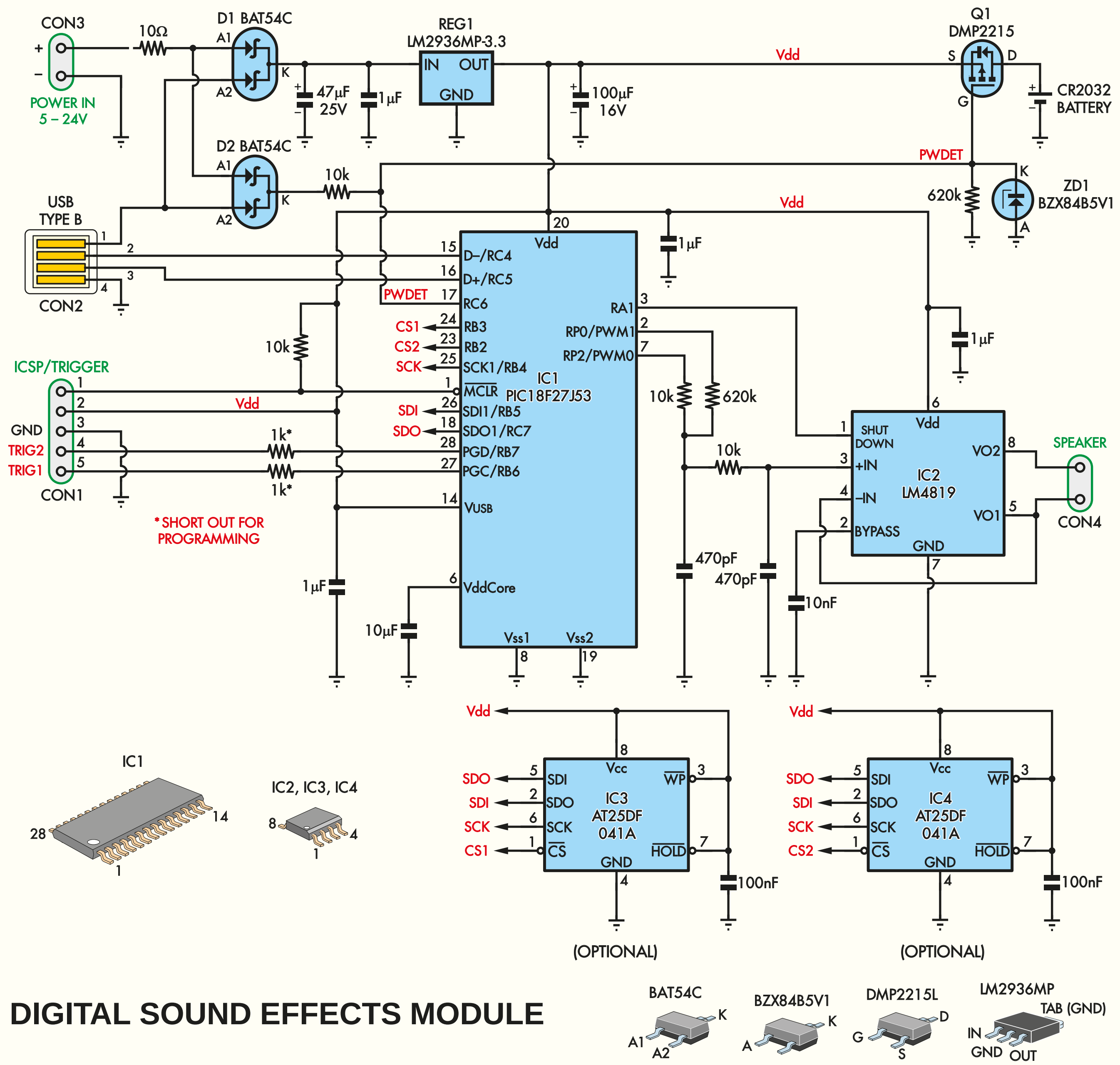


Fig.3: complete circuit of the *Digital Sound Effects Module*. IC1 generates the PWM waveforms which are filtered and then passed to audio amplifier IC2. IC3 and IC4 are optional Flash memory chips for more storage space and these are controlled using a 5-wire serial bus. REG1 provides a regulated 3.3V rail when the unit is plugged into a USB port or is running from an external supply. The rest of the time, it runs off a CR2032 lithium cell. Sounds are triggered by pulling pins 4 or 5 of CON1 low and CON1 can also be used to program IC1 with an in-circuit serial programmer.

More memory

The firmware occupies 20KB of IC1's 128KB internal Flash memory, which leaves 108KB available for sound storage. This will be sufficient for some applications, but if you want multiple sound effects or longer sounds, you are going to need more memory space than this.

In practice, the total Flash memory can be expanded to either 620KB or 1132KB by adding one or two low-cost serial Flash chips – IC3 and IC4. These each store 4Mbit (512KB) of data. IC1 automatically detects if either or both of the memory chips are installed at power-up.

Table 1 shows the total playback time available with various combinations of IC3 and IC4 installed. IC1 communicates with the Flash chips using a 3-wire SPI (serial peripheral interface) bus plus two chip-select lines – CS1 and CS2.

The specified Flash chips (AT25DF041A-SSHF) were chosen for their wide operating voltage range (2.3-3.6V) and low power consumption. IC1's minimum operating voltage is 2.15V, but in practice, we expect that all the ICs will run down to about 2V. The supply voltage for IC3 and IC4 is critical during erase and write operations, when they run from a regulated 3.3V rail derived from an external PC's USB port, via D1 and REG1.

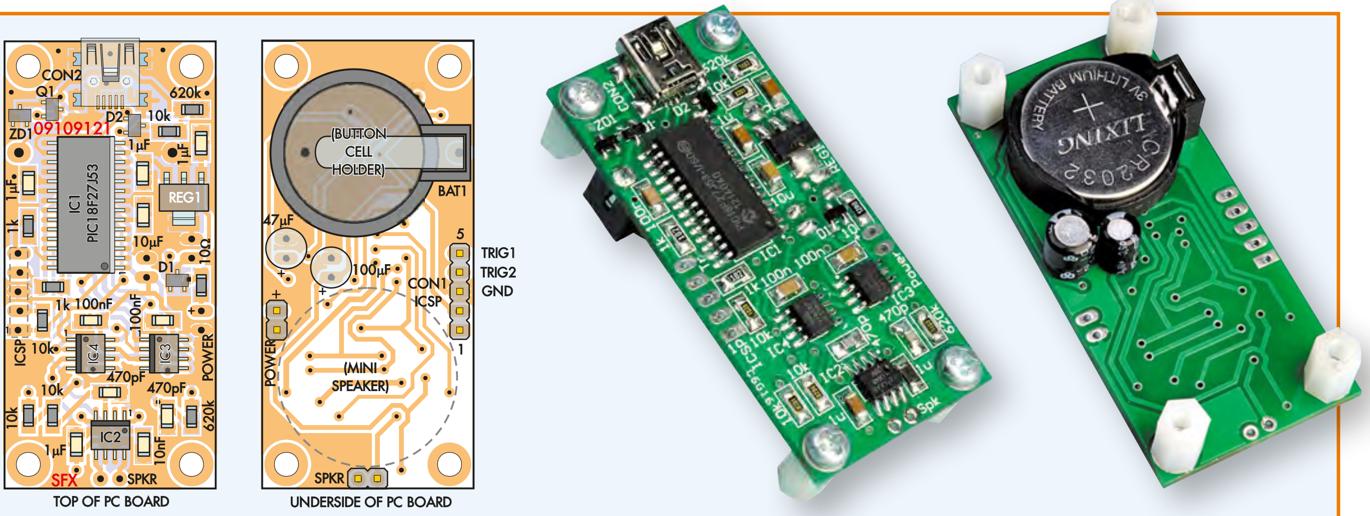


Fig.4: the SMD parts all mount on the top side of the PCB while the through-hole parts, including the cell holder, are mounted on the bottom. CON1 is a friction-fit for programming, but can be soldered in to connect the trigger inputs if you don't want to solder wires direct to the PCB. Note that there is room for a small speaker to be taped to the bottom of the PCB, but an off-board baffled speaker will give better results.

Sleep mode

When the module is not plugged into a USB port and not playing any sounds, IC1 goes into sleep mode to save power and the whole circuit typically draws less than 10μA from the CR2032 cell. If IC3 or IC4 are installed, they are placed in 'deep power-down' mode, which, according to the data sheet, gives them a typical current consumption of 15μA each.

You would expect then that installing IC3 and/or IC4 would reduce the standby cell life substantially. However, we measured the actual sleep current for IC3 and IC4 at about 2μA each. This likely reflects manufacturing process improvements since the AT25DF041A data sheet was written, and we expect most constructors will find that installing these chips has little effect on cell life.

During playback, IC3 and IC4's operating current is negligible compared to that of IC1 and IC2, due to the low data rate (72kbits/s maximum).

USB interface

The PIC's USB interface is used to transfer sound data for later playback. It's also used to configure the various trigger options. The only external component required for the PIC to communicate via USB is the mini-B type connector (CON2). The necessary USB impedance-matching and pull-up resistors for the D+ and D– communication lines (pins 16 and 15) are inside IC1.

In operation, the PIC monitors the USB V_{CC} line, to determine when the unit is plugged in. This is necessary so that the internal USB module can be turned off at other times to save power. The method used will be explained shortly.

Power supply

When a CR2032 3V lithium cell is installed, it powers all the ICs via MOSFET Q1, which provides reverse polarity protection. Q1 is a P-channel type with its gate tied to ground via a 620kΩ resistor, so that it is switched on by default. However, if the cell is somehow inserted backwards, its gate will instead go positive compared to its source. In that case, Q1 switches off and its internal body diode is reverse biased, so no current can flow.

Conversely, when it's on, Q1 has a very low on-resistance (<0.2Ω). As a result, there is very little voltage drop across it, given the low current drain from the battery (<50mA).

As stated, the circuit can also be powered via the USB port or from an external DC or AC supply. In these cases, the 3.3V supply for IC1-IC4 comes from REG1, an LM2936 low-dropout linear regulator. This is especially important for USB communications, as IC1 requires a supply rail that's close to 3.3V for proper USB operation.

When an external supply is used and the LM2936 is powering the ICs, its output voltage will typically be above the cell's voltage (nominally 3V). Hence, we need to prevent it charging the cell, which could damage it.

This function is also performed by Q1. The external supply voltage pulls Q1's gate high via dual Schottky diode D2 and a 10kΩ resistor. One half of this diode conducts if an external USB supply is connected, while the other half conducts if an external supply is fed in via CON3. As a result, Q1 is switched off and no current can flow into the cell (since Q1's internal body diode is also reverse biased).

Note that dual-diode D2 is necessary so that you can't accidentally feed power from CON3 into the computer's USB port (if connected).

Zener diode ZD1 protects both Q1 and pin 17 of IC1 from damage should the external supply be above 5.5V. Pin 17 of IC1 is used to detect when external power is applied, to enable the USB transceiver (this pin is 5.5V-tolerant and so can be used for this task). The software sets this pin as an interrupt source, so it can wake the micro when the USB interface is connected.

DC/AC supply

The external supply can be either 5-24V DC or 5-24V p-p (peak-to-peak) AC and is fed in via CON3. This suits many applications, including a model railway system with DCC (Digital Command Control), which uses a 15-22V AC square wave. For AC, one half of dual-Schottky diode D1 rectifies the supply voltage, while for DC, this diode provides reverse polarity protection.

A 47µF 25V electrolytic capacitor filters the resulting supply rail, while a 10Ω series resistor limits the in-rush current when power is first applied. This prevents D1 from burning out when the unit is first powered up. As with USB power, REG1 then provides the 3.3V supply for the ICs.

REG1 can pass up to 50mA, which gives an instantaneous dissipation of around 1W with a 24V input. That would be too high if it were sustained, but in practice, power is drawn in bursts by the audio amplifier. This lowers the average dissipation to an acceptable level.

Trigger inputs

CON1 serves both as an ICSP (in-circuit serial programming) header for IC1 and as the trigger input connector. For programming, the two 1kΩ series resistors must be shorted out. These resistors normally protect the IC inputs from accidentally applied voltages above 3.3V during operation (eg, you can use a 0-5V trigger signal if necessary).

Normally, to trigger a sound, either TRIG1 or TRIG2 is pulled to ground, although the unit can be re-configured to invert the trigger logic.

Software

IC1's software must perform a number of tasks. As explained earlier, it goes into and out of sleep mode as necessary, powering up the USB interface and the serial Flash chips only when needed. Pin-change interrupts on pins 17, 27 and 28 are used as wake-up signals.

When the USB interface is enabled, the module appears as a virtual serial port. The XMODEM protocol is used to upload audio files (8-bit or 16-bit mono WAVs). Configuration commands are sent as text over the serial port and the module responds to indicate that they have taken effect. You can also query some information from the module, such as how much memory is free.

When you upload a WAV sound file, it checks that the format is valid and that there is enough free memory, then stores it. If a 16-bit file is uploaded, it is converted to 12-bit format on-the-fly, to save memory and speed up the playback code.

There are a number of configuration options, such as whether the sounds are looped, whether the sound continues playing to the end of the file once the trigger input is released, which input has priority, how to deal with multiple sounds and so on. These are set using text commands over the USB serial interface and stored in IC1's Flash memory to be used when the unit is triggered (more on this later).

Features and specification

Module size: 59 × 28 × 13mm

Trigger inputs: 2

Number of sound effects: 1-8, triggered round-robin or random

Audio sampling rate: 8-48kHz

Audio resolution: 8-bit or 12-bit

Sound memory: 108KB, 620KB or 1.12MB

Total playback time: 1.5-125 seconds depending on sampling rate and data memory (see Table 1)

Output power: Approx. 100mW into 8Ω

Supply options: CR2032 lithium cell, USB 5V, DC 5-24V, AC 5-24V peak-to-peak

Cell operating voltage: 2.15-3.3V (2.3-3.3V with memory >108KB)

Standby current: typically 9-14µA, depending on installed memory

Standby cell life: >1 year

Playback cell life: 4-24 hours, depending on sound volume, etc

Configuration interface: USB (mini type B socket)

USB protocol: virtual serial port (CDC), file transfer via XMODEM

Computer operating system: Windows XP, Vista, Windows 7*

*** In theory, the module will work with Linux and Mac OSX using the CDC driver but we haven't tested it. The driver will need to recognise our Vendor ID and Product ID (04D8, FD52).**

Construction

The *Digital Sound Effects Module* is built on a double-sided PCB coded 09109121 and measuring 28 × 59mm. Fig.4 shows the parts layout. The first job is to fit the surface-mount devices to the top side of the PCB.

Start by laying the board flat on your workbench and fitting the USB connector (CON2). This has two plastic locating posts on the underside which go into matching holes on the PCB. Ensure that the socket end is at the edge of the PCB and that the connector is sitting flat, then solder one of the mounting feet.

That done, check that the five pins are properly aligned on their pads, then solder the other three feet plus the five pins. You will have to angle the soldering iron when soldering the pins, as they are under the main body of the connector.

Don't worry about solder bridges at this stage; just make sure they are soldered correctly. It's then simply a matter of using solder wick to clean up the bridges (note: adding a bit of flux paste makes this much easier). Finally, check that the bridges are gone using a magnifier; if not, add more flux and fix them.

The four SOT-23 (small-outline transistor package) devices can be installed next (D1, D2, Q1 and ZD1). Be sure to remove them from their packaging one at a time so you can't get them mixed up (they look virtually identical).

In each case, it's just a matter of placing a small amount of solder on one of the pads, then reheating the solder while you slide the device into place. If it isn't aligned properly, simply reheat the solder and nudge it until it is correctly aligned. The other pins can then be soldered.

Follow with the ICs, taking care to get the orientation correct. In each case, pin 1 is indicated with a dot on the PCB. IC1 and IC2 should have a divot near pin 1, while the other two ICs (if fitted) have a bevelled edge on the same side as pin 1.

As before, it's just a matter of applying some solder to one of the end pads, then reheating this solder as the device is slid into place. That done, solder the diagonally opposite pin,

Serial commands for the Digital Sound Effects Module

Commands are sent to the Digital Sound Effects Module by typing them into the serial terminal. There are three basic types of command: those which give you information, those which are used to upload sound files and those which are used to change the module's configuration.

Most commands have an immediate effect and respond with information after you press the enter key. If there is an error (eg, you mistyped the name of the command), it will respond with information about what has gone wrong.

Having prepared the sound files, the next step is to use the Send command to upload them. If you have a speaker wired up at this stage, you can then check that everything is working using the Play command.

Here is the list of available commands with some information about how to use them.

Command: 'Info'
Description: displays the firmware version, amount of memory installed and free, what sound files are loaded and the configuration settings.
Example:
Info
SILICON CHIP Sound Effects Module v1.0
Total memory: 1131.9KB
Free memory: 721KB
Sound #1: 22050Hz, 12-bit, 12.8s, 411KB, loop, stop immediately
Trigger #1: NO, sound #1, priority, random
Trigger #2: NO, no sounds, round robin
Unsaved configuration changes

Command: 'Clear all'
Description: deletes all sounds loaded into the Digital Sound Effects Module, freeing up all memory for new sounds
Example:
Clear all
Memory cleared, 1131.9KB free

Command: 'Clear last'
Description: deletes the last sound loaded into the Digital Sound Effects Module, freeing up the memory it occupied.
Example:
Clear last
Sound #2 cleared, 721KB free

Command: 'Send'
Description: initiates the upload of a sound file to the Digital Sound Effects Module. After a successful Send command, the sound is uploaded via XMODEM. The sound file is given the next available index, starting with #1.
Example:
Send
Ready for file via XMODEM
Saved to index #1

Command: 'Abort'
Description: cancels a pending Send command. Can be used if the transfer failed for some reason but the unit is still waiting for it to finish. You can also re-start a transfer by doing a Send command again.
Example:
Send
Ready for file via XMODEM
Abort
Transfer aborted

Command: 'Play <index>'
Description: immediately plays back the sound loaded in the specified location. The USB interface does not respond during playback. A response will be sent once playback is complete and the serial port interface is then ready for more commands.
Example:
Play 1
Playing file #1 (12.8s)...
Playback complete

Command: 'Options <sound index> <options>, <option> ...'
Description: once you have uploaded a sound file, you can set some options that determine how it is played back. By default, when triggered, the sound will play once and won't stop until the end of the file (unless interrupted, see below). If you want it to loop as long as the trigger input is held on, use the 'loop' option (or 'once' if you don't; this is the default). If you want the sound to stop as soon as the trigger input is released, rather than wait for playback to complete, use the 'partial' option (the default is 'complete').
Example:
Options 1 loop, partial
Sound #1: 22050Hz, 12-bit, 12.8s, 415KB, loop, partial

Command: 'Sounds <trigger index> <sound index>, <sound index> ...'
Description: allocates one or more sounds to a trigger index (1 or 2). Sounds can be allocated to either or both trigger inputs. This determines which sounds are played back when the specified trigger input is activated (one at a time, see below for information on how they are chosen).
Example:
Sounds 1 1
Trigger #1: NO, sound #1, priority, random

Command: 'Trigger <trigger index> <option>, <option> ...'
Description: sets the options for trigger 1 or 2. The available options are 'NO' or 'NC' to set the input mode to suit normally open or normally closed switches (or active low and active high signals, respectively), 'priority' (which allows it to interrupt sounds which are triggered by the other input) or 'nopriority', 'roundrobin' (with multiple sounds allocated, they are played in sequence) or 'random' (with multiple sounds, one is randomly selected each time).
Example:
Trigger 1 priority, random
Trigger #1: NO, sound #1, priority, random

Command: 'Save'
Description: configuration commands (except for Send) are not permanently saved until this command is executed. If you don't save configuration changes, they will be lost when the unit loses power.
Example:
Save
Configuration saved

Digital Sound Effects Module: Parts List

1 PCB, code 09109121, available from the *EPE PCB Service*, size, 28mm × 59mm
1 PCB-mount button cell holder (Jaycar PH9238)
1 CR2032 lithium cell
1 5-pin header, 2.54mm pitch (CON1)
1 SMD USB connector, mini-B type (CON2)
1 8Ω mini-speaker (eg, 27mm or 40mm diameter)
1 100mm length 2-wire ribbon cable
1 USB cable, type-A plug to mini-B plug
4 M3 × 9mm tapped nylon spacers
4 M3 × 6mm machine screws

Semiconductors
1 PIC18F27J53-I/SO microcontroller programmed with 0910912A.hex (IC1)
1 LM4819 audio amplifier [SOIC-8] (IC2) (Digi-Key LM4819MXCT-ND) OR
1 LM4889MA 1W audio amplifier [SOIC-8] (IC2) (Element14 1286916)
1 LM2936MP-3.3 50mA 3.3V LDO regulator [SOT-223] (REG1) (Element14 1469062)
1 DMP2215L P-channel MOSFET [SOT-23] (Q1) (Element14 1713864)
1 5.1V Zener diode [SOT-23] (ZD1) (Element14 1431236)
2 BAT54C dual Schottky diodes [SOT-23] (D1, D2) (Element14 1467518)

Capacitors (SMD 3216/1206 unless specified)
1 100µF PCB-mount low-profile electrolytic (eg, Element14 9452567)
1 47µF 25V PCB-mount low-profile electrolytic (eg, Element14 1165523)
1 10µF
4 1µF
1 10nF
2 470pF

Resistors (SMD 3216/1206, 0.25W 1%)
2 620kΩ
2 1kΩ
4 10kΩ
1 10Ω

Optional parts for longer playback time
2 AT25DF041A-SSHF-B 4Mbit Flash memory ICs [SOIC-8] (IC3, IC4) (Element14 1636622)
2 100nF ceramic chip capacitors [3216/1206]

Note: the PCB and software are available from the *EPE* website

and then solder the remaining pins, ignoring the inevitable solder bridges.

Removing the solder bridges

Once the device is in place, apply a thin layer of flux paste along both rows of pins, then clean up the solder bridges with solder wick. That's done by first placing the solder wick alongside (but not on top of) the pads. The soldering iron is then placed on top of the solder wick and the wick gently slid towards the solder on the pads.

As the wick heats, it will start to melt the flux and the excess solder, creating visible smoke. At that point, you can slide it right up against the pins and most of the excess solder should then be sucked into the braid.

Repeat this procedure until all the solder bridges are gone. It's not strictly necessary to clean off the flux residue provided you are using no-clean (non-corrosive) flux. However, if you do want to clean it off, this can be done using pure alcohol (eg, isopropanol).

For a more detailed description on soldering SMDs, see the article in the July 2010 issue of *EPE*.

The passive SMDs are next on the list. These include nine 3.2 × 1.6mm (3216) resistors and 8-10 similarly sized ceramic capacitors. The resistors have their value code printed on top, but the capacitors will be unlabelled. As before, the best tactic is to remove them one at a time from their packaging, so you don't get them mixed up.

Regulator REG1 is the last SMD components to be installed. It's mounted in a similar manner to the ICs and SOT-23 devices.

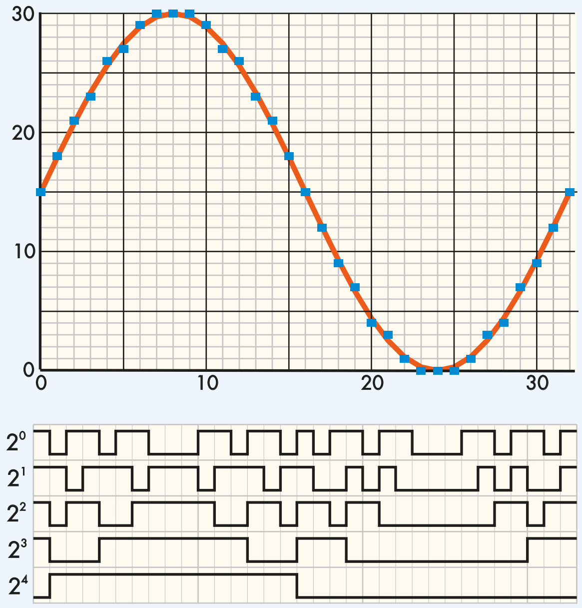


Fig.5(a): 32-sample sinewave with 30 voltage steps (5-bit resolution)

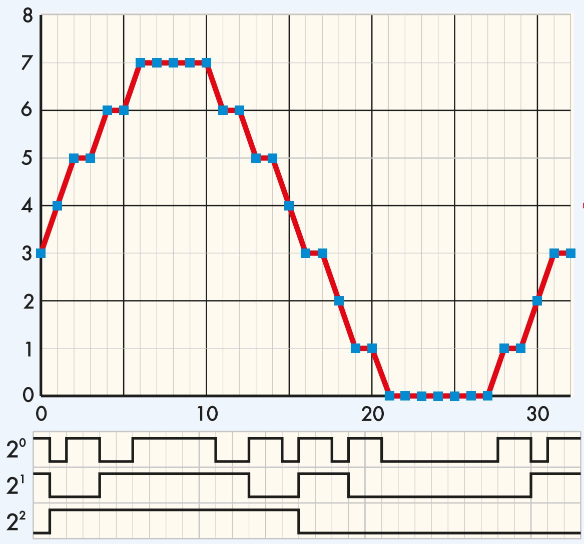


Fig.5(b): three most significant bits with corresponding waveform

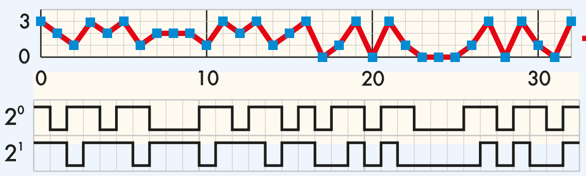


Fig.5(c): two least significant bits with corresponding waveform

Using PWM to reproduce PCM audio

Uncompressed digital audio is stored in pulse-code modulation or PCM format. This consists of a series of numbers which represent a proportional voltage at a point in time. The voltage is sampled at a fixed rate (the sampling rate) and stored. The resulting numbers form a representation of the audio waveform.

Refer to Fig.5(a); this shows a sinewave converted to 5-bit PCM with 32 samples. With five bits, we have about 30 voltage steps, and as you can see, some of the sample points (blue) don't quite line up with the original waveform (red). In reality, we use more than five bits; this is just an example.

At the bottom of Fig.5(a) is a plot of the five data bits. Consider the first sample (left-most blue dot), which has a value of 15. This is encoded as $2^0 + 2^1 + 2^2 + 2^3$ (1 + 2 + 4 + 8) and hence the bits corresponding to these numbers are high (one) whereas the top bit, 2^4, is initially low (zero). Some bits then flip as the sampled value changes and a new sample is binary encoded.

Now look at Fig.5(b). We've taken the three most-significant bits (MSBs) and re-numbered them to start from zero, without changing the data. The resulting sample values are plotted above. The resulting waveform has the same general shape as the original, but it lacks the fine details since the least-significant bits (LSBs) are gone.

This is a type of audio decimation; dropping some of the LSBs is an easy way to reduce the amount of data required to store a PCM stream, but it also reduces the audio quality. It's how we convert 16-bit audio to 12-bit for storage in the Digital Sound Effects Module (as mentioned early in the main article).

In Fig.5(c) we plot the two LSBs missing from Fig.5(b). This shows the 'residual' or the difference between the original and

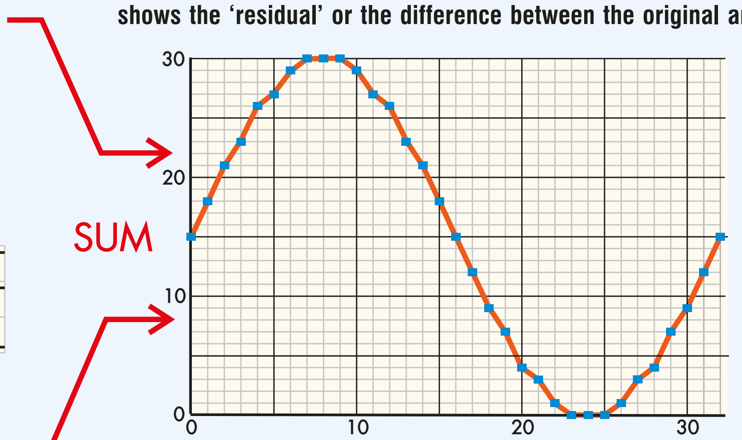


Fig.5(d): summing waveforms with appropriate scaling reproduces original wave shape; deviations are due to limitations of the 5-bit resolution

Through-hole parts

Now flip the PCB over and mount the cell holder. The two electrolytic capacitors can then be fitted, with their longer leads going through the holes marked '+' on the PCB.

Finally, complete the assembly by fitting four M3 × 9mm tapped nylon spacers to the corner mounting holes. These are secured using M3 × 6mm machine screws.

Programming

If you don't have a pre-programmed PIC (available from the SILICON CHIP PartShop – **www.siliconchip.com.au**), program it now. To do this, temporarily short out the two 1kΩ resistors (eg, using a lead off-cut) and then plug (or solder) in a 5-way pin header for CON1 (friction will hold it in place).

That done, connect an ICSP (in-circuit serial programmer) with its pin 1 oriented as shown. If you are decimated waveforms. If we add this waveform to the decimated version with the correct ratio, we reconstruct the original 5-bit audio data, as shown above. This summing can occur either digitally or in analogue.

The 12-bit audio used in the Digital Sound Effects Module sounds almost as good as 16-bit audio, but only requires 75% as much memory. Using the technique shown here, we split each 12-bit sample into the six MSBs and the six LSBs.

These sample values are each then converted to an analogue voltage using a pair of 6-bit PWM (pulse-width modulation) outputs on the microcontroller. A sample value of 0 give us a 0% duty cycle and a value of 63 ($2^6 – 1$) gives us a near-100% duty cycle. The PWM square waves pass through low-pass RC filters, which remove most of the switching noise and give us smoothly varying voltages that are proportional to the duty cycles and hence sample values.

All that's left is to then sum the two resulting analogue waveforms in the correct ratio (64:1). This is achieved using a resistive voltage divider/mixer and we then have an analogue signal which closely approximates the original audio waveform, to within about 0.025% (1/4095).

Oversampling

Using 6-bit PWMs gives a maximum switching frequency of 188kHz (the 12MHz CPU clock divided by 2^6 or 64). We want a switching frequency well above 20kHz so that we can filter out most of the switching harmonics without affecting the audible frequencies (20Hz-20kHz).

A typical audio sampling rate is between 8kHz and 48kHz, giving between 23.4 and 3.9 PWM pulses per audio sample. To give a smooth output waveform without lowering the switching frequency (for the reasons explained above), we generate intermediate steps for the samples so that we can update the PWM duty cycle after each pulse.

You can think of this as a joining-the-dots exercise (see Fig.5(b)). The original samples are shown as blue dots, but we could also put dots anywhere along the red line segments joining them to get an estimated intermediate sample value that we can then use to update the PWM duty cycles, making the output less 'steppy' and more smooth. This is shown in the scope grabs in the main article.

using a PICkit programmer, you can power IC1 at 3.3V from its inbuilt power supply.

Alternatively, you can connect a USB cable from a PC for power (although the device won't be detected yet). The software, 0910912A.hex, is available from *EPE* website (**www.epemag.com**).

Unplug the CON1 pin header when you have finished programming IC1.

Installing the driver

Assuming that the PIC micro has been programmed, the next step is to plug the unit into a USB port and check that it is detected. A message should pop up adjacent to the System Tray saying 'Installing device driver software' (Windows 7) or 'Found New Hardware' (XP) – see Fig.6. You will then be prompted to locate a driver. You need to use the USB serial port driver, which is available for free download from the *EPE* website (**www.epemag.com**).

The accompanying panel details the driver installation and tells you how to determine which COM port number has been assigned.

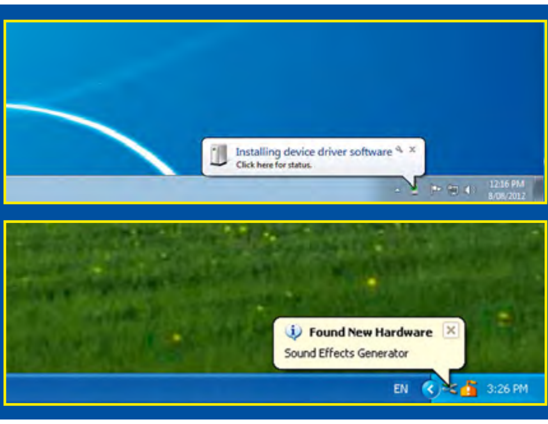


Fig.6: these are the messages that appear adjacent to the System Tray in Windows 7 (top) and Windows XP (bottom) when the *Digital Sound Effects Module* is initially plugged into a USB port (ie, before the USB driver is installed).

That done, download and install the free serial terminal program TeraTerm Pro (available from **www.ayera.com/teraterm**). Launch it and open the port assigned to the USB driver.

Now type 'Info' and press enter and you should get a response confirming that the module is working and showing its firmware version and the amount of free memory.

Preparing the sound files

You now need to prepare the sound file(s) so that they can be uploaded to the module. They must be saved as mono 8-bit or 16-bit PCM WAV files with a sampling rate of between 8kHz and 48kHz.

To check the format of your files or to convert them if necessary, you can use a free sound-file editing program called 'Audacity' (**http://audacity.sourceforge.net/download**).

Load up Audacity and open a sound file. At the left side of the window, you can see whether it is stereo or mono. If stereo, use the 'Stereo Track to Mono' option from the 'Tracks' menu to mix them together.

At the bottom of the screen, select the desired sampling rate (labelled 'Project Rate (Hz)'). Keep in mind that higher sampling rates give better audio quality, but also use more memory. There's no point selecting a higher rate than that of the original file (which will be the default).

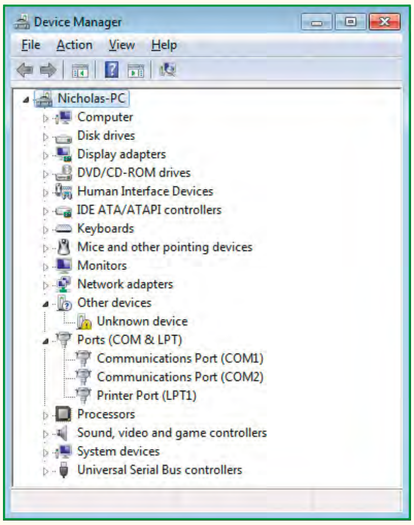
Volume adjustment

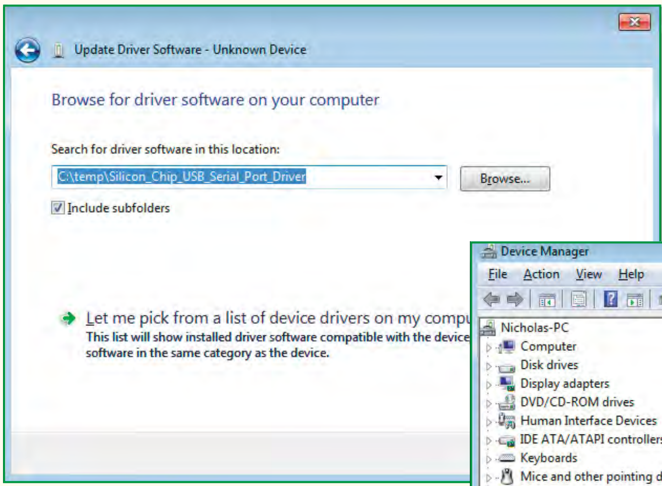
The volume adjustment can now be done. The module plays the file back with a fixed scale (the supply voltage will affect the volume somewhat).

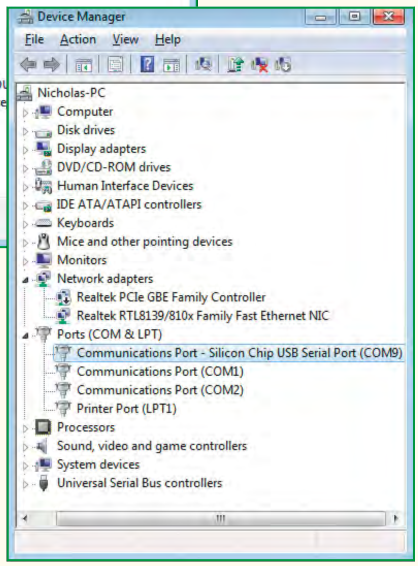
If your sound files are full scale (ie, normalised), then the peaks may be slightly clipped due to the limited output power of the unit, especially if they have heavy bass. For best results, the audio file should be normalised to about 1dB below full scale. This can be achieved by using the 'Amplify' option from the 'Effects' menu, then reducing the dB level shown by 1dB and clicking 'OK'.

If you find the sound is too soft or too loud, you can repeat these steps later, but turn the dB level up or down as necessary. Keep in mind that as you increase the amplification, you may find the sound gets distorted due to clipping. In some cases though, this may be acceptable – it depends on the characteristics of your sound.

How to install the USB driver







FOLLOW THESE steps to install the USB CDC driver in Windows 7 and XP (the procedure is similar for Vista):

1) Plug in the Module, open Device Manager and check that it has been detected as an ‘Unknown device’ or ‘USB device’ in the ‘Other devices’ category.
2) If the Found New Hardware Wizard doesn’t automatically launch, right-click on the device and select ‘Update driver’. You may be asked whether you want to check Windows Update for a driver. If so, select ‘No, not at this time’ or similar.
3) In Windows XP, choose to install the software (driver) automatically. In Windows 7, select the ‘Browse my computer for driver software’ option. For Windows XP, select ‘Install from a list or specified location’. Then for both operating systems, browse for and select the folder containing the SILICON CHIP USB driver.
4) You will now likely get a warning that the driver is not signed. Choose to continue and install the driver anyway.
5) Verify that the driver installation is successful. The device should now show up under the ‘Ports’ category in Device Manager. Make a note of the COM port number assigned.

Saving the file(s)

Now use the Export function from the File menu. If you want to upload the file to the module with a 12-bit resolution, select ‘WAV (Microsoft) signed 16-bit PCM’ from the drop-down at the bottom of the file dialog (it will be converted from 16-bit to 12-bit by the module).

For an 8-bit resolution, select ‘Other uncompressed files’, then click the Options button. For Header, choose ‘WAV (Microsoft)’ and for Encoding, select ‘Unsigned 8-bit PCM’. Then click OK.

You can now select a location, type in a name and press the Save button. The file is then ready to be uploaded. Repeat this process if you are going to upload multiple sound files.

With the files prepared, plug the module into a spare USB port, load up TeraTerm Pro (or if you prefer, another XMODEM-capable terminal program) and connect to the virtual serial port, as described earlier. You can now upload the files using the ‘Send’ command, as described in the ‘Serial Commands For The Sound Effects Module’ panel.

Using the module

With the sounds uploaded and the configuration set (don’t forget to save it!), you are ready to hook up the power, speaker and trigger inputs.

Connect the speaker across the two solder pads. Any 8Ω speaker will do and the more efficient it is, the better. It will also sound much better if it is baffled.

The simplest way to do this is to mount the speaker in a timber box. A tuned box will give the best sound quality, but in general, any baffle is better than none.

You can connect the speaker to the terminals either way around, since the phase doesn’t matter.

There is also space to glue or tape a small (~27mm) speaker to the back of the PCB, next to the cell holder. You can do this if you’re really pressed for space and your sound requirements are modest. However, it will limit the volume and will also give poor bass response.

The trigger switches must be connected between the trigger input pads and the nearby ground pad, either via a pin header connector or by soldering thin wires (eg, ribbon cable) directly to the PCB. You can use microswitches, pushbuttons, reed switches or even the output of a microcontroller or digital logic IC to trigger the unit.

Having done all that, it’s just a matter of inserting the lithium cell into its holder or wiring up the external power supply (AC or DC) to CON3. You can then activate one of the trigger inputs and check that the sound(s) play back as they should. ***EPE***

EPE EXCLUSIVE

Win a Microchip LCD Explorer Development Board

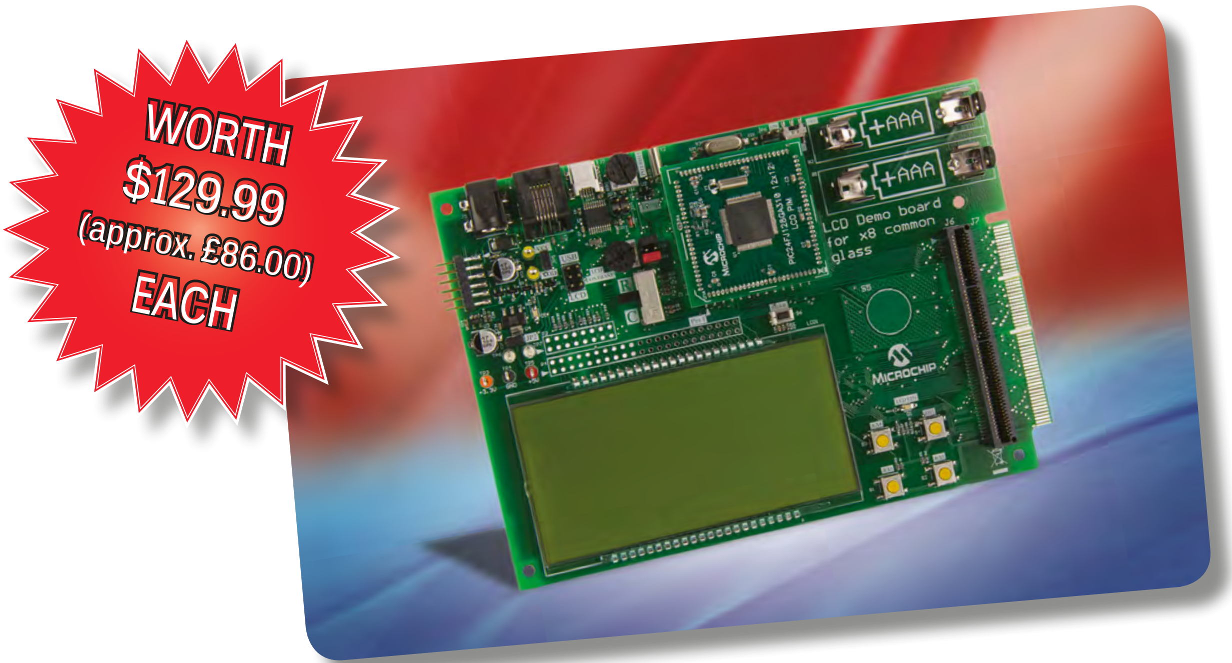
EVERYDAY PRACTICAL ELECTRONICS is offering its readers the chance to win an LCD Explorer Development Board (#DM240314) from Microchip. The LCD Explorer Development Board supports Microchip's 100-pin Microcontrollers with ×8 common-segment LCD drivers. This board provides an ideal platform for *EPE* readers to evaluate an MCU with a ×8 common LCD driver on a 37 segment × 8 common LCD display. PICtail Plus connections allow you to evaluate the selected MCU in a complex system by adding Microchip's PICtail Plus daughter boards.

The on-board potentiometer, temperature sensor, four buttons, mTouch key and PICtail Plus expansion connectors provide a versatile platform for low-power system development.

The kit contains the LCD Explorer Development Board, a 100-pin PIC24FJ128GA310 LCD PIM and example software programmed on PIM.

Features

96 segment by 37 segment × 8 common LCD Glass, four buttons and one mTouch capacitive button, analogue potentiometer and temperature sensor, power input from 9V power supply, battery or USB power source, separate Vbat battery supply, RJ11 and 6-pin PICkit3 programming and debug connectors.



HOW TO ENTER

For your chance to win an LCD Explorer Development Board, please visit: **www.microchip-comps.com/epe-lcd** and enter your details in the online entry form.

CLOSING DATE

The closing date for this offer is 30 September 2013

Déjà vu

TechnoTalk

Mark Nelson

This month, a past technology makes a comeback – plus, LED light bulbs that popped onto supermarket shelves and then disappeared look set to stage a return – Mark Nelson reports

EPE readers are a knowledgeable bunch, so I won't insult your intelligence by asking if you recognise the term 'fluidics'. However, it may be an unfamiliar term for younger readers. Fluidics, or to be precise 'fluidic logic', is the use of a fluid substance to carry out analogue or digital operations similar to those usually performed by electronics. Unlike pneumatics and hydraulics, fluidic devices tend to have no moving parts, or at least parts that only barely move. Like electronics, fluidic devices can act as non-linear amplifiers: a jet of fluid can be deflected by a weaker jet striking it at the side, working rather like a transistor. As Wikipedia explains, fluidics is used mostly in environments where digital electronics would be unreliable – for example, in systems exposed to high levels of electromagnetic interference or ionising radiation.

The next big thing?

Back in the 1960s and 70s, fluidics was all set to be 'the next big thing', proposed for a wide range of applications. In Britain, Plessey even developed a working telephone exchange controlled by fluidics at its Roke Manor research station, but the technology only reached prototype stage. However, fluidics never went away and now analysts forecast major growth in microfluidics – see: **www.fluidics.eu**. According to Benjamin Roussel, a technology and market analyst for Microfluidics & Medical Technologies at Yole Développement (France), the microfluidic device market will grow fourfold, from $1.4 billion in 2013 to $5.7 billion by 2018. Applications are in the pharmaceutical, life sciences, *in vitro* diagnostic and medical device markets. This time, fluidic devices will be integrated with and not replacing electronic systems.

If you find this hard to believe, you may be surprised to learn that you probably own a sophisticated fluidic device – and even use it on a regular basis. To date, the most successful commercial use of microfluidics is in print heads for inkjet printers. Other proposed domestic applications include personal healthcare systems, biological smoke alarms and fuel cells.

The return of LED light bulbs

Despite the fanfare, LED light bulbs have all but disappeared from shops. Customers were reluctant to pay between £15 and £20 for a 'mere' light bulb, and poor experience with compact fluorescents may also have been a factor. However, experts are agreed that LED lighting offers significant potential cuts to electricity bills and hence greenhouse gas emissions. All we need is affordable LED bulbs – by bringing down the manufacturing cost.

Cutting quality is not an option; legislation in the US specifies a minimum lifetime for LED bulbs, so manufacturers dare not sell a substandard product. To reduce costs, the only option is to lower the component count. One solution comes from Power Integration, a Silicon Valley-based supplier of electronic components used in high-voltage power-conversion systems. Its latest product is a new type of LED driver IC, featuring greater than 90 per cent efficiency and meeting (North American) Energystar and (European) Ecodesign requirements. The cost of the driver IC has been reduced to a trifling 29 cents by cutting out little-used features (the bulb is not dimmable for instance), which brings down the total cost of manufacturing an LED bulb to just seven dollars.

Cavity solution

Another approach, taken by electrical giant Siemens, is to find a way of shrinking the size of LED spotlamps and streetlights. These use separate power supplies that generate significant amounts of heat and so need heat sinks. Siemens' solution is to make the heat sink from a new ceramic, and incorporate cavities to house the switch-mode transformers, which Siemens has also reduced in size.

Two techniques are used to reduce transformer size. First, the switching frequency is quadrupled, exploiting the fact that higher frequencies allow smaller transformer geometry. Researchers also developed a layered system of magnetic ceramic films that allows the ferrite core and the windings to be easily incorporated into a ceramic circuit board. These changes mean the transformer size can be reduced by 80 per cent, enabling the driver to be installed in an LED heat sink that is just 10cm by 5cm. So now, the LED modules no longer need separate power supplies, even though their performance and brightness are unchanged.

Save the planet – with LEDs

Still in Germany, a consortium of research companies has been examining energy consumption trends in commercial and service industries. Although energy consumption in trading and services organisations has reduced significantly over the past seven years, there is still plenty of scope for further improvement. More than 40 per cent of the electricity consumed in this sector is used for lighting, so investing in energy-efficient LED technology offers high returns.

These are all reasons to expect LED light bulbs prices – and hence your electricity bill – to fall.

Bargain batteries?

Last month, I ran out of space with the scare stories, so here's one that I had to hold over. It's based on a manufacturer's announcement of the perils of buying 'counterfeit' batteries for cellphones and laptops. The cynic in me dismisses this as mere sales talk. After all, inkjet printer manufacturers warn constantly about using third-party 'compatible' ink in their machines, without offering solid evidence of any harm caused by these products, so why should we be concerned about batteries?

The answer is simple: dubious batteries increase the risk of personal injury. That's according to Electrochem, who design and manufacture batteries for the portable medical, energy, military and other markets. The company analysed counterfeit batteries and discovered worrying variations in manufacturing quality. Shortcomings noted in 'bargain batteries' included insufficient electrical isolation of the printed circuit assembly from the cells, inadequate release of vented gases and poor protection against continuous charge, over-discharge, overcharge, and short circuits. Fortunately, potentially dangerous battery packs are easy to spot visually. So, be on your guard for:

- Unusual manufacturers' names
- Poor quality moulding or printing
- Terminals that protrude significantly from the battery pack enclosure
- Welding that looks substandard
- Inadequate plastic enclosures
- Solder connections with more than 50 per cent of the hole or slot unfilled
- 'Globby' lumps of flux that could 'creep' and corrode other components
- Unsleeved metal tie-strips that could touch and cause short circuits.

EPE EVERYDAY PRACTICAL ELECTRONICS BACK ISSUES

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

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

JULY '12

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

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Make high-quality audio recordings with this . . .

USB Stereo Recording & Playback Interface

. . . it uses balanced mic, S/PDIF and line inputs

Now you can use your laptop PC to make high-quality stereo audio recordings with professional-standard balanced microphones. This interface unit lets you make recordings at sampling rates up to 48 kilosamples/second and provides high-quality stereo analogue line outputs for playback or monitoring. There's also an S/PDIF digital audio input for recording and an S/PDIF digital audio output for playback.

By JIM ROWE

WHILE MOST LAPTOPS have a built-in sound card, they're no good for high-quality audio recordings. Most built-in sound cards are of somewhat indifferent quality when it comes to the recording side and they don't provide balanced inputs for professional type microphones, which are really necessary for making high-quality recordings.

Hence, if you want to use a laptop, you need an 'audio front-end' with balanced-input microphone preamps feeding a pair of high-quality analogue-to-digital converters (ADCs). And since most laptops have at least one USB port, the easiest way to connect such an audio front-end to them is via a USB cable. This has the added advantage of allowing the audio front-end to draw its power from the laptop, via the same cable.

This was the rationale behind the low-cost audio front-end unit we're describing here. Or at least, those were our basic goals when we started its development. Along the way it 'grew some' when we realised that it wouldn't be too difficult to provide it with various bonus features:

1) Line-level analogue stereo recording inputs
2) Line-level analogue stereo outputs for playback and/or monitoring
3) S/PDIF digital audio input and output for direct digital recording and playback.

In effect, it has become a flexible multi-purpose USB audio interface – not just for laptops, but for virtually any PC. It's easy to build and much lower in cost than comparable commercial units. What's more, there's no software to install – you just connect it up and it runs on Windows XP SP3, Windows

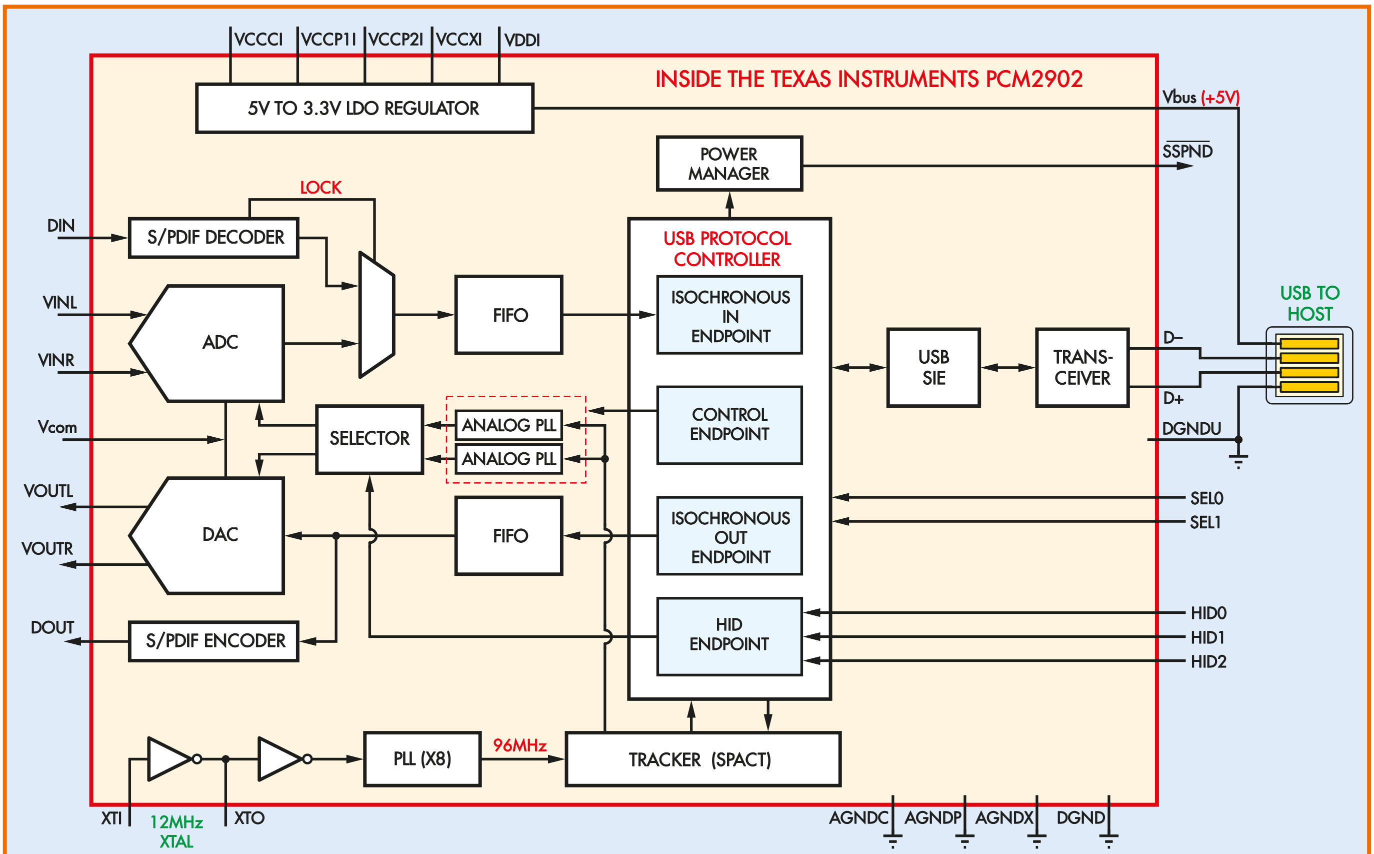


Fig.1: this block diagram shows what's inside the PCM2902 stereo audio CODEC IC. It provides line-level analogue stereo inputs and outputs, an S/PDIF digital audio input, an S/PDIF output and a full-speed USB interface.

Vista and Windows 7 (both 32 and 64-bit). It should also work with recent Linux and Mac operating systems.

What's inside?

The heart of the project is the PCM2902 IC from Texas Instruments. This was originally developed by Burr-Brown, which was acquired by TI not long ago. The PCM2902 is described as a single-chip stereo audio CODEC with an inbuilt full-speed USB protocol controller, SIE (serial interface engine) and transceiver.

As well as providing line-level analogue stereo inputs for recording and line-level stereo outputs for playback, it includes an S/PDIF digital audio input for recording and an S/PDIF output for direct digital playback. And of course, it has an inbuilt full-speed USB interface.

Fig.1 shows the goodies packed inside the PCM2902. To the right of centre is the USB protocol controller block which provides four main USB 'end-points':

1) A control end-point which receives control commands from the PC host
2) An HID (human interface device) end-point which allows inputs to the chip to generate keypress events on the host PC, to control muting, volume etc
3) An isochronous IN end-point which handles the transfer of audio recording data from the ADC section IN to the PC via the USB
4) An isochronous OUT end-point which handles the transfer of audio playback data OUT of the PC via the USB, feeding it to the DAC section.

Don't worry too much about these terms, but you might like to know that 'isochronous' means that the audio data packets are transferred at a constant rate (isochronous = equal time). You might also want to note that we're not actually making use of the HID end-point in this project.

To the right of the USB protocol controller block are the USB SIE and transceiver sections, which transmit and receive all the data and control packets transferred over the USB signal lines. Just above the protocol controller is the power manager block, which controls the power taken by the external circuitry, as directed by the host PC's USB driver.

Thus, when the PC directs the PCM2902 protocol controller to switch the device into low power 'suspend' mode because no activity has been detected for a few milliseconds, the power manager block drops the logic level on the $\overline{\text{SSPND}}$ output pin. This is used by external control circuitry to turn off power to everything but the 'brains' of the PCM2902 chip itself.

As soon as the PC directs the protocol controller to resume normal operation, the power manager pulls the $\overline{\text{SSPND}}$ line high again, so power is restored to the external circuitry and it can get back to work.

The sections to the left of the USB protocol controller block in Fig.1 are those involved in processing the record and replay signals. In the upper area, there's the stereo ADC section for converting incoming analogue audio into 16-bit digital samples, together with the S/PDIF digital audio input decoder. The digital bitstream from one of these is fed through a FIFO (first

What the acronyms mean

ADC: an analogue-to-digital converter, which samples incoming analogue (audio) at a designated rate such as 44,100 samples per second and outputs the samples as a digital serial bitstream. A stereo ADC samples both channels simultaneously, but interleaves the samples in the output bitstream (ie, L-R-L-R and so on).

CODEC: short for 'COder/DECoder' – basically a combination of one or more ADCs with one or more DACs. It can also include functional blocks for encoding and decoding the digital samples.

DAC: a digital-to-analogue converter, which converts digital data samples into the equivalent analogue voltages or currents. A stereo audio DAC is really two separate DACs, one of which converts the left channel samples in the incoming bitstream, while the other DAC converts the right channel samples.

FIFO: a First-In-First-Out buffer, which provides temporary storage for a stream of digital data. Although it functions like a serial delay line, most FIFOs are actually implemented with dual-ported random-access memory, RAM.

LDO: a Low-DropOut voltage regulator – ie, one which requires a very small difference between the unregulated input voltage and the regulated output voltage in order to operate correctly.

PLL: a Phase-Locked Loop, which is a functional block designed to lock an oscillator to an exact multiple or sub-multiple of a frequency from another oscillator.

SIE: short for 'Serial Interface Engine'. A functional block which manages the packaging/transmission and reception/unpackaging of data transferred via a serial interface like USB.

S/PDIF: the Sony/Philips Digital Interface Format, a protocol and physical layer specification used to transport digital audio signals between devices and components. The signals can travel over either a coaxial cable or an optical fibre cable (in the latter case it is usually called 'TOSLINK'). It is a consumer-level adaptation of the original AES/EBU (Audio Engineering Society/European Broadcasting Union) standard for professional digital audio. The serial audio data stream is encoded with 'biphase mark coding'.

TOSLINK: short for Toshiba Optical Serial Link, the version of S/PDIF which uses optical fibre cables to carry the digital audio bitstream.

USB: short for 'Universal Serial Bus', the serial data communications bus now very widely used to link PCs with a broad range of peripheral devices. The original USB 1.0/1.1 standard supported communication at low speed (1.5Mbits/second) and full speed (12Mb/s). When USB 2.0 was subsequently introduced this also covered high speed (480Mb/s), while the recently adopted USB 3.0 standard adds super speed (5Gb/s). USB 1.1 and 2.0 use a standard 4-wire cable, with different connectors at each end – Type A for connection to the 'downstream' port of the PC or an intermediate hub, and Type B for connection to the 'upstream' port of the USB peripheral device.

in, first out) buffer to the isochronous IN end-point of the USB protocol controller, for transmission to the PC host.

By the way, if there's a signal from the S/PDIF input decoder it becomes the recording signal, but if there is no S/PDIF signal, the bitstream from the ADCs is fed to the FIFO block as the recording signal.

In the lower area of the block diagram there's a second FIFO buffer, which is fed from the protocol controller's isochronous OUT end-point with audio playback data received from the PC host. The output of this second FIFO is fed to the stereo DAC section to be converted into analogue playback audio. At the same time, it is fed to the S/PDIF encoder section to produce a digital playback bitstream.

So the playback signals simultaneously appear at both the analogue audio outputs and the digital S/PDIF output.

Note that the clock signals used by all parts of the PCM2902 are derived from a single 12MHz oscillator inside the chip itself (apart from the crystal and some minor components). An internal PLL (phase-locked loop) is used to multiply the crystal frequency by eight, producing a 96MHz clock that's used to drive most of the chip's circuitry – including the ADCs, DACs and USB control circuitry.

An important feature of the PCM2902 is the 'tracker' section you can see just below the USB protocol controller. This takes the 96MHz internal clock and locks it to an audio clock signal derived from the USB data packets, using what TI calls its 'SpAct' architecture. This is claimed to reduce clock jitter for both recording and playback, and also allows simultaneous recording and playback at different sampling rates.

Note that the PCM2902's ADCs use 16-bit delta-sigma conversion and can work at any of seven standard sampling rates: 8, 11.025, 16, 22.05, 32, 44.1 and 48kHz. The DACs also use 16-bit delta-sigma architecture but can only operate at the three most popular sampling rates: 32, 44.1 or 48kHz.

As you can see, the PCM2902 is a very powerful chip, containing all the main functions needed for a high-quality USB stereo recording and playback interface.

Circuit description

Refer now to Fig.2 for the complete circuit of the *USB Stereo Recorder & Playback Interface*. Now that you've seen inside the wondrous PCM2902 chip, you should be able to follow its operation without any problems.

All the circuitry to the left of the PCM2902 itself (IC3) is concerned with preparing the incoming audio signals for recording. The left-channel analogue recording circuitry is shown at top, with identical circuitry for the right channel below it. Each channel has a balanced microphone input connector (CON1 and CON3) and each of these feeds a balanced-input mic preamp using three sections of an MCP6024 low-noise, low-voltage CMOS quad op amp (IC1c,b and d and IC2c,b and a).

The gain of these preamps is adjusted via a dual-gang potentiometer (VR1a and VR1b). This allows the gain to be optimised without running into overload. The maximum preamp gain is 201, which should be sufficient for most microphones.

The line-level output from each mic preamp (ie, at pin 14 of IC1d and pin 1 of IC2a) is fed to its corresponding position on double-pole switch S1. Alternatively, the second position of each pole is used to select the signals from the line-level input sockets (CON2 and

CON4). The signals selected by S1a and S1b are then fed to third-order active low-pass filters based on IC1a and IC2d.

These are used for 'anti-aliasing' and filter out any audio components above about 22kHz. Without these filters, there could be audible alias components being generated as part of the sampling process.

The outputs of the anti-aliasing filters are in turn fed to the ADC inputs of the PCM2902 (VinL at pin 12 and VinR at pin 13) via 1µF coupling capacitors.

Note that because the op amps in IC1 and IC2 are being operated from a single DC supply rail (Vcc) of approximately 4.0V, they must be biased midway between Vcc and 0V to ensure maximum output swing with minimum distortion. This Vcc/2 bias voltage is derived from a resistive voltage divider consisting of two 2.7kΩ resistors (just above IC1a). The same voltage is also used to bias the replay filters and output buffers in IC4, which we'll come to in a moment.

The only remaining part of the recording circuitry is CON5. This is the S/PDIF digital bitstream input. Its signal is simply fed into the Din input (pin 24) of the PCM2902 via a 100nF capacitor.

Specifications

Purpose: a digital stereo recording and playback interface for laptop PCs, which links to the PC via a standard USB cable and is powered from the PC's USB port via the same cable. Features include:

- **Twin balanced-input microphone preamps for use with professional type microphones.**
- **Selectable line-level stereo analogue inputs.**
- **High-quality stereo ADCs for recording at any of seven standard sampling rates (8, 11.025, 16, 22.05, 32, 44.1 and 48kHz).**
- **Built-in stereo DACs for replay at any of three standard sampling rates (32, 44.1 and 48kHz).**
- **An S/PDIF digital audio input to allow recording directly from an S/PDIF digital audio signal, as an alternative to the analogue audio inputs.**
- **An S/PDIF digital audio output to allow playback via a high-quality digital sound system, as an alternative to the analogue audio outputs.**
- **16-bit delta/sigma ADCs and DACs.**
- **Fully compliant with the USB 1.1 specification.**
- **Installs automatically on Windows XP SP3 and later operating systems (plus recent Mac and Linux systems) using the standard USBaudio.sys drivers – no custom drivers required.**
- **Fully compatible with Windows-based audio recording and playback software such as 'Audacity'.**
- **Frequency response: Recording = 20Hz to 17kHz +0dB/–1.0dB, 15Hz to 20kHz +0dB/–2.0dB; Playback = 30Hz to 18kHz +0dB/–1.0dB, 20Hz to 21kHz +0dB/–2.0dB**
- **Low current drain (below 70mA).**

Replay circuit

The replay circuitry is shown to the lower right of the PCM2902. The DAC output signals appear at VoutL (pin 16) and VoutR (pin 15) of the PCM2902 and are fed via 1µF coupling capacitors to active low-pass filters based on IC4b and IC4c. These two filters are identical to those used in the recording channels and remove any glitches that are present in the DAC outputs. The filtered signals are then passed through unity-gain buffer stages IC4a and IC4d and fed to the line output connectors (CON7 and CON8) via 1µF capacitors.

The S/PDIF digital replay output appears at the Dout pin (pin 25) of the PCM2902. This is fed to the S/PDIF output connector (CON6) via a 150nF capacitor and a resistive divider to provide the correct peak-to-peak amplitude.

The external components needed by the PCM2902's 12MHz master clock oscillator are shown just below the Dout output pin. Apart from the 12MHz crystal itself, there are two low-value NPO ceramic capacitors, which are used to bring the crystal's frequency into the correct range (12.000MHz ±6kHz), plus a 1MΩ bias resistor to ensure that the oscillator has minimum 'start-up' delay when power is applied.

USB interface

The only part of the circuit we haven't yet discussed is the USB interface and power management section. Because the SIE and USB transceiver are inside the PCM2902, the external part of the USB interface is really very simple. As shown, the four pins of USB connector CON9 are connected to the corresponding pins on the PCM2902, via 22Ω suppressor resistors in the case of the D+ and D– signal lines, and via a 2.2Ω current-limiting resistor in the case of the Vbus line.

The +5V supply applied to pin 3 (Vbus) when the interface is connected to the PC host (via a USB cable) is passed through an LDO (low dropout) regulator inside the PCM2902. The LDO's output in turn appears at pin 27 (Vddi). Because the D+ signal line of the USB interface is connected to this pin via a 1.5kΩ resistor, this means that the D+ signal line is pulled up to a voltage close to Vbus. According to the USB specification, this is the correct way of indicating to the PC host controller that a USB device is capable of full-speed (12Mb/s) operation.

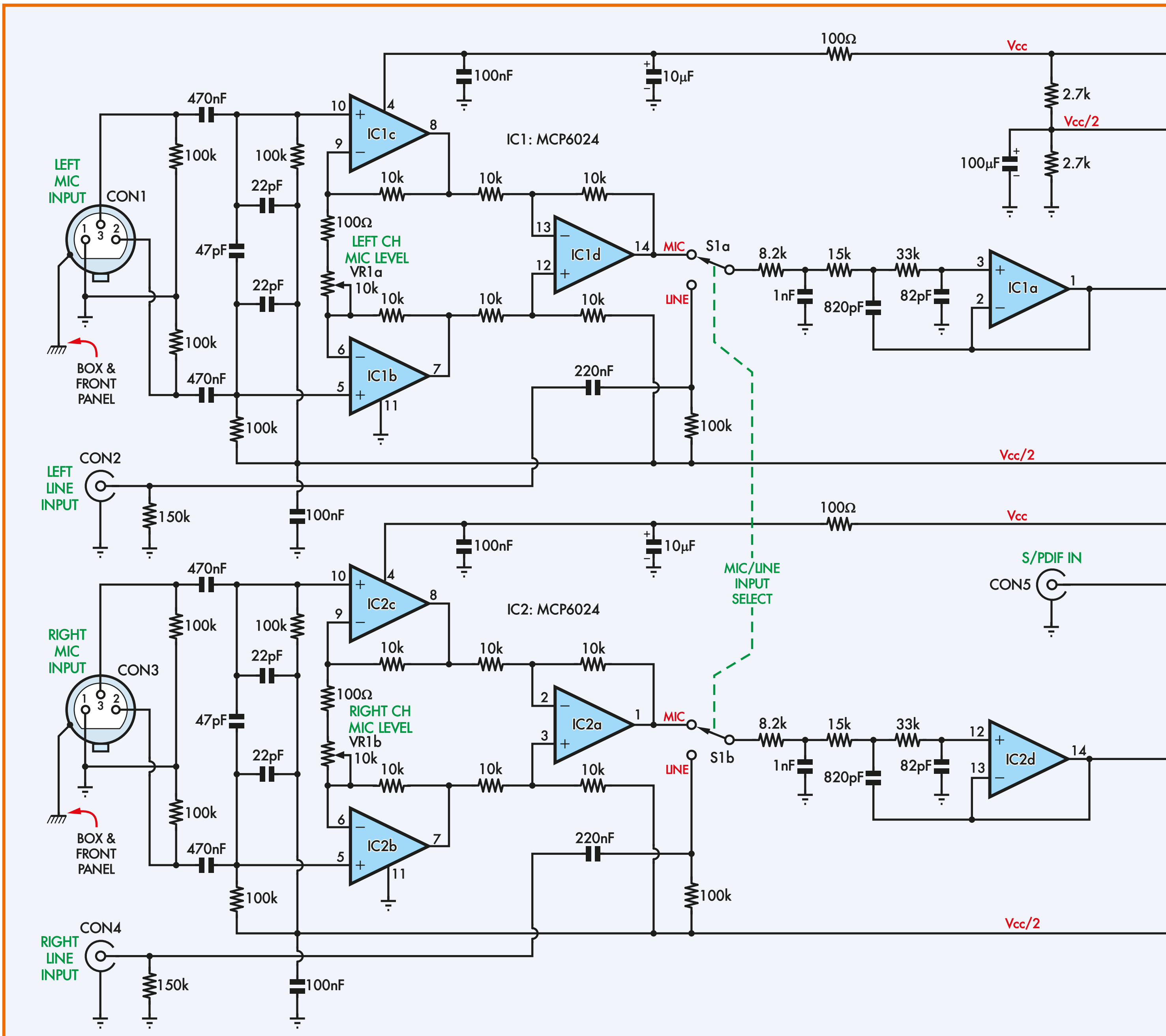
Finally, we come to the power management circuitry, which is based on REG1, a REG103GA-A LDO regulator made by TI. There are two features that make this regulator special.

The first is that its output voltage can be adjusted, something that's not all that common with LDOs. The second is that it's provided with an enable input (pin 5), so its output can be turned on and off very quickly by a control signal applied to this pin.

These two features, plus its use of internal DMOS circuitry to achieve an exceptionally low drop-out voltage (typically <20mV for 90mA output current) make the REG103GA-A ideally suited for this sort of application.

REG1's output voltage is set to 4V by the resistive divider connected to pin 4 (ADJ). In addition, pin 5 (EN) of REG1 is connected to pin 28 ($\overline{\text{SSPND}}$) of the PCM2902. So, whether or not REG1 provides this output voltage depends not only on the presence of +5V from the PC via pin 1 of CON9, but also on the logic level of the $\overline{\text{SSPND}}$ control signal derived from the power management circuitry inside IC3.

If the PC directs the USB protocol controller inside IC3 to reduce the USB device's power level and enter 'suspend' mode, the power management circuitry inside IC3 pulls pin 28 down to 0V. This in turn pulls the EN pin of REG1 low and switches off the Vcc output voltage. As a result, IC1, IC2 and IC4 all shut down, as does the circuitry inside IC3, which gets



USB STEREO RECORDING AND PLAYBACK INTERFACE

Fig.2: the circuit for the *USB Stereo Recording & Playback Interface*. Quad op amps IC1 and IC2 form balanced microphone preamp and filter stages, while IC4(a)-4(d) filter and buffer the line outputs from IC3. In addition, IC3 directly interfaces to the S/PDIF input and output sockets and to a type-B USB socket.

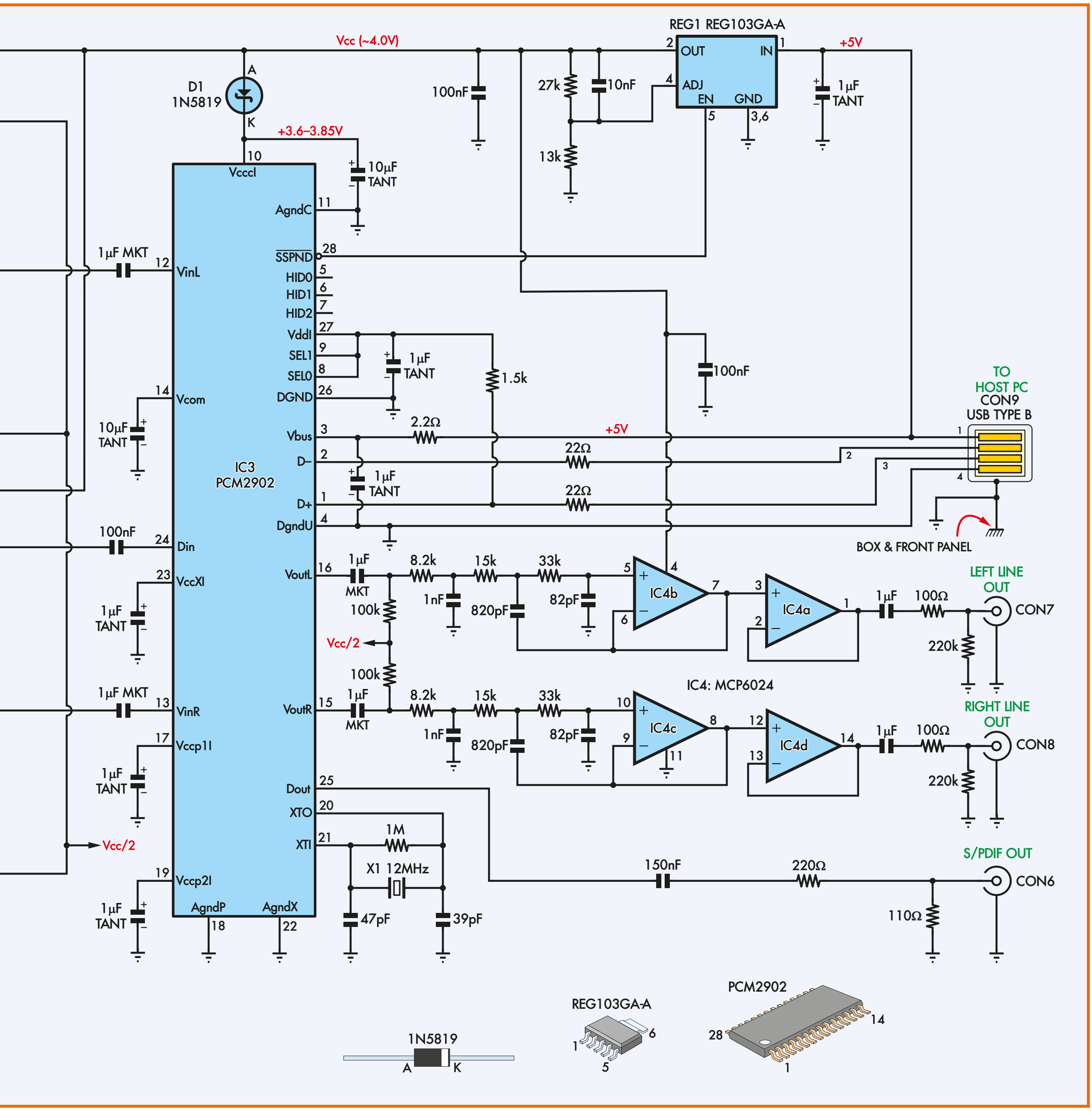
its power from the Vcc line via diode D1 and pin 10 (Vccci).

When the PC directs the USB protocol controller inside IC3 to resume normal operation, its power management circuitry pulls pin 28 high again. REG1 then switches its output voltage (Vcc) back on again, thus restoring normal operation.

At this stage, you may be wondering how the protocol controller, SIE, USB transceiver and master clock oscillator inside IC3 are able to respond to any directions from the PC after it has entered suspend mode (ie, when REG1 has turned off the power). The secret here is that these sections inside the PCM2902 are all powered from the internal LDO, which is fed with the +5V applied to its Vbus pin (pin 3) from pin 1 of CON9.

This voltage is available all the time, as long as the device is connected to a PC host via a USB cable. Hence these sections inside the PCM2902 are always able to respond to commands from the PC.

The rest of the circuitry inside IC3 (eg, the ADCs and DACs) is powered from the Vcc line via D1 and the Vccci pin. As a result, it's only these sections inside IC3 which 'go to sleep' in suspend mode. Since these are the parts of the PCM2902 which draw the most current, they need to be shut down when the device enters suspend mode.



The result of this power management system is that the total current drawn by the *USB Stereo Recording & Playback Interface* in suspend mode is less than 220µA; much lower than the 60-70mA drawn in operating mode. This means that it comfortably meets the appropriate USB specification – that all USB devices must be capable of entering a suspend mode, where they must draw no more than 2.5mA from the USB power line.

Building it

All parts, except for switch S1, potentiometer VR1 (microphone gain) and the two XLR mic input sockets (CON1 and CON3) are mounted on a double-sided PCB, coded 07106111. This is housed in a standard diecast aluminium box measuring 119mm × 94mm × 57mm.

Fig.3 shows the parts layout on the PCB. Begin by checking the board for any defects (especially around IC3 and REG1), then test fit the RCA sockets to make sure their mounting holes are the correct sizes. Check also that the corner cut-outs have been made.

Once that's done, start the assembly by installing the two SMDs (IC3 and REG1). IC3 (PCM2902) comes in an SSOP-28 package, while REG1 comes in a 5-pin SOT223 package. As shown in Figs.3 and 4, both devices are mounted on the top of the board.

It's important to use a soldering iron with a very fine tip to install these

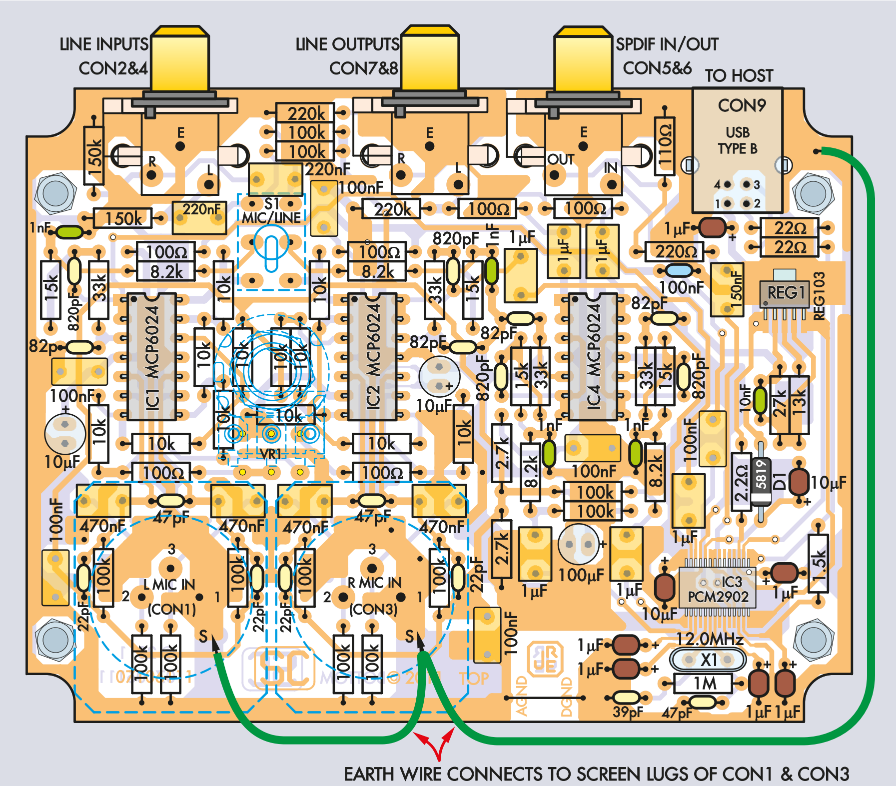


Fig.3: follow this diagram to install the parts on the PCB, starting with REG1 and IC3. The parts with blue outlines mount on the case lid and are connected via wire extension leads. Note that you can substitute 1µF monolithic ceramic capacitors for the 1µF tantalums shown on the overlay.

two devices. You also need some fine-gauge resin-cored solder and some solder wick. A magnifying lamp or magnifying glass will also be handy.

REG1's pins are more widely spaced than IC3, so install it first. Start by carefully positioning the device accurately over the pads on the board, then lightly tack solder one of its outside pins. Adjust its position if necessary, then solder the remaining pins. **Note that you also have to solder its heatsink tab (opposite the pins) to the matching rectangular pad on the PCB.**

IC3 is a bit trickier to install but the procedure is similar. Make sure it is oriented correctly, with the dimple in the 'pin 1' corner at upper right, then lightly 'clamp' it into place using a pair of self-closing tweezers. Check that it is accurately positioned, then place a tiny drop of solder on the tip of your iron and just touch the tip to the end of pin 1, so that the solder flows down and 'tacks' the pin to the PCB pad.

Now do the same for pin 15 which is diagonally opposite, at the lower left corner of the device. These two 'tacked' pins will now hold the device in place while you solder the remaining pins.

Use a minimum of solder for each pin, but don't worry if you make a few inadvertent solder bridges between the tracks or adjacent pins.

Once you've soldered all 28 pins, use a magnifying glass to check for solder bridges. If you do find any, they are quite easy to remove using a narrow strip (ie, 2mm wide) of desoldering braid or solder wick.

The trick is to place the braid directly over the bridged pins (or tracks), then press the braid firmly down onto the pins using the tip of your iron for a couple of seconds. The braid then not only heats up the pins, but also 'sucks up' and removes the solder bridge as well.

In practice, you'll find that this is much easier to do than it sounds, especially if the PCB has a solder mask.

Once you've finished, check all the pins again with a magnifying glass, just to make sure. It will be harder to remove any remaining problems later when the adjacent parts are in place.

The 'through-hole' parts can now be installed on the PCB, starting with the single wire link and the resistors. Check each resistor using a DMM (digital multimeter) before soldering it into place on the PCB, then fit diode D1 (watch its orientation) and the 14-pin DIL sockets for IC1, IC2 and IC4.

Follow with the low-value ceramic and MKT capacitors, then install the electrolytic and tantalum capacitors. The electrolytics and tantalums are all polarised, so be sure to fit them with correct orientation as shown on Fig.3.

Note that both the circuit and overlay depict the use of six 1µF tantalum capacitors. Alternatively, you can substitute 1µF monolithic ceramic capacitors (see parts list).

The 12MHz crystal (X1) is next on the list and this goes in just below IC3. **It should be fitted with a thin insulating washer underneath it, so that its metal case cannot make contact with any of the nearby copper tracks on the top of the board** (it's a good idea to fit this, even if the PCB has a solder mask). This insulating washer can be made from a small rectangle of clear plastic film, with two small holes punched in it 5mm apart to allow X1's pins to pass through.

Alternatively, you can mount the crystal so that its case is slightly proud of the PCB.

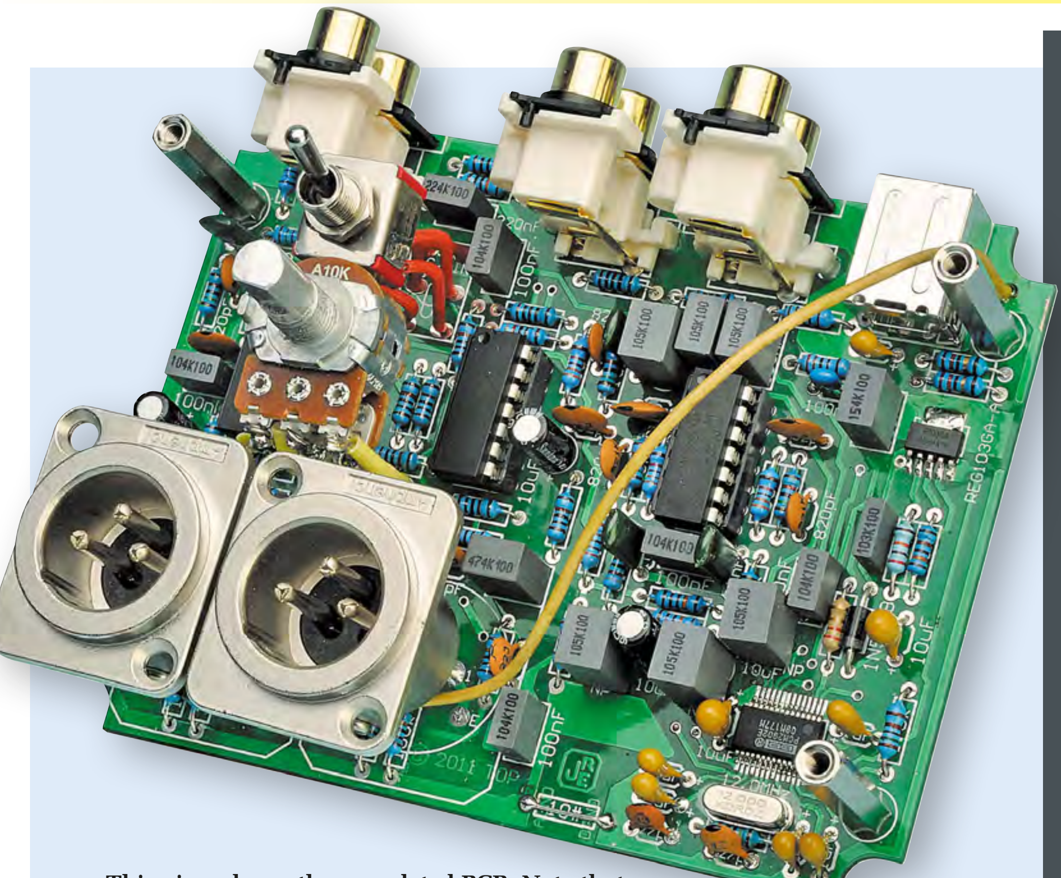
The PCB assembly can now be completed by plugging in the three ICs and fitting the three double-RCA sockets and the USB-type B socket. Make sure that the ICs are correctly oriented.

Drilling the case

If you build this project from a kit, the box and its lid may be supplied pre-drilled and the lid may also come with a screen-printed front panel. If not, then you'll have to drill and cut the holes in the case yourself.

Fig.5 shows the drilling details. Note that holes 'B' in the rear panel for the 'upper' RCA sockets are 12mm diameter, while holes 'A' for the 'lower' sockets are 11mm diameter. The reason for this difference is that the larger 'B' holes allow easier entry of the lid/PCB assembly into the box, during final assembly.

Having drilled, cut and de-burred all of the holes, the next step is to fit the front panel to give the unit a professional finish. Fig.6 shows the front-panel artwork and you can either copy this or download the panel in PDF format from the *EPE* website and print it out. The panel can then be laminated and attached to the lid using double-sided tape.



This view shows the completed PCB. Note that it must be secured to the case lid before soldering the leads from the switch, potentiometer and XLR sockets (see text).

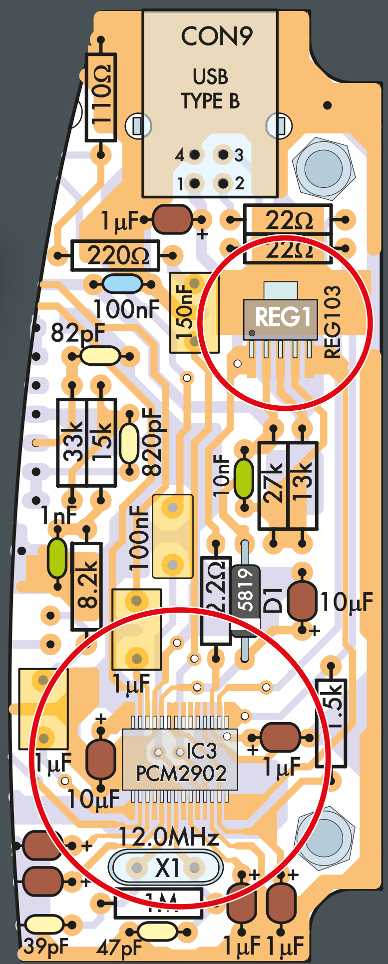


Fig.4: this enlarged section of the PCB shows mounting details for REG1 and IC3. Use a fine-tipped iron to solder their pins (see text).

Once it's in position, cut out the holes using a sharp hobby knife.

Final assembly

Now for the final assembly. The first step is to fit switch S1, potentiometer VR1 and the two XLR sockets to the lid assembly. Cut the pot shaft to about 10mm long before fastening it in position.

The switch and pot are secured using the supplied nuts, while the XLR sockets are each held in place using two M3 × 10mm machine screws, star lockwashers and nuts.

The next step is to fit extension leads to the terminals of both S1 and VR1. These leads are run using 0.7mm tinned copper wire and should be about 25mm long for S1 and about 35mm long for VR1. That done, sleeve the extension wires with either 1.5mm heatshrink tubing or 2mm varnished cambric tubing. The sleeves for the leads from S1 should be about 18mm long, while those for VR1's leads should be about 28mm long.

The three main connection spigots on the rear of XLR sockets CON1 and CON3 are fitted with similar extension leads. These need to be only about 12mm long, as the sockets extend downwards much further than the switch and pot terminals. They also don't need any insulating sleeves, as there will be only about 4mm free above the PCB when it is subsequently mounted on the lid.

Fig.7 shows how the assembly goes together. Before mounting the board in place, you need to fit four 35mm-long spacers to the holes near the corners of the lid. These spacers are made up using M3 × 25mm and M3 × 10mm tapped metal spacers which are stacked together and secured using M3 × 20mm machine screws.

As shown, the screws go through the front panel and initially secure the 10mm spacers in place. The 25mm spacers are then wound on over the protruding ends of the screws.

Once the spacers are in position, you're ready to attach the PCB to the lid. It will be necessary to dress the leads from S1, VR1 and the XLR sockets so that their ends align with their matching holes in the PCB. It also helps if the various leads have their ends trimmed to staggered lengths, so that they can be guided through in sequence.

A pair of long-nose pliers can be used to help guide the leads through their respective holes.

If this proves too awkward, remove S1 and potentiometer VR1 from the lid, then slip their leads down through the PCB. The lid can then be introduced to the PCB, at the same time guiding the six XLR socket leads through their holes. Once it's in position, secure the board using four M3 × 6mm machine screws, then slip the switch and pot back up through their mounting holes and do up their nuts.

Finally, the leads from the XLR sockets, the pot and the switch can be soldered to the PCB pads and trimmed to length.

Earth lead

There's just one more wiring step to complete the front panel/PCB assembly. This is to fit an insulated 'earthing' lead which connects from the PCB earth copper to the body/screen lugs of

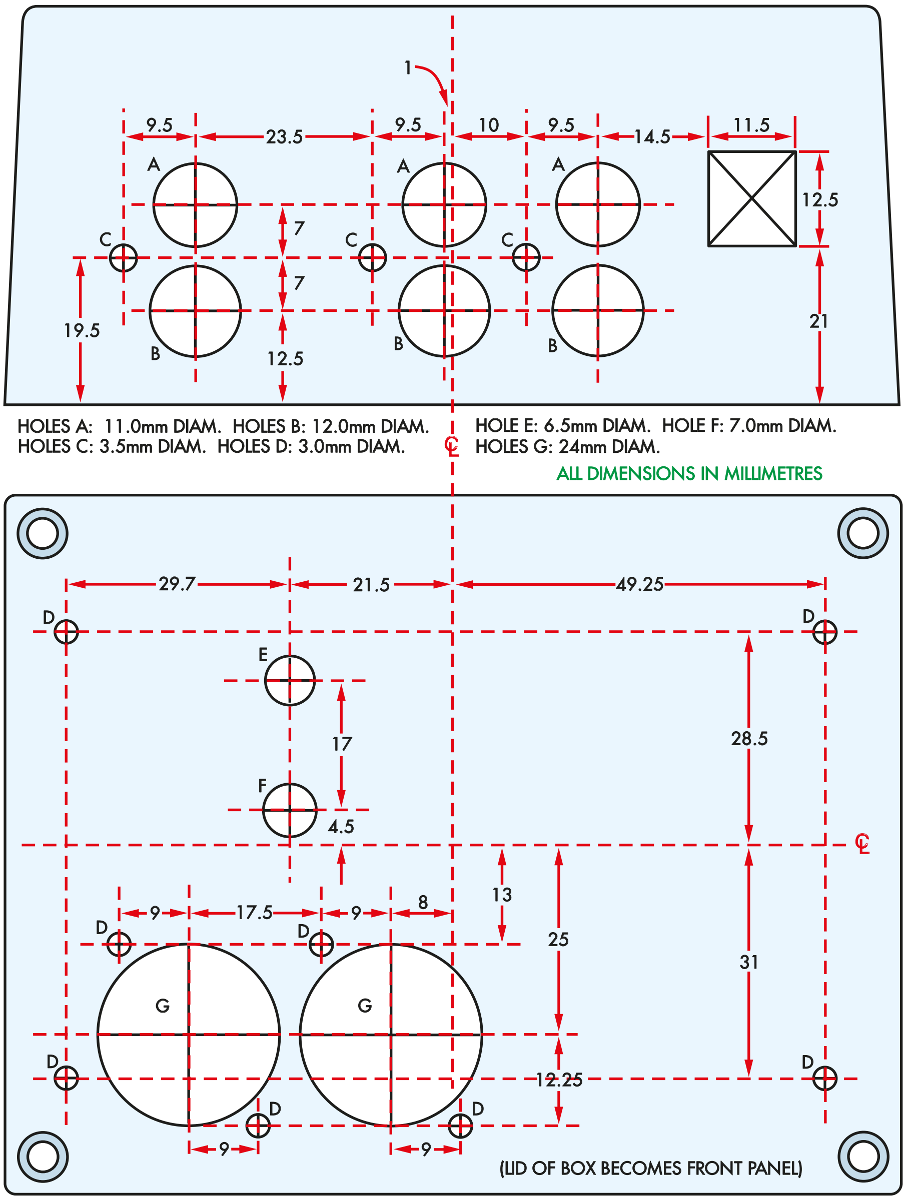
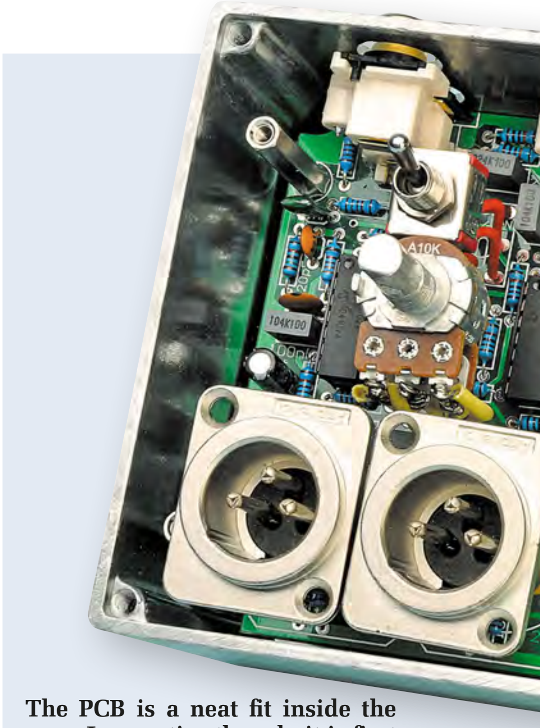


Fig.5: this is the drilling template for the case. Start each hole with a small pilot drill to ensure accuracy and use a tapered reamer to enlarge the holes for the RCA sockets (A and B). The two holes for the XLR sockets (G) can be made by drilling a series of small holes around the inside diameters, knocking out the centre pieces and filing for a smooth finish.



The PCB is a neat fit inside the case. In practice though, it is first attached to the lid before the entire assembly is dropped into place.

the XLR connectors. This in turn connects the PCB earth to the metal case when it's all later screwed together.

Fig.3 shows how to install this lead. It's run using insulated hook-up wire and is connected to the PCB earth copper just to the right of CON9. It then runs across the board to the screen lug of CON3 and then to the screen lug of CON1.

That done, the PCB/front panel assembly can be completed by fitting the mic gain pot (VR1) with its control knob.

The final step is to slip the PCB/front panel assembly down into the box. This is done by tilting it at an angle so that the RCA connectors can enter their clearance holes in the back of the box. This then allows you to swing down the front of the assembly and lower it all the way into the box.

That done, fasten the lid to the box using the four M4 countersink-head screws supplied and use three 4G × 9mm self-tapping screws to secure the three dual RCA sockets to the rear of the case. These self-tapping screws pass through the 'C' holes on the rear panel and ensure that the RCA sockets are not pushed back inside the case when the cables are attached.

Don't over-tighten these screws, otherwise you'll strip the holes in the plastic bodies of the RCA sockets.

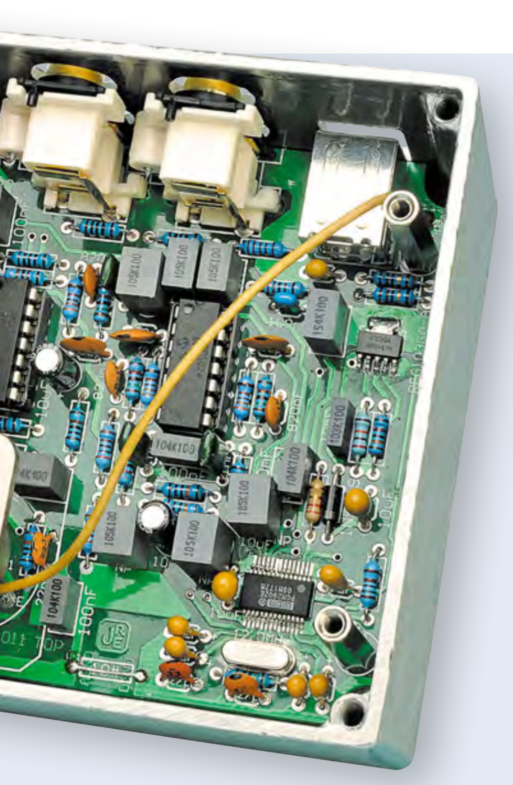
Installation and testing

Testing involves little more than connecting the unit to a spare USB port on a PC running Windows XP (Service Pack 3), Windows Vista or Windows 7. Alternatively, you can connect it to a spare downstream port on an external USB hub that's connected to the PC.

After a few seconds, you should hear a greeting from the PC's sound system to indicate that the operating system has recognised that a new Plug and Play USB device has been connected. It then shows pop-ups from the System Tray as it identifies the device and automatically installs the standard USB audio drivers for it.

The next step is to check that this has all taken place correctly. In Windows XP, click the Windows Start button, launch the Control Panel and double-click on 'Sounds and Audio Devices'. This should bring up the Sounds and Audio Devices Properties dialog. If you then click on the 'Audio' tab, you should see 'USB Audio CODEC' listed in the drop-down device selection lists for both Sound Playback and Sound Recording (Fig.8). This should also be the case if you click on the 'Voice' tab.

Now click on the 'Hardware' tab and select 'USB Audio Device'. You should see the following information in the Device Properties area:



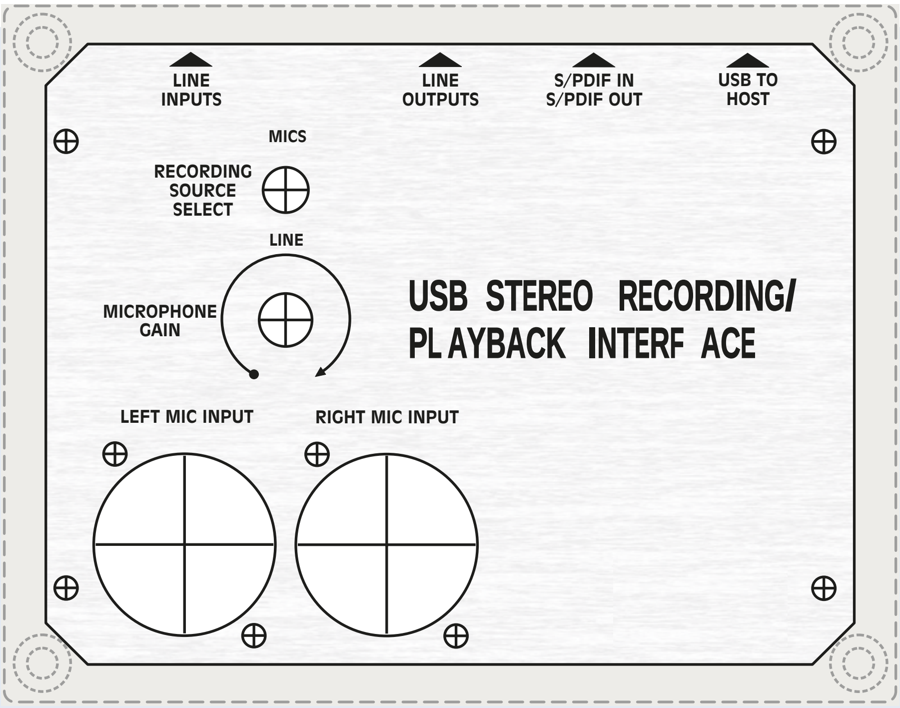


Fig.6: this full-size front panel artwork can be copied or you can download it in PDF format from the *EPE* website and print it out.

Manufacturer: (Generic USB Audio)
Location: Location 0 (USB Audio CODEC)
Device Status: This device is working properly.

If you are using Windows 7, launch the Control Panel and double-click on the 'Sounds' icon. This brings up the dialog box shown in Fig.9 and you should see that the 'USB Audio CODEC' has been installed as the default device.

You can also check the device has been correctly installed in Device Manager. Launch Device Manager from Control Panel, then expand the 'Sound, video and game controllers' entry and check that 'USB Audio CODEC' is listed – see Fig.10. This applies to both Windows XP and Windows 7 (and Vista).

Using it

Using the unit with your PC for audio recording and playback is straightforward. The first step is to select it as the 'Default device' in the drop-down lists under both the Audio and Voice tabs of the Sounds and Audio Devices Properties dialog (Windows XP). You can also use the Volume tab to adjust the replay volume and to get Windows to provide a volume control icon in the system tray at the end of the taskbar.

Your new *USB Stereo Recorder & Playback Interface* will now be the default device on your PC for both audio recording and playback. And because

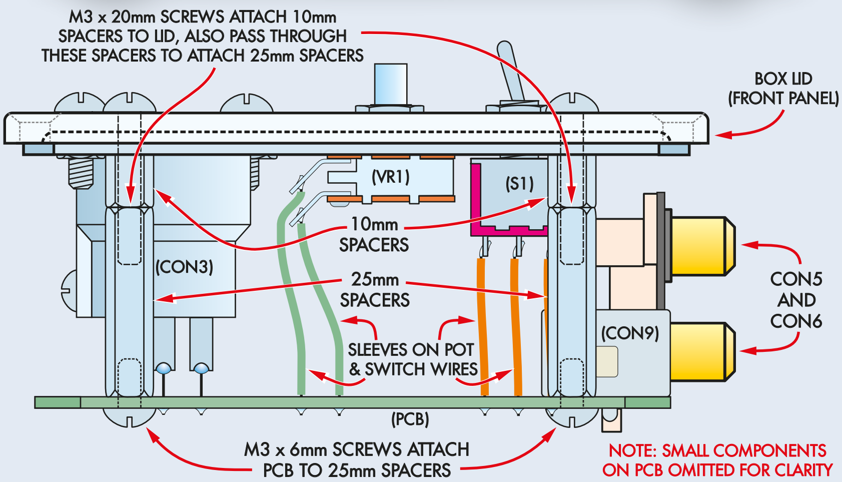


Fig.7: here's how the assembly fits inside the case. Six wire extensions are required for VR1, six for switch S1 and three each for the XLR sockets.

Parts List

1 double-sided PCB, code 07106111, available from the *EPE PCB Service*, size, 109mm × 84mm
1 diecast metal box, 119mm × 94mm × 57mm
1 mini DPDT panel-mount toggle switch (S1)
1 10kΩ 16mm dual pot. (VR1)
1 knob to suit
2 XLR balanced male connectors, panel-mount
1 12.000MHz crystal, HC49/4H case (X1)
3 PC-mount dual RCA sockets
1 PC-mount type-B USB socket
3 14-pin DIL IC sockets
4 M3 × 25mm tapped metal spacers
4 M3 × 10mm tapped metal spacers
4 M3 × 20mm machine screws, Phillips head
4 M3 × 10mm machine screws, Phillips head
4 M3 × 6mm machine screws, Phillips head
4 M3 hex nuts
4 M3 star lockwashers
3 4G × 9mm self-tapping screws
1 600mm length of 0.7mm tinned copper wire
1 330mm length of 1.5mm heatshrink tubing
1 200mm length of insulated hook-up wire

Semiconductors
3 MCP6024-I/P quad op amps (IC1, IC2, IC4) (from Microchip Direct)
1 PCM2902 stereo audio CODEC (IC3) (from RS Components)
1 REG103GA-A adjustable voltage regulator (REG1)
1 1N5819 Schottky diode (D1)

Capacitors
1 100µF 16V RB electrolytic
2 10µF 16V RB electrolytic
2 10µF 16V tantalum
6 1µF 25V monolithic ceramic or tantalum
6 1µF MKT polycarbonate
4 470nF MKT polycarbonate
2 220nF MKT polycarbonate
1 150nF MKT polycarbonate
7 100nF MKT polycarbonate
1 10nF MKT or greencap
4 1nF 50V NPO ceramic
4 820pF 50V NPO ceramic
4 82pF 50V NPO ceramic
3 47pF 50V NPO ceramic
1 39pF 50V NPO ceramic
4 22pF 50V NPO ceramic

Resistors (0.25W 1%)

1 1MΩ	4 8.2kΩ
2 220kΩ	2 2.7kΩ
2 150kΩ	1 1.5kΩ
12 100kΩ	1 220Ω
4 33kΩ	1 110Ω
1 27kΩ	6 100Ω
4 15kΩ	2 22Ω
1 13kΩ	1 2.2Ω
12 10kΩ	

it's fully compatible with all the standard audio drivers built into Windows XP/SP3 and later operating systems, you'll be able to use it with virtually any of the popular audio recording, editing and playback applications.

Even if you don't have such a suitable application installed on your PC at present, there are quite a few available for free downloading on the web. One I can recommend is Audacity, which can be downloaded from the Audacity website at **audacity.sourceforge.net**

The current version for Windows XP/SP3 is V1.2.6, but there's also a beta V1.3.13 that's described as 'the best version for Windows 7 and Vista'. There are also versions for the Apple Mac and Linux systems.

Via shutdown error

Finally, note that with this device connected, you may get a shut-down error on machines with Via sound systems, which automatically launch the Via Audio HD Deck applet. You can prevent this by closing this applet before shutting down – just right-click the Via HD Audio Deck icon in the System Tray and click 'Exit' (Fig.14).

Another option is to prevent the Via HD Audio Deck applet from automatically starting when the PC is booted. That's done by clicking Start, typing in *msconfig*, selecting the Startup tab and clearing the relevant check box. Or you can simply ignore the shut-down error and click OK to close the applet and force a shut-down.

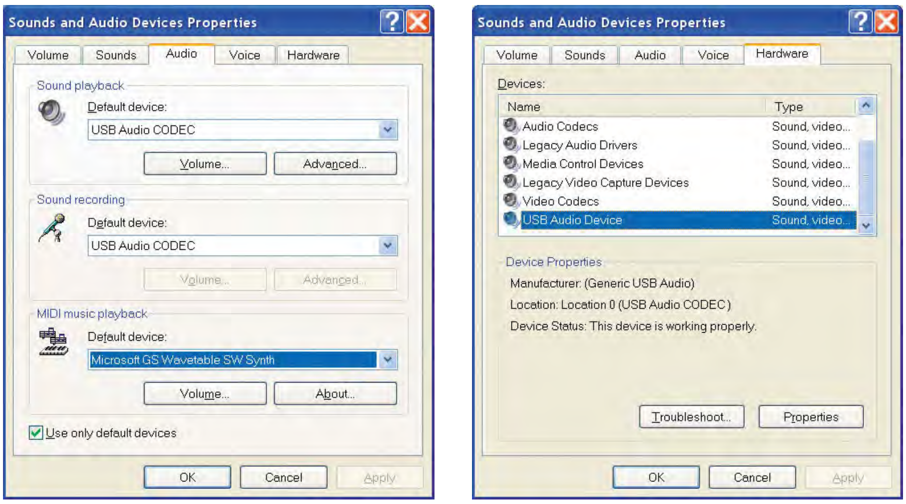


Fig.8: the USB Audio CODEC should become the default device when the *USB Stereo Recording and Playback Interface* is plugged in (Windows XP dialog boxes).

Notes and errata

USB Recording/Playback Interface
Ideally, the XLR connectors for the microphone inputs should be female, in line with the usual convention.

Female XLR connectors can be fitted to the front panel and the connections between pins 3 and 1 of each connector swapped over between the connector's rear lugs and the pads on the PCB – instead of passing straight down. This can be done quite easily if short lengths of insulated hook-up wire are used to make these connections, thereby ensuring that there will be no accidental shorts.

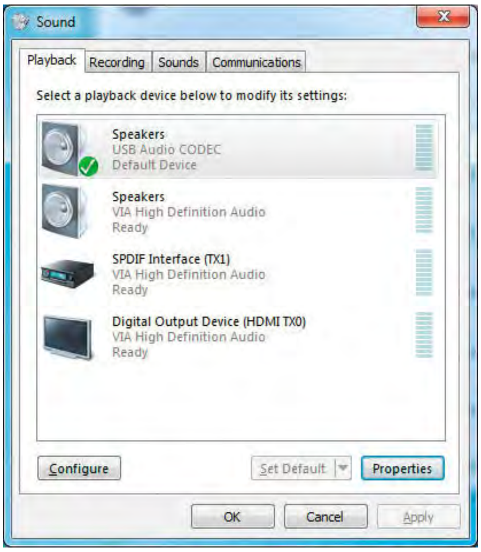


Fig.9: here's how the interface appears in the 'Sound' dialog box (launched via Control Panel) under Windows 7.

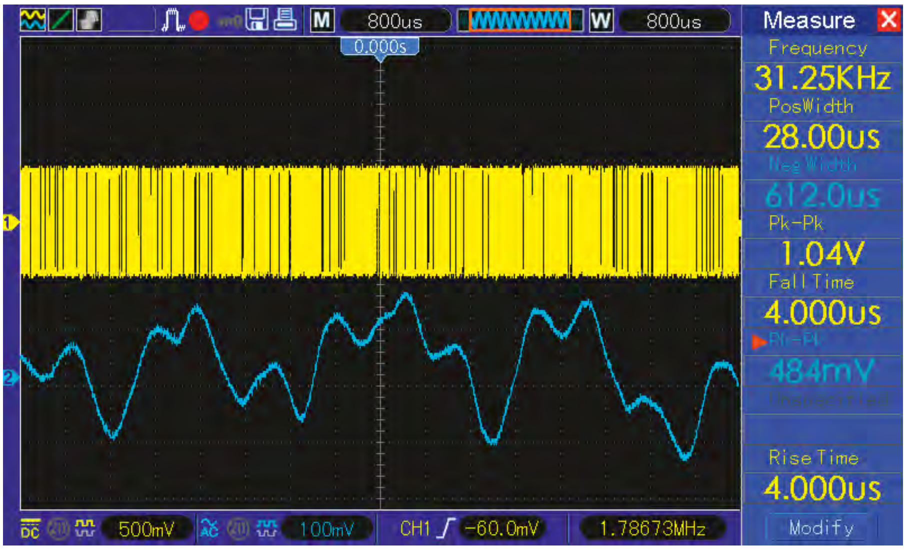


Fig.11: this scope grab compares the S/PDIF digital audio output from the interface (yellow trace) with the analogue audio output waveform (blue trace), when a WAV file is being played back. The timebase here has been slowed down to show the audio waveform clearly.

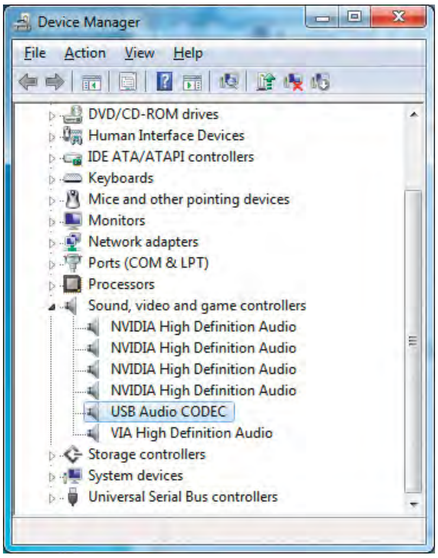


Fig.10: the USB Audio CODEC should also appear in Device Manager under 'Sound, video and game controllers'.

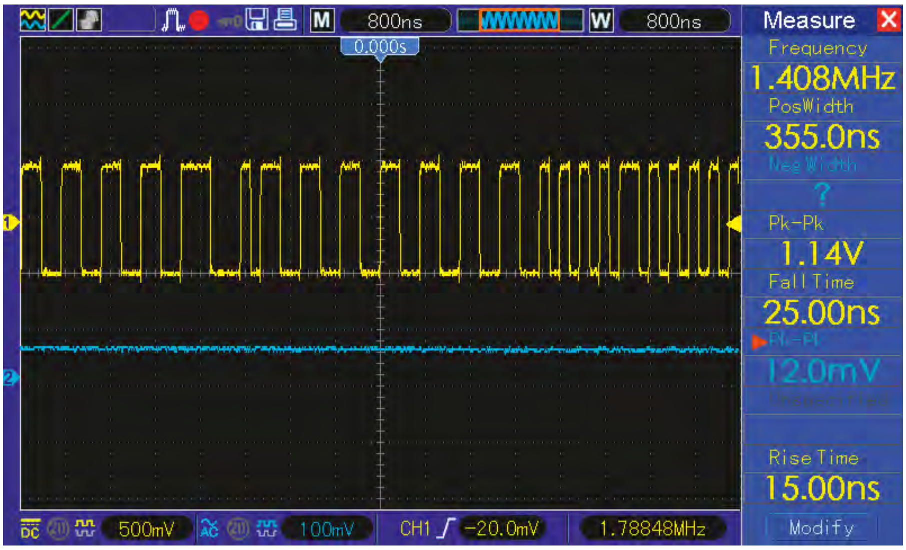


Fig.12: this second scope grab shows the same S/PDIF digital output (yellow) and the analogue audio output (blue) but with a much faster timebase speed so you can see the S/PDIF waveform. At this speed, the analogue waveform appears to be an almost flat horizontal line.

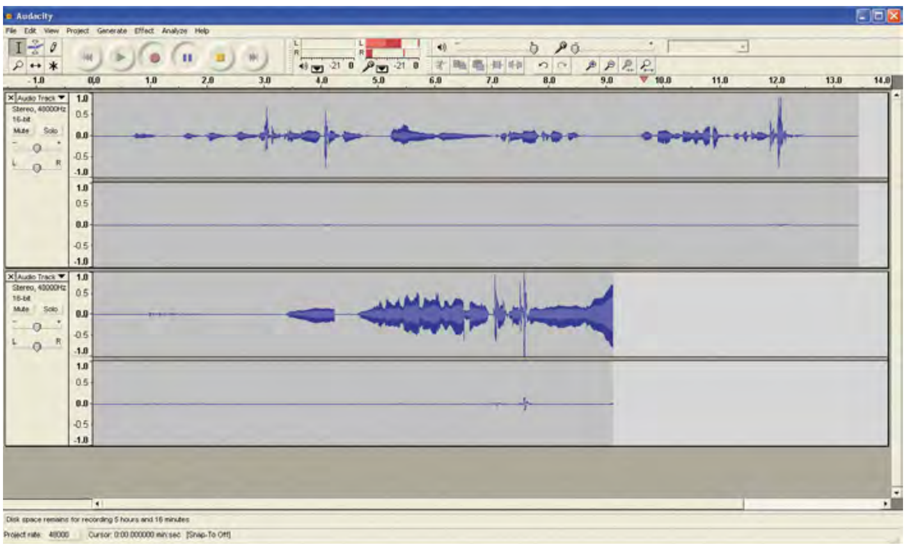


Fig.13: (left) Audacity is an excellent freeware program for recording and editing audio files, with versions available for Windows, Apple Mac and Linux systems (from **audacity. sourceforge.net**).

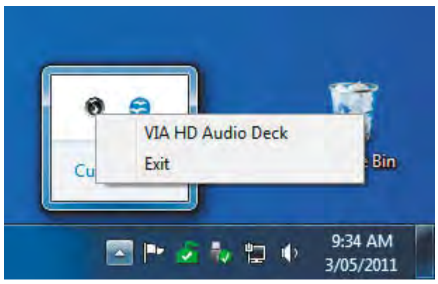


Fig.14: you can exit the VIA HD Audio Deck applet by right-clicking its icon in the System Tray.

Computer error: reliable digital processing – Part 2

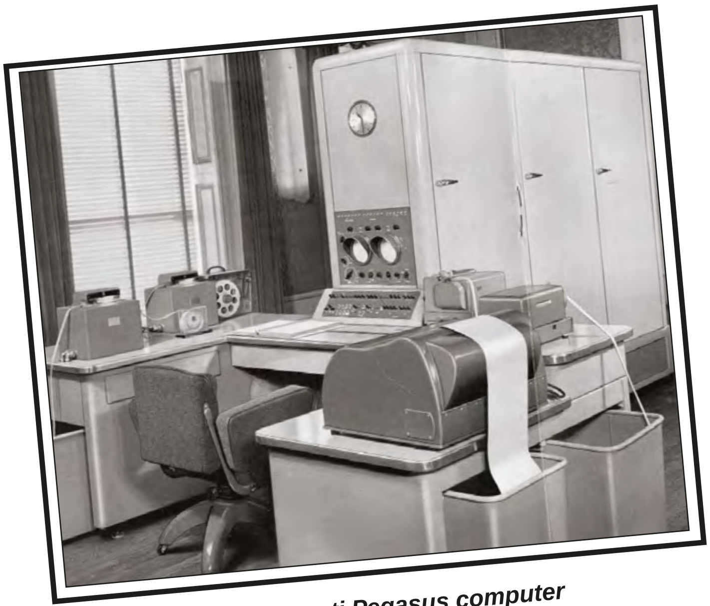


Fig.1. Ferranti Pegasus computer

A short history of high-reliability computing by Dr William Marshall

Valves give way to transistors

Last month, in Part 1 of this series we saw how electronic computer pioneers used thermionic valve (vacuum tube) technology for switching units in their early designs. Various ingenious ways of operating were developed to ensure that the machine would work for a sufficient interval to achieve useful results. The LEO I computer of 1951 demonstrated that computers could move out of secret military establishments and universities into the commercial world, giving rise to the first business machines. However, the dubious reliability and large physical size of these early machines, not to mention their enormous power requirements, kept them firmly fixed in large, well-ventilated rooms.

In 1953, the world's first computer using transistors became operational at Manchester University. It used 92 point-contact transistors, 550 diodes and a few valves in the clock circuits. A Mark 2 machine started work in 1955 with 200 transistors. Unfortunately, first-generation transistors were no more reliable than valves and the computer could only manage an MTBF (mean time between failures) of 1.5 hours. Nevertheless, the new computers consumed far less power and took up less space than their predecessors.

It took a while for the relatively new transistor technology to be accepted. In 1956, Ferranti launched their Pegasus computer, designed for high-speed computation – and still full of valves. The approach taken here was to reduce the MTTR (mean time to repair) factor by introducing modularity. This appears to violate Rule 1 of fault avoidance, no redundancy, by increasing the number of components, particularly connectors. However, the variety of modules was kept to a minimum and replacement once a fault was traced was very quick. Fig.2 shows a Pegasus module, complete with convenient handle to pull it out. Note also that the valves are placed so that a blown heater filament can be quickly spotted. Fig.1 shows a Pegasus computer image from contemporary literature.

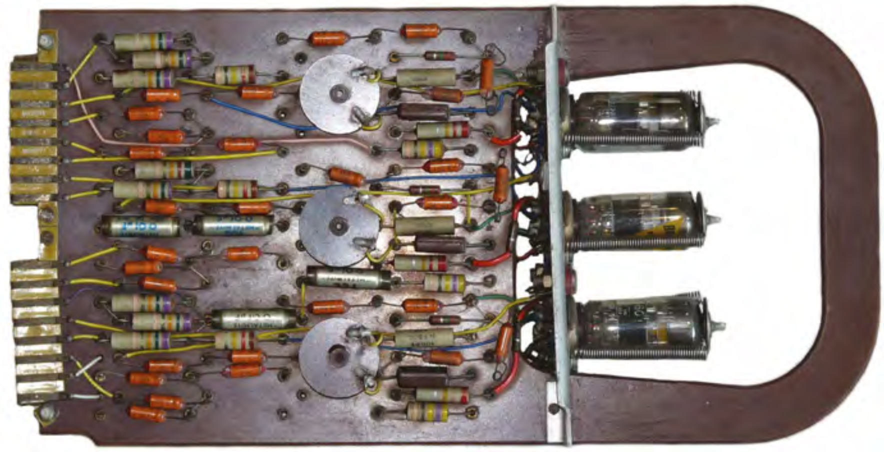


Fig.2. Ferranti Pegasus plug-in logic board with vacuum tubes conveniently placed for easy replacement

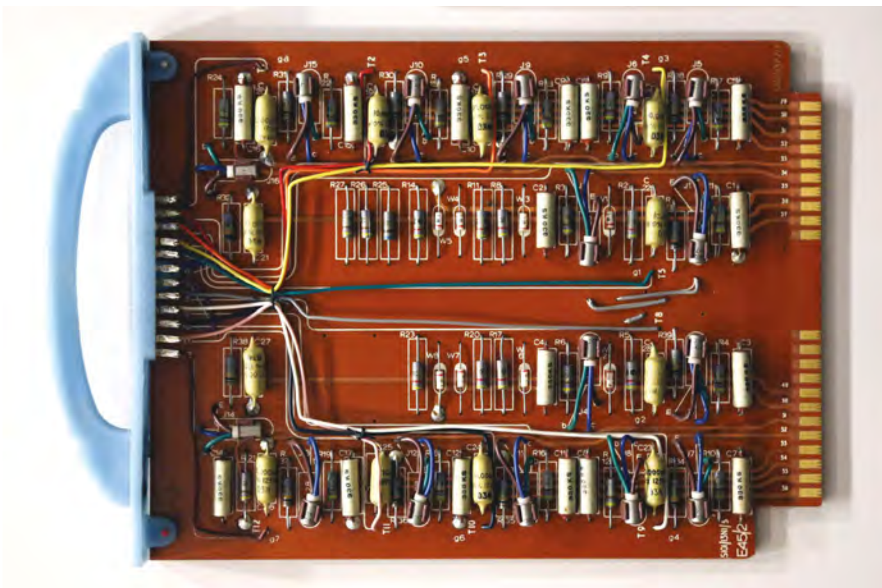


Fig.3. LEO III plug-in logic board; note the use of transistors in their familiar three-terminal silver housings – for example, third and sixth component from the right on the lower row

The era of valves was inevitably limited, especially with the arrival of junction transistors, which were a vast improvement both in performance and reliability compared to early fragile point-contact designs. The all-transistor LEO III appeared in 1961 with the same modular structure as Pegasus (Fig.3).

A further advantage of transistor-based circuits was that they were much safer to work on, thanks to the lower operating voltages required by solid-state devices (transistors and diodes). Fault finding on a valve-based computer required great care when prodding about with a 'scope probe on live circuit boards. A useful tip, presumably learnt the 'hard way', was for technicians to keep one hand behind their back, with the probe in the other to avoid inadvertently placing several hundred volts across their heart.

A key feature of early computers was that they were used in non-safety-critical applications, so as long as they kept going during the working day and faults could be quickly traced and fixed by the next day, then their reliability was considered acceptable. However, once computers started shrinking in size and power consumption, thanks to solid-state technology, mobile applications became possible. The snag was that reliable operation now meant safe operation and the question was soon asked… 'Would you trust your life to a computer?'

Computers into space

The race to be the first to land a man on the moon in the 1960s led to rapid developments in a whole range of technologies, the most obvious and far reaching being solid-state electronics. The real-time calculations required to operate a vehicle like the Saturn V rocket, or navigate to a point on the moon hundreds of thousands of miles away, required fast, powerful and reliable computers – and those computers had to fly on board the space vehicle.

NASA's Apollo Guidance Computer (AGC) was the result, and was ready by 1966. Unfortunately, it became known to the general public in 1969, not because of its amazing performance, but because it seemed to get overloaded at a critical moment, and Neil Armstrong had to take over minutes before landing on the moon. It had performed faultlessly up to this point and only got into trouble when a switch was left in the wrong position. The machine itself consisted of two parts: the main electronics box and the Display-Keyboard (DSKY) on the control panel (Fig.4). Both the lander and the command module had one of these incredible machines.

The main electronics box was made small enough and light enough to be carried thanks to the first integrated circuits: the manned flights used an AGC based on 2800 Resistor-Transistor Logic (RTL) dual 3-input NOR gates (Fig. 5). The use of only one type of technology yielded a much more reliable system than others based on mixed Diode-Transistor (DTL) and diode logic. The surface-mount devices in the picture look remarkably modern, but each only contains six transistors and a few resistors.

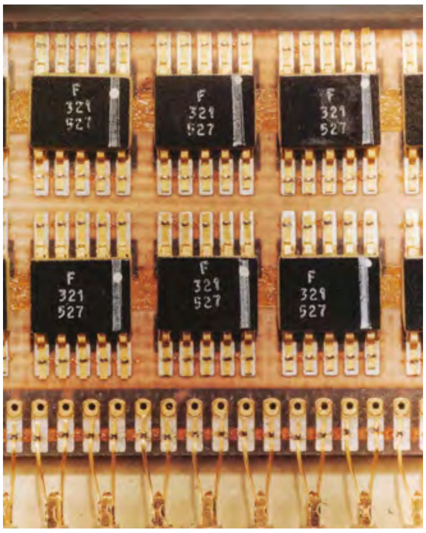


Fig.5. Apollo AGC logic gate chips

Launch Vehicle Digital Computer

Before leaving the topic of the Apollo computers, there is an unsung hero that should be recognised: the Saturn V rocket Launch Vehicle Digital Computer (LVDC), shown with the Saturn V project director designer Wernher von Braun in Fig.6. Most of the round-capped connectors on each side are electrical, but some are for cooling water hoses. The real-time control operations involved in driving a vehicle to the moon are far too complex for the human brain to deal with, so the Saturn V rocket had a digital autopilot. In essence, an on-board computer was loaded with 3-dimensional coordinates for a point in orbit prior to launch, a 'Go' button was pressed and the astronauts relaxed while the LVDC piloted them into space.

The LVDC system was designed so that the rocket commander gripped an abort handle in case something went wrong – which it did with Apollo 12. Seconds after lift-off, all telemetry from the rocket went haywire. The astronauts and the support engineers didn't know it at the time, but the rocket had been struck by lightning, which threw half the spacecraft electronics into a spasm. Fortunately, one of the flight controllers at Mission Control thought he recognised the symptoms and suggested to the astronauts that they just needed to turn an obscure switch to 'AUX'. It worked, and telemetry was restored. Meanwhile, the rocket had just kept on going on its preset course. The ability of the LVDC to cope with this emergency was probably down to its extremely advanced architecture, involving 'triple modular redundancy' (TMR) with voting logic, a concept which will be discussed in detail in Part 3 as we move from fault avoidance to fault-tolerant design.

The Apollo moon-landing project proved that computer technology was now reliable enough to perform real-time tasks in situations where failure could lead to loss of life. Initially, the people trusting their lives were astronauts and military pilots, who were prepared to

Fig.4. Apollo DSKY User Interface (Photo: Steve Jurvetson)

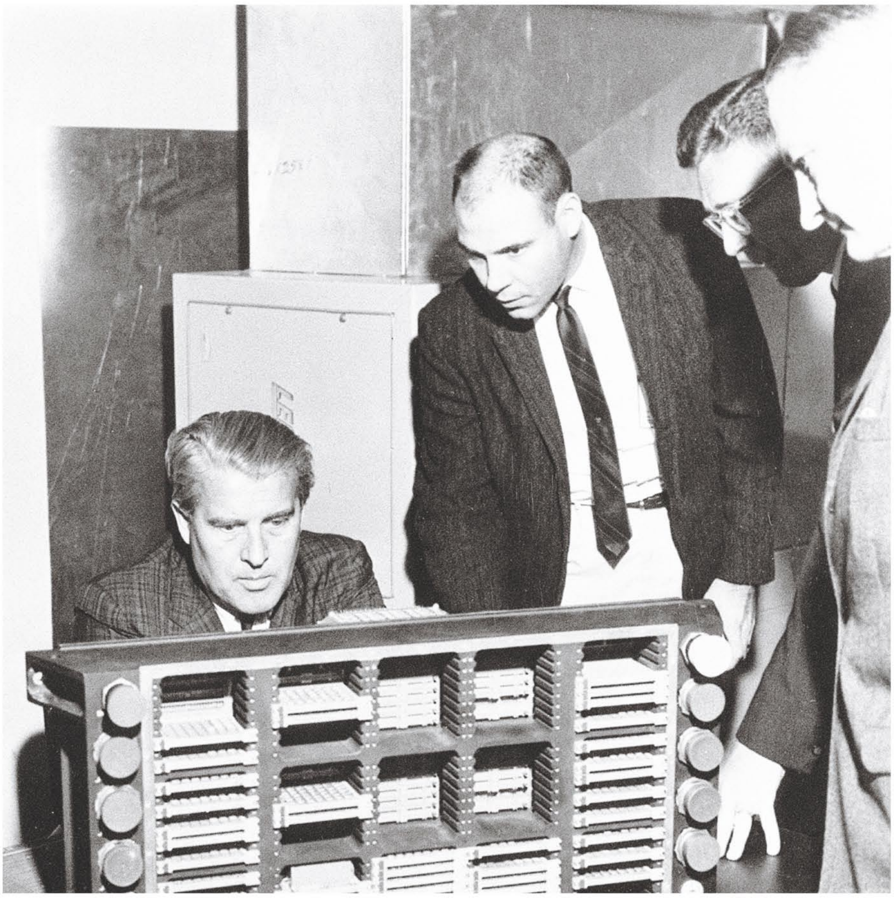


Fig.6. Wernher von Braun (seated) with the Apollo LVDC

accept the risks involved. After all, given their professions, the added risk of computer failure probably seemed small alongside all the very obvious physical hazards.

Failure is not an option

Civilians on the other hand do not wish to factor-in the likelihood of computer error leading to a fatal outcome for their holiday flight plans. The Airbus A320 airliner first flew in 1984 and featured the first use of 'fly-by-wire' controls on a civilian aircraft. From that point, the design principle has been that the computer must not fail, or if it does, the failure must be predictable and benign. This means the machine must detect faults itself and deal with them. The only way to do this is through the use of redundant components: two or more processors all running the same program (but not necessarily the same code) and their outputs compared before control actions are taken. These computer architectures not only improve safety, they also improve reliability in applications such as space probes, where repair is simply never an option. Some of the latest multi-core microcontroller devices developed for the automotive and medical equipment markets have this redundancy built in.

Next month, we conclude this series with an examination of the latest thinking in computer reliability design philosophy.

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Recycle It!

BY NENO STOJADINOVIC

Vacuum Pump from Junk

Every 'techie' needs a vacuum pump. They rate alongside the air compressor, multimeter and soldering iron as one of the most useful tools in an experimenter's arsenal. This guide will show you how to make a serious vacuum pump for next to nothing. Add a vacuum tank for much the same price and you are all set.

IT used to be that every young scientist needed a vacuum pump. There was metal to sputter, glass envelopes to evacuate when producing X-ray tubes and investment to 'de-bubble' when making castings.

Nowadays, there are commercial products available to replace these venerable old staples, but hobby scientists have compensated by expanding the scope of their activities.

I don't sputter my own telescope mirrors, but I do pot my own coils and ultrasonic transducers and use vacuum to remove all air bubbles from the resin.

I don't make X-ray tubes but I do make robot parts with 'prepreg' carbon fibre that uses a process called vacuum bagging to mould the material.

And call me funny, but I find a strange fascination with the science of refrigeration. In refrigeration systems the flow rate and pressure can be considered analogous to current and voltage in electronic circuits.

With the advent of LP gas as a refrigerant and cheap manifold gauges, I find a lot of tech heads like me sitting around watching ice form on their home made evaporator coils.

Where do you get it?

Vacuum pumps live in the bottom of every refrigerator, except they are cleverly disguised as refrigeration compressors. Countless refrigerators are thrown out due to gas leaks, faulty thermostats or some other minor fault, leaving a perfect compressor that is just ripe for a new purpose in life. Refrigeration compressors of this type are commonly referred to as 'sealed units', and are a simple piston pump running in an oil bath for longevity.

Liberating the compressor is simple enough – but it needs to be approached with a bit of caution. Most discarded fridges I've seen are devoid of gas but the gas lines can still be under pressure and may also be partly full of refrigeration oil. Thus, it is important to put on goggles before you begin, and don't point the pipes at yourself as you're cutting them.

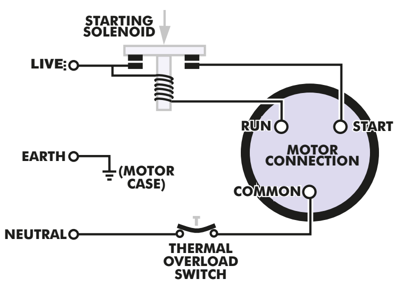


Fig.1: Wiring diagram for a typical fridge compressor. Note the over-temperature cutout.

So to begin: peer under old fridges until you find a compressor that doesn't have capacitors near it. (It's not difficult to drive a capacitor motor but there are plenty available that don't use them at all, so I avoid the capacitor jobs as a needless complication).

Cut all of the gas lines to the compressor, leaving a handy length to work with. Use a pair of side cutters or a tube cutter to sever the lines, as a saw will introduce fragments of metal into the compressor.

Cut the electrical connections, unbolt the compressor and the prize is yours!

Test drive

First, find out if it runs. Most simple compressors use a split phase start winding which is energised by a solenoid that is connected in series with the main, or 'run' winding.

MAINS EQUIPMENT
Take extra care when salvaging any old 230V AC mains equipment. Be aware that insulation may have broken down, previous repairs may be 'dodgy' ...and mains voltages can kill. Remember that old adage: 'If in doubt, don't!'

When the motor is first started, the main winding draws a large current. As the solenoid is connected in series, the heavy current creates a magnetic field that pulls the contacts shut and thus energises the start winding. As soon as the motor is up to speed, the current in the main winding dwindles and the solenoid drops out, thus cutting off power to the start winding. Hopefully, Fig.1 should make it all clear. Once you've got it wired up, just stand back and plug it in. Remember, quiet fridge-type hum good, flames bad!

Once you have a good one up and running, partially block the thick pipe near the top of the compressor. You should feel a bit of suction; don't block the pipe completely, because if you do, the compressor oil will froth up inside the housing and then squirt violently out of the other pipe.

Here's what you're looking for. It almost certainly won't look as pristine as this (in fact, it will probably be at least a bit rusty and/or covered with grease and dust). But most fridges these days have a compressor looking something like this one.

If all is well, power it down and get cracking to change the oil.

The oil is drained by undoing the service plug and just letting it pour out. Of course, we don't have to say that it must be disposed of properly... seriously!

Once it's all gone, the compressor can be refilled by pumping new oil into the vacuum (thick) pipe.

It is possible to get many different grades of vacuum oil, mostly selected for our intended vacuum level and similar types of pumps, but for most

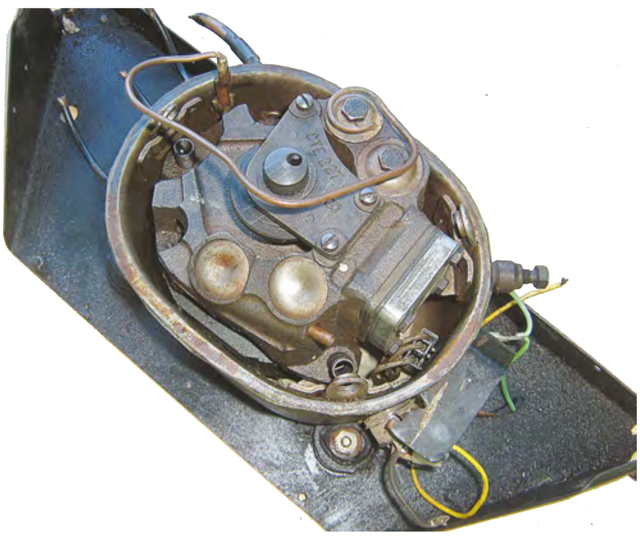


Fig.2: a compressor with the lid cut off. Gas enters the stub of pipe near the bottom of the figure and exits through the long thin pipe that loops across the top. This pipe always exits into an equally thin pipe on the outside of the housing. The compressor is normally suspended from three springs, but these are disconnected in the photo.

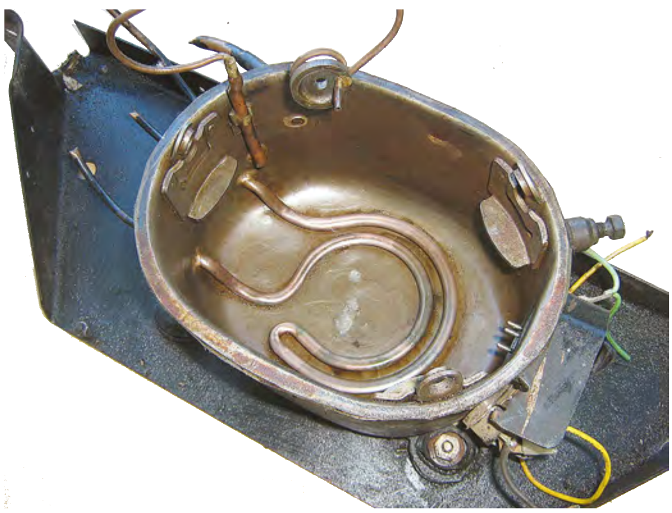


Fig.3: the casing itself. The loop at the bottom is a heat exchanger and leads out to two thin pipes near the bottom of the casing. Gas is drawn directly into the casing and the inlet port can just be seen at the top of the figure. Inlet gas is hot and not very dense, so it always flows through large diameter pipe. The service port can be seen at right.

Fig.4: a reservoir tank made from a 9kg gas bottle, adapted to a standard air line fitting. It is worth knowing that most pipe fittings have a BSP (British Standard Pipe) thread. This includes air lines, refrigeration, plumbing, irrigation, it is a fairly universal thread. BSP fittings will even screw into most American (NPT) fittings. Note though that gas lines use a tapering thread (BSPT) while most other pipes use a parallel thread (BSPP).

Fig.5: you'll find many vacuum gauges on eBay, new and used, ranging from next-to-nothing to next-to-ridiculous. This one, for example, was brand new and about £15 plus postage. Most common are the combined vacuum/ boost gauges intended for automotive use – they're fine for our purposes and often the cheapest (sometimes <£7).

jobs I use standard air compressor oil.

It is available at most places that sell air compressors and comes in a handy squeeze bottle that allows you to partially fill the compressor before your wrists totally give out.

Then you can use the compressor itself to suck the rest in – just block off the service port and stick the vacuum pipe into the oil bottle. Stop the pump every now and again to check if the oil level has reached the level of the service plug and once it's oozing out you are done.

Pull vacuum

Vacuum pumps require you to learn a new vocabulary and some new physical principles. First of all, if you convince all of the air molecules in a container to vacate the premises, you will have yourself an absolute vacuum. The gauge pressure, relative to atmosphere, will be –101kPa, or in old money, –14.7psi (pounds per square inch) if you're over 45 years old. Americans will say –30in Hg (mercury), while Europeans will say minus one bar or possibly –760mm Hg.

I buy little vacuum gauges on eBay (see Fig.5) and they can tell you that the typical home-made vacuum pump will pull better than –25in Hg if allowed to run for a while.

Remember that below certain vacuum levels you are not so much pumping air as convincing air molecules to float into your pump.

Once it's all up and running, I like to solder a hose barb onto the vacuum line to suit the job at hand, perhaps build it into a handy tool box so I can carry it around, all nice and neat.

Note that standard compressed air hoses and fittings work just as well under vacuum as they do under pressure.

You will find that the pump ejects an oil mist while it's running. I catch the oil in a can and run a hose to the vacuum line so I can draw the oil back in once a bit has collected.

Care and feeding

First and foremost, don't ever use your vacuum pump as a compressor. You will inevitably draw impurities into the pump while it's running on evacuation duty and some of them can be explosive when subsequently in contact with compressed air.

And following on from that, vacuum pumps will be damaged if you allow them to suck up crud. The cure is to use a separator. They are commonly used in distillation (especially the moonlight kind) so look them up.

If you want to suck up large quantities of liquid, dust etc, it is best to use a large vacuum tank as a reservoir. Old gas bottles can be found at most dumps, and it is a simple matter of buying a matching fitting to convert it to a vacuum tank – see Fig.4.

Places that sell barbecues are a gold mine of fittings, valves and hoses that can be re-purposed for our warped needs. Once you've evacuated the tank, you'll be amazed at the sheer power of a measly one bar of (absent) air.

Politically correct message about refrigerant

Most of the fridges I've seen at the local dump have been very obviously emptied of gas; it seems nobody treats malfunctioning whitegoods very well and broken pipes are common. I even found one that was riddled with bullet holes!

It is environmentally unfriendly and illegal to release refrigeration gas to the atmosphere. So, if you can't find a 'pre-mauled' unit, the next best thing is to go and visit your local refrigeration mechanic. Refrigeration repair is yet another industry that has been hit hard by cheap imported goods and many people lug in a fridge only to be told that a repair would cost more than a new one.

Suddenly you have a fridge waiting for you and the mechanic will suck all of the gas out for a small fee.

Even better is that mechanics are generally friendly folks and have all sorts of goodies for the likes of us. How about a 12V fridge compressor? (They are very common in caravan units).

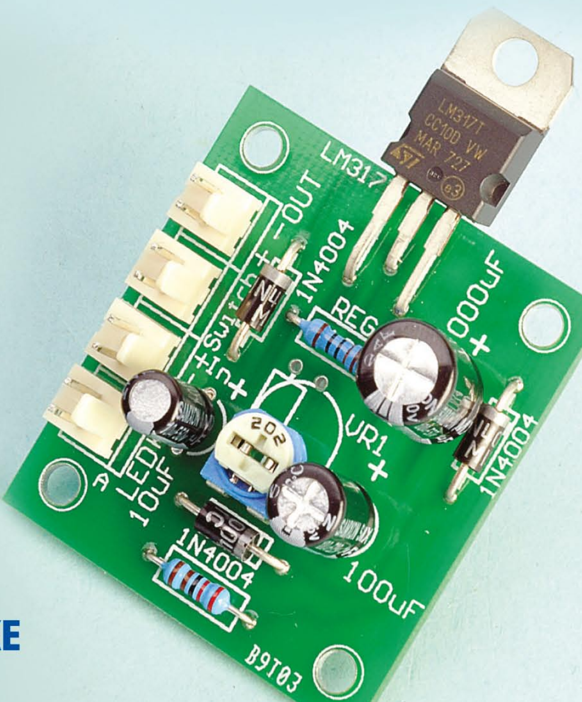
Or maybe a complete condensor unit? They are those boxes that you see on the sides of buildings used for coolrooms and split system air conditioners, and they are full of goodies. I got a working unit for £10.

WARNING: Use a full face shield when evacuating glassware. Glass will eventually weaken and implode when subjected to vacuum, causing shards to explode outwards.

For those times when a fixed regulator is not suitable. . .

MiniReg 1.3-22V Adjustable Regulator

Design by
JOHN CLARKE



This compact regulator PCB can be used to produce a fully regulated DC supply ranging from 1.3V to 22V at currents up to 1A. Depending on how much current you need, it can fit into tiny spaces and is easily connected with 2-pin headers for DC input, DC output, an on/off switch and an LED.

THERE are many fixed-voltage IC regulators available, such as those with 5V, 6V 8V, 9V, 12V and 15V outputs. But what if you want a voltage output that does not fit into one of the standard ranges, or if you want to be able to easily adjust this output voltage?

The *MiniReg* is the answer: it can be set to provide the exact voltage you require. It's based on an LM317T three-terminal regulator. The PCB holds only a few other components: three diodes, three capacitors, two resistors and a trimpot to set the output voltage from the regulator.

Circuit details

Fig.1 shows the circuit details. The LM317T adjustable regulator provides a nominal 1.25V between its OUT and ADJ (adjust) terminals. We say it is a 'nominal 1.25V' because, depending on the device, it can be anywhere between 1.2V and 1.3V. This doesn't really matter though, because we can adjust the output voltage to the required level using trimpot VR1.

The output voltage from REG1 is set by the 110Ω resistor (R1) between the OUT and ADJ terminals, and by the resistance between the ADJ terminal and ground.

This works as follows: by using a 110Ω resistor and assuming an exact 1.25V reference, the current flow is set at 11.36mA. This is calculated by dividing the voltage between the OUT and ADJ terminals (1.25V) by the 110Ω resistor. This current also flows through trimpot VR1.

This means that if VR1 is set to a value of 1kΩ, then the voltage across this resistor will be 1kΩ × 11.36mA or 11.36V. This voltage is then added to the 1.25V reference to derive the output voltage – in this case 12.61V.

In practice, the current flow out of the ADJ terminal also contributes slightly to the final output voltage. This current is of the order of 100µA. So if VR1 is set to 1kΩ, this can add 0.1V to the output, ie, we get 12.71V.

If you are interested in the output voltage equation, then it is:

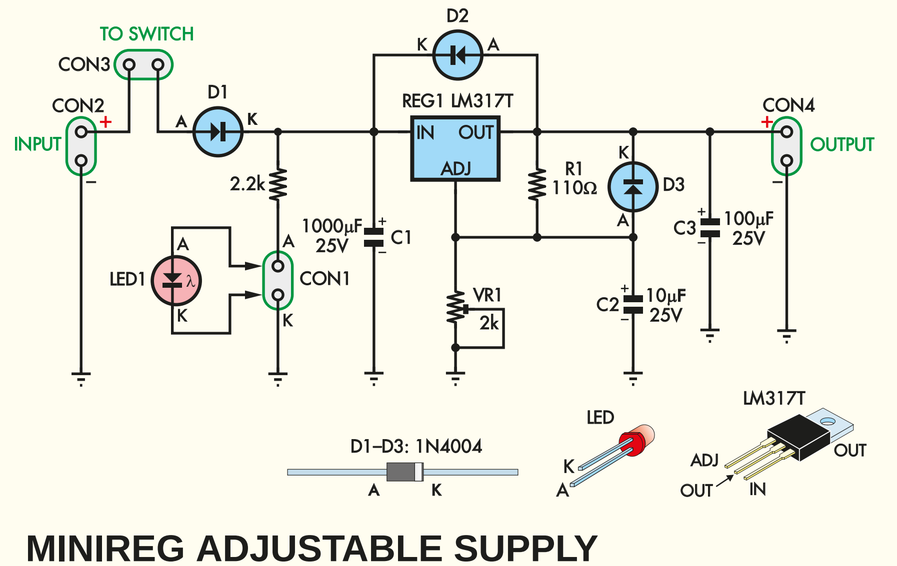
$$V_{OUT} = V_{REF}(1 + R1/R2) + I_{ADJ} \times R2$$

where V_{OUT} is the output voltage, V_{REF} is the voltage between the OUT and ADJ terminals and I_{ADJ} is the current out of the ADJ terminal (typically 50µA, but as high as 100µA).

R1 is the resistance between the OUT and ADJ terminals, while R2 is the resistance between the ADJ terminal and ground.

Diode D1, in series with the input, provides reverse polarity protection. This means that if you connect the supply voltage around the wrong way, you cannot do any damage.

Diode D2 protects the regulator if the input becomes shorted to ground while



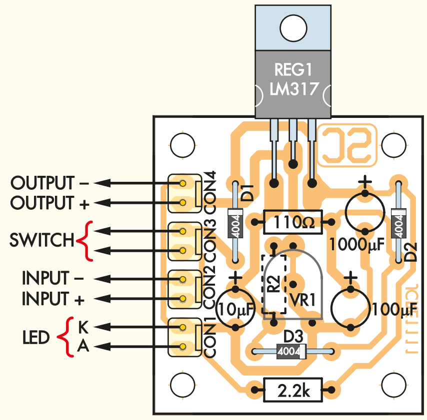


Fig.1 (left): the circuit diagram of the *MiniReg*, along with Fig.2 (above) – the PCB component overlay. Note the provision for a fixed resistor (R2) instead of VR1, if required.

it is powered up. Without D2, current would attempt to flow back from the output capacitor through the regulator to the shorted input and that could kill it. But D2 becomes forward biased and conducts, effectively preventing any reverse current flow through REG1.

Diode D3 is also included to protect REG1. It does this by clamping the voltage between the ADJ terminal and the OUT and IN terminals in the event that one of the latter is shorted to ground.

Finally, capacitors C1 and C2 reduce ripple and noise by bypassing the IN (input) and ADJ terminals respectively. C3 prevents regulator oscillation by swamping any low-value capacitance that may be connected to this output.

Construction and options

All the parts for the *MiniReg* are mounted on a 35mm × 38mm PCB, coded 18112111. This PCB is available from the *EPE PCB Service*. Fig.2 shows the parts layout. This shows an identical component layout to the PCB in the photo, but there is nothing to stop you from making a few changes. For example, do you want to use a conventional potentiometer to vary the output voltage, rather than using the on-board trimpot?

No problem: just omit the trimpot and wire up the external potentiometer in the same way.

Or do you want to use a 12V LED bezel instead of LED1? Again, no problem; especially if your DC input voltage is reasonably close to 12V. In that case, replace the 2.2kΩ resistor with a wire link and wire the 12V LED to the 2-pin header for the LED.

Similarly, you might want to omit the on/off switch. In this case, just install a 2-pin shorting link on the 2-pin header for the switch.

Assembling the PCB is not likely to take very long. You can begin by installing the 110Ω resistor (R1) and the three diodes, making sure the latter are all oriented correctly (the banded ends are the cathodes). Then capacitors C1-C3 can be installed, again taking care with their orientation, since they are all electrolytics.

Next, install the four 2-pin headers. You will need to make up four matching cables with 2-way polarised header connectors. We discuss how to make these later.

The three-terminal regulator can then be mounted. It can either be mounted on the top of the PC board (as shown in the photo) or underneath it, so that it can be fastened to a heatsink.

Do you need a heatsink?

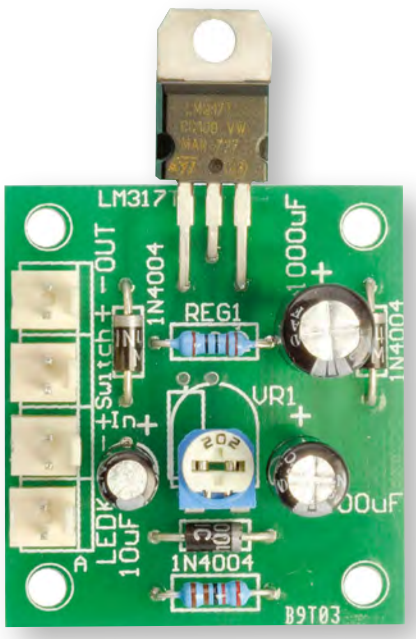
Whether or not you need a heatsink for REG1 depends on how much power it is likely to dissipate.

The output current and the voltage between the IN and OUT terminals of the regulator are the critical values. That's because these two values together determine the power dissipation within the regulator. It's found simply by multiplying the two values together to get the power dissipation in watts, ie, P = VI.

Generally, if the dissipation is less than about 0.5W or 500mW, no heatsink will be required. For example, if the current drawn from the regulator is 100mA and the voltage between the IN and OUT terminals is 5V, then the dissipation will be 0.5W and no heatsink will be necessary.

However, if the dissipation is more than this or if it is installed in in a small, enclosed space, you will need to fasten the regulator to a heatsink to keep it cool.

For example, let's say that the current drawn from regulator REG1 is 250mA



This photo of the completed PCB is deliberately over-size for clarity, so you can see exactly what goes where. Note the resistor (R2) shown on the PCB under/adjacent to VR1 is in case you want to substitute a fixed resistor to give you a specific output voltage.

Parts List – MiniReg

1 PCB, code 18112111, available from the *EPE PCB Service*, size, 35mm × 38mm
4 2-way polarised pin headers, 0.1in spacing (with matching leads – see below)
1 LM317 voltage regulator (REG1)
3 1N4004 power diodes (D1-D3)
1 LED (any colour)
1 1000µF 25V electrolytic capacitor
1 100µF 25V electrolytic capacitor
1 10µF 25V electrolytic capacitor
1 110Ω 0.25W resistor
1 2.2kΩ 0.25W resistor
1 2kΩ PC-mount trimpot
(Heatsink, silicone insulator, etc if needed)

and that the voltage across it is 5V. In this case, the dissipation will be 1.25W (ie, 5 × 0.25) and a heatsink *will* be necessary.

The type of heatsink required depends on the power dissipated by the regulator and the temperature rise that can be tolerated. Typically, a 20°C rise in heatsink temperature is OK because this means that at a typical room temperature of say 25°C, the heatsink will run at 45°C, which is quite acceptable.

Most heatsinks are specified by their temperature rise in °C per watt (°C/W). This means that a 10°C/W heatsink will rise 20°C above ambient when dissipating 2W.

Usually, it will be necessary to electrically isolate the tab of the regulator from the heatsink. The reason for this is that the heatsink may be connected to ground, while the regulator tab sits at the output voltage.

To isolate the tab, use a TO-220 silicone insulating washer and secure the assembly to the heatsink using an M3 nylon screw and nut. Alternatively, you can use a metal screw provided you fit an insulating bush into the regulator tab.

Note that capacitor C1 may need to be increased in value if the input voltage has a lot of 100Hz ripple.

In addition, you should make sure that the input voltage does not go above C1's 25V rating. Increase C1's voltage rating to at least 35V if it does. In fact, you can apply up to 35V to the input if C1 is a 35V type.

Making up connecting leads

As noted above, you will need to make up four cables with polarised 2-way header connectors. We show how to do these in the panel below.

Adjusting the output

Note that the input voltage applied to CON2 must be several volts higher than the required output voltage. This is necessary in order to provide regulation.

The minimum voltage across REG1 required for regulation is called the 'dropout voltage'. For the LM317T, this voltage varies with the current and is typically 1.5V for currents below 200mA, rising to 1.7V at 500mA and 2V at 1A.

Note that the drop across diode D1 must be added to the dropout voltage in order to calculate the required input voltage.

For example, if our power supply draws 200mA and the required output voltage is 6V, then the input voltage must be 6V plus 0.7V (to compensate for voltage across D1) plus 1.5V (for the dropout voltage), ie, the input voltage must be at least 2.2V higher than the output voltage.

Therefore, we need to apply 8.2V minimum to the input for regulation. This is the absolute minimum and to ensure correct regulation under varying loads, a 9V input to the supply would be ideal. Note also that any ripple on the input supply that drops below the required voltage will cause problems, since the supply will not be regulated during these low-going excursions.

Once you've connected the supply, it's just a matter of adjusting trimpot VR1 to set the required output voltage.

Finally, note that in some applications, you might want to replace VR1 with a fixed resistor (eg, if the resistance value you measure at VR1's setting is close to a standard fixed value). This has been catered for on the PCB – just replace VR1 with resistor R2 (shown dotted). ***EPE***

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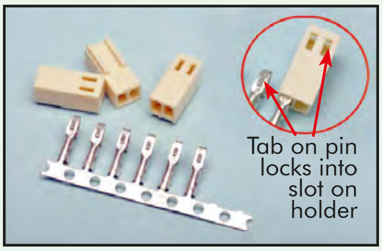
Making up the polarised header connector leads

You can buy ready-made header leads but they are not particularly easy to find. It's usually much quicker and cheaper to buy the bits and make up your own, even if it is fiddly!

The connector terminals are usually supplied in a strip, as shown at right – these need to be separated by either individually cutting them off or bending back and forth until they break off.

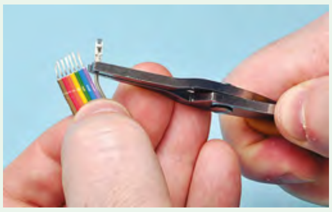


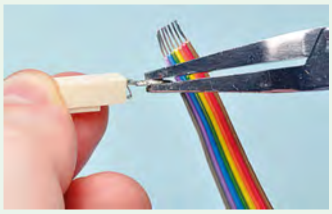
These terminals, when completed, slide into the connector housing and have a small tab which prevents them coming out again (so get it right the first time!).

Before you make up the connectors, take a note of which way around your terminals need to go – most of the time, they are polarised and the connector only fits on the header pins one way.

Making up the leads is not difficult, but it is a bit fiddly. It's easiest to do one pin at a time.

1) **Strip all the ribbon lead ends for the number of connectors required – it's best done with a wire stripper to get them nice and even.**
2) **Crimp the bare wires into the connector using a pair of fine pliers. Make sure no loose strands of wire are left out.**
3) **Solder the wires in place. It's a belt'n'braces approach but it does ensure that you don't have any wires separating later on.**
4) **Using your fine pliers, push the connector into the housing, noting which way is up and which way gets the right polarity. If you do have to remove it, push the tab with a fine needle.**





CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Filters and frequency response

RECENTLY, *EPE Chat Zone* contributor ***james*** posted a question about LC filters prompted by a radio receiver circuit in article from the *Jump Start* series.

The circuits in Fig.1 have cut-off frequency $F_c = 1/(2\pi RC)$*; in Fig.2 the cut-off frequency* $F_c = R/(2\pi L)$*.*

My question – what's the formula to calculate the cut off frequency of an LC filter? (Fig.3)

Mike and Richard Tooley use the low-pass form of this filter in this month's Jump Start *(June 2013 issue) in their radio's AM demodulator.*

They use: L = 3.3mH; C = 100nF

Which I would assume gives a cut-off frequency of somewhere around 20kHz.

I know that the resonant frequency is given by: $F_{res} = 1/(2\pi * SQRT(LC))$

Cheers, James

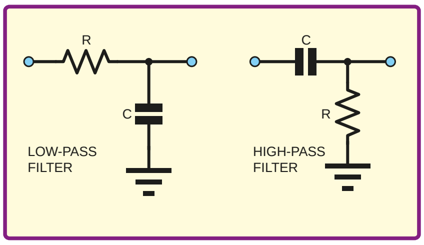


Fig.1. RC filters

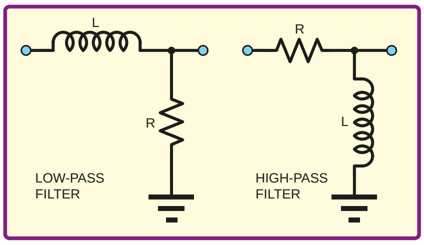


Fig.2. RL filters

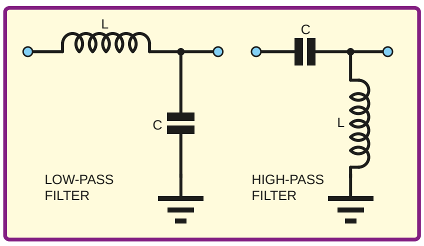


Fig.3. LC filters

This question raises the issue of the frequency dependence of the basic passive components – resistors (R), capacitors (C), and inductors (L). Circuits built from these (passive) components, with the aim of passing signals at some frequencies and blocking others, are called passive filters. Using just RC or RL circuits we can create filters (such as those in Fig.1 and Fig.2), but we find that it is not possible to make circuits with very sharp transitions between the blocked and passed frequencies (at the cut-off frequency). However, if we use inductors and capacitors together the circuit exhibits a property called resonance and the filter cut-off can be much sharper.

In this article we will look some of the properties of the circuits like those in Fig.1 to Fig.3, discuss some aspects of resonance and consider the relationship between resonance and cut-off in a basic low-pass filter using both a capacitor and inductor.

We can use AC analysis in a simulator such as LTSpice to plot the variation of magnitude of impedance (effective resistance) of resistors capacitors and inductors with frequency. Specifically, we can find the magnitude of the voltage divided by the current in the three circuits shown in Fig.4. LTspice is a popular free analogue circuit simulator from Linear Technology, which as regular readers will know, we frequently use in *Circuit Surgery*. See **www.linear.com/ltspice** for more information.

The opposite trends for capacitor and inductor mean that there is a frequency where any two such components will have the same resistance. For the inductor and capacitor in Fig.4 this occurs at about 8.8kHz (where the lines cross in Fig.5), here the magnitude of impedance for these components is about 181.7Ω. If they were connected together they would exhibit resonance at about 8.8kHz. We will discuss resonance in more detail later.

The trends for capacitor and inductor frequencies continue as indicated in Fig.5 to very high and very low frequencies. It follows that as frequency increases towards infinity, a capacitor will become a short circuit and an inductor an open circuit. Similarly, as frequency decreases towards zero a capacitor will become an open circuit and an inductor a short circuit.

Thinking about these extreme cases can be useful as a quick way to determine what a circuit will do. For example, the low-pass RC filter from Fig.1 can be analysed in this way, as shown in Fig.6. This confirms that the circuit will pass low frequencies, but the output will decrease towards zero as frequency increases. A similar look at the other circuits in Fig.1 to Fig.3 will confirm that their descriptions are consistent with the frequency dependence of their components.

We can simulate the RC low-pass filter (Fig.1) to get a more detailed view of its behaviour. The results with R = 181.7Ω and C = 100nF are shown

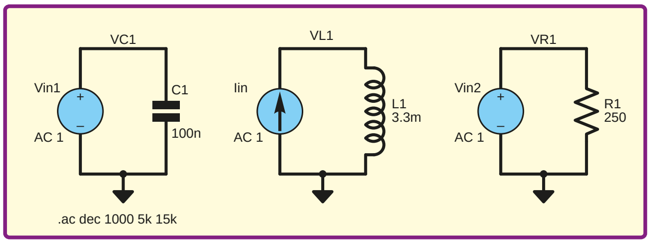


Fig.4. LTspice schematic for observing variation of passive component impedance magnitude with frequency

The results are shown in Fig.5. These were obtained using 'expression plots' in LTSpice with the axes changed to linear from the default logarithmic plots used for frequency responses. The three figures show impedance variation from 5kHz to 15kHz. From these plots, we see the impedance of the capacitor impedance decreases with frequency and that of the inductor increases. The resistance of a resistor does not change with frequency.

in Fig.7. The graph uses a logarithmic frequency axis in order to display a large range of frequencies without compressing the low frequencies into an unreadable small space. From the graph, it is clear that the output signal diminishes as frequency increases, but it is not intuitively evident where the cut-off frequency might be – there is no sharp corner in this response which jumps out at us as an obvious single cut-off point.

Fig.5. LTspice simulation results showing variation of passive component impedance magnitude with frequency. Green curve – resistance, blue curve – capacitor impedance, red curve inductor impedance

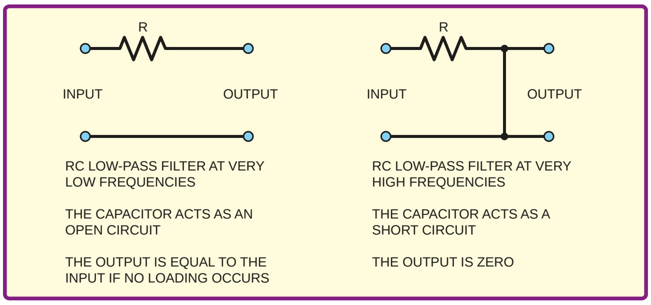


Fig.6. Looking at a circuit response at extreme frequencies can help understanding of overall behaviour

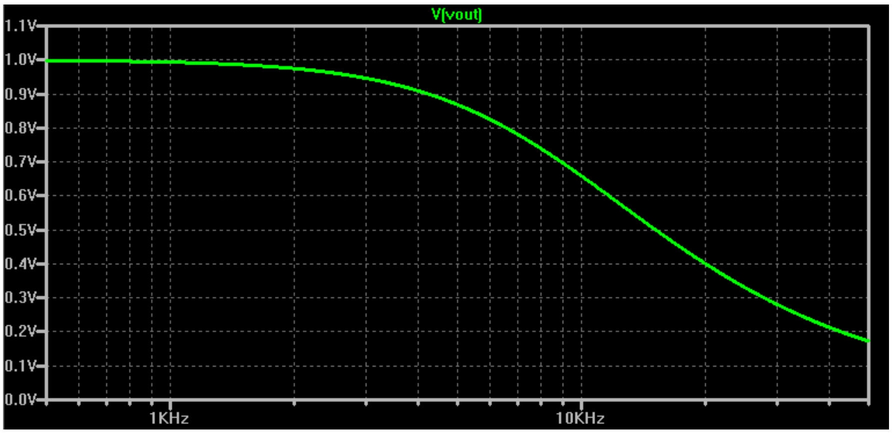


Fig.7. LTspice frequency response simulation (ac analysis) for RC low-pass circuit in Fig.1 with R = 181.7Ω and C = 100nF

The standard definition for cut-off frequency is the point at which the output power falls to half that in the pass band. Assuming the load is a constant resistance (which we also assume to be very large so that the filter is not heavily loaded), and noting that power in resistor is V^2/R, the half power point occurs when V^2 is reduced by a factor of 2, or V is reduced by √2 = 0.707. Reading from the graph we find this is about 8.8kHz. On LTspice a cursor can be applied to the curve by clicking its title; this makes it easier to read values accurately.

As stated by james, the cut-off frequency of the RC filter is given by $1/2\pi RC$. Using the values R = 181.7Ω and C = 100nF gives f_c = 8.8kHz, just as we read from the graph.

If we try repeating the low-pass filter simulation using the LC circuit from Fig.3 the results might not be as expected. Using the LTspice schematic and simulation command shown in Fig.8, we get the result shown in Fig.9. This looks like a very narrow band-pass filter, not a low-pass one. Furthermore, we can see the output voltage reaches a peak of nearly 550V, somewhat larger than the 1V input!

There is obviously something going on here, something which is more than might be implied by a simple analysis using the frequency dependence of impedance magnitude shown in Fig.5.

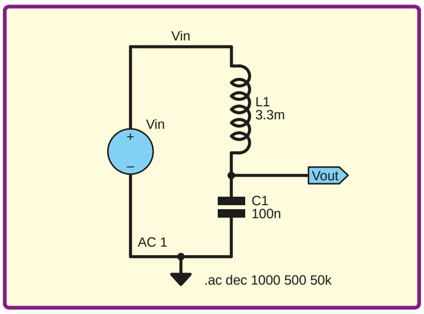


Fig.8. LTspice schematic for simulation of LC filter

That something is resonance, which we will return to in a moment. First though, it is worth mentioning that Fig.9 does not do the best possible job of displaying the circuit's frequency response.

The vertical axis used in Fig.9 is linear, but it is better to use a logarithmic scale, just as we have done for frequency. To achieve this it is usual to convert the gain to decibels (dB), so instead of plotting V_{out}, or more correctly V_{out}/V_{in} against frequency, we plot $20\log(V_{out}/V_{in})$. The result is shown in Fig.10. LTspice calculates decibels for you if you select this as the option for the left vertical axis. On the decibel scale the cut-off point is at 3dB below the pass band gain (20log(1/√2) = –3).

The results in Fig.10 show that the circuit in Fig.8 does indeed have a low-pass response. At low frequencies, below a few kHz, the gain is close to unity (0dB). At high frequencies, above 10kHz, the gain decreases with increasing frequency. By 50kHz it is –30dB, which is a gain of about 0.03, so output is significantly reduced here. The large peak in the response is due to resonance. This occurs at the frequency indicated by the equation stated by ***james***, that is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

With L = 3.3mH and C = 100nF the resonant frequency is about 8.8kHz. As mentioned above, this is the point where the magnitudes of impedance of the capacitor and inductor are equal. The curves in Fig.5, which use the same L and C values, cross at this frequency.

Resonance does not only occur in circuits; it is something which we are aware of in everyday situations, even if we do not always name it as such. Perhaps the most well known, and most often quoted, examples are bells, glasses and children's playground swings. These can illustrate various aspects of resonant systems. The physics of resonance involves the

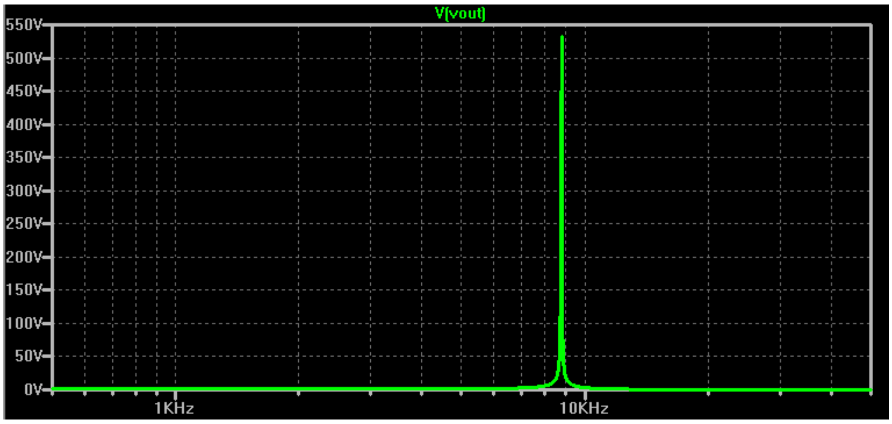


Fig.9. LTspice frequency response simulation (ac analysis) for the RC low-pass circuit in Fig.8 with L = 3.3mH and C = 100nF

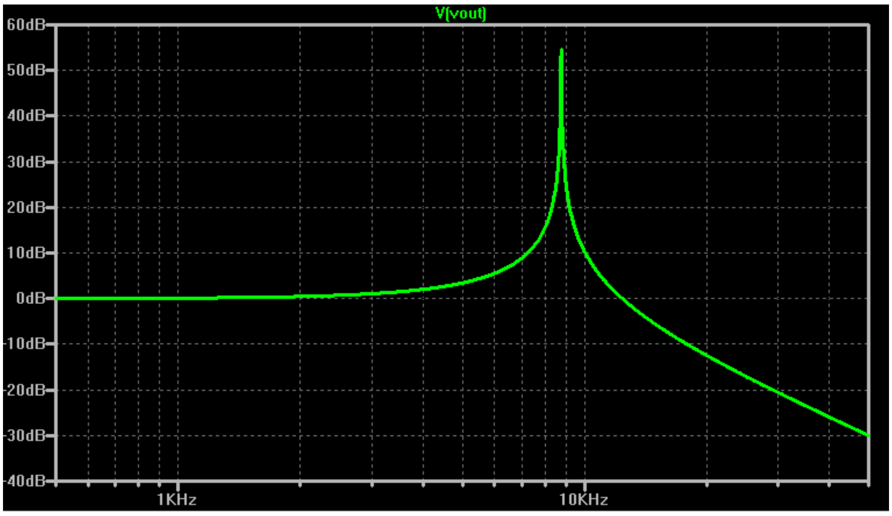


Fig.10.the results from Fig.9 replotted using a decibel scale. The low-pass action of the circuit can now be seen

efficient transfer of energy between different forms. For a swing (or pendulum) these are kinetic and potential energy. Capacitors and inductors both store energy (in electric and magnetic fields) and transfer the energy easily via current flow. Circuits containing just *R* and *C*, or just *R* and *L* do not show resonant behaviour because there is only one type of energy storage present.

The sound obtained by striking a bell is close to what would be called an impulse response in circuit theory. If the bell is of high quality it will produce a pure tone when struck, which will decay over time. An LC circuit will respond in a similar manner, producing a decaying sine wave oscillation if an input voltage spike or step is applied. This is called a free oscillation.

A child being swung by a parent is pushed once on each cycle exactly as the swing reaches its peak amplitude. If the pushing is stopped, the swing will continue oscillating for a while with decaying amplitude – this is similar to the free oscillation of the bell. If the pushing continues we have what is known as a forced oscillator. This corresponds to applying a sine wave to an LC circuit (as in Fig.8). If the swing is pushed at the right moments then the forcing frequency is at the resonant frequency and the result is a large amplitude oscillation (and hopefully a happy child). If one attempts to push a swing at the wrong times (ie, not at the resonant frequency) the oscillations will be much smaller in amplitude. This relates to the results we see in Fig.9 and Fig.10 – if the input is at the resonant frequency the output amplitude is large.

It is well known that it possible (although quite difficult) so shatter a glass using sound (the classic scenario is an opera singer and a wine glass). This is another example of forced oscillation at resonance. It further illustrates that amplitudes in resonant systems can become very large, as we have seen in Fig.9.

There are a number of animations and videos on line to illustrate the properties of resonance using examples such as a child's swing and shattering glasses. They should not be too hard to find using a search engine.

The LC circuit in Fig.8 is built from perfect components (this is the default for Spice simulation). This means that the amplitude at resonance is infinite. The results in Fig.8 do not show infinite voltage because the data points used by the simulator do not happen to include the exact resonant frequency. If the simulation is re-run with more data points per decade, then higher voltages are obtained, because some data points will be closer to the exact resonance point; for example with 5000 points per decade the peak obtained was over 30kV.

Such high voltages are unlikely in a real circuit due to imperfections in the components, principally the series resistance of the inductor. The presence of resistance causes some loss of energy as it is transferred between capacitor and inductor. This limits the amplitude under forced oscillation and causes any free oscillations to decay (just like the swing or the sound from the bell mentioned above). This is often referred to as damping.

LC circuits such as the one in Fig.8, when built with real components, can still produce voltages significantly higher than the input. This must be borne in mind during design and component selection to ensure that ratings are not exceeded.

The close to ideal, pure-LC low-pass frequency response shown in Fig.10 is probably not very useful as a low-pass filter due to the huge peak. By deliberately adding resistance to the circuit we can reduce the peak and select a response shape to suit our needs. However, before we look at this in more detail it is worth returning to the comment made at the start of the article about LC circuits providing sharper cut-off than just RC or RL circuits.

The circuit in Fig.8 is a second-order low-pass filter. This means to a get a similar response with an *RC* circuit we need two stages (ie, two of the low-pass filters from Fig.1 cascaded

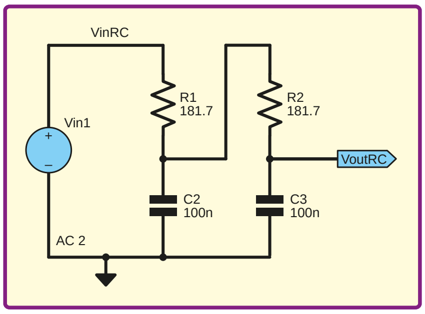


Fig.11. LTspice schematic of second-order RC low-pass filter for comparison with Fig.8

together). The circuit is shown in Fig.11, and its frequency response simulation results are shown in Fig.12 (blue curve), with the response of the LC circuit from Fig.8 shown on the same graph (green curve). The range of frequencies is much larger than shown in Fig.9 to illustrate what is happening a long way from the cut-off point.

This shows that the two circuits have the same response at very low and very high frequencies. In particular, this means that at high frequencies the gain of both circuits falls away at the same rate, specifically 40dB per decade (a decade is a 10-fold frequency change). The key difference is around the cut-off point, these are at different frequencies for the two

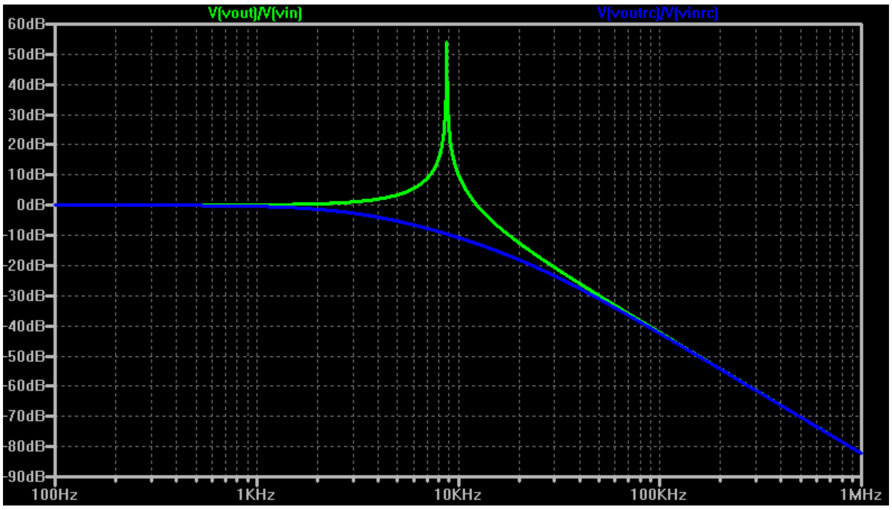


Fig.12. LT spice simulation to compare LC and RC second-order low-pass filters

circuits, but the important thing is the gain of the LC circuit decreases much more rapidly just after the cut-off frequency. This is desirable because it provides a sharper separation between passed and blocked frequencies. The two-stage RC filter also has a larger component count.

Adding resistance in series with the inductor produces the circuit shown in Fig.13. Fig.14 and Fig.15 show frequency responses for various values of R. The response of the two-

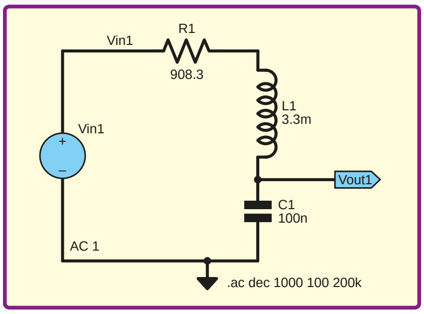


Fig.13. RLC low-pass filter. The resistor adds damping to the circuit in Fig.3

stage RC circuit from Fig.12 is also included for comparison. As all the RLC circuits have the same *L* and *C* values they have the same resonant frequency and same behaviour at extreme frequencies; however, their cut-off frequencies are seen to be different. Thus a general answer to james' question is that the cut-off frequency depends on any resistance present in the circuit and not just on the *L* and *C* values.

Useful low pass RLC filters will not generally have strong resonate peaks, because this will cause ringing (oscillation) with fast changing inputs. Furthermore, there is usually little point in making the resistance so large that the response is no better than an RC circuit. This limits the range of appropriate resistance values. The shape of the frequency response curve can be characterised in terms of a parameter called damping. We previously mentioned the general idea of damping being a property that caused energy loss from the resonant system and hence the decay of any oscillations. The damping, *d* for the RLC circuit in Fig.13 is given by:

$$d = 2\pi f_0 RC = \frac{R}{2\pi f_0 L} = R\sqrt{\frac{C}{L}}$$

where f_0 is the resonant frequency, as given by the equation above. The damping values for the various responses are shown on Fig.14. The damping and corresponding resistor values are shown in Table 1.

Table 1: damping (*d*) and corresponding resistor (*R*) values used for simulations of Fig.13

d	*R*
5	908.3
2	363.3
1.732	314.6
1.414	256.9
0.767	139.3
0.1	18.2

LC circuits are also used in undamped (or realistically, minimally damped) mode in circuits such as those used for radio tuning. This was described in the *Jump Start* article to which james refers, but his question is about the low-pass filter, not the tuning circuit. For tuning, the circuit needs the strongly peaked response, similar to that shown in Fig.9 and Fig.10, to filter the narrow range of frequencies corresponding to the radio station of interest. Band-pass filters like this are characterised in terms of the quality factor, *Q*, which indicates how tall and narrow the pass band peak is.

Q and *d* are, in fact, fundamentally the same thing because $d = 1/Q$. When discussing narrow pass-bands filters, the idea of *Q*-factor is intuitively related to what we want from the circuit. For low-pass filters the concept of damping is more appropriate. The definition of damping, *d*, used here is not the only one. There is also $\zeta = 1/2Q$, so $d = 2\zeta$. The symbol α is also used instead of *d* for damping.

There is quite a narrow range of damping values which are suitable for the low-pass filter in Fig.13, from approximately *d*=0.75 to *d*=2. Values of *d* of 0.1 and 5 are also plotted on Fig.14 and Fig.15 to provide a wider illustration of how *d* affects the frequency response. These values do not provide particularly useful low-pass filters.

Certain *d* values correspond to the characteristics of widely used filter types such as Bessel, Butterworth and Chebyshev. The names of filter types often come from the underlying mathematic functions on which they are based, these in turn are typically named after the mathematicians who discovered or developed the theory behind those functions. Three of the responses plotted in Fig.14 and Fig.15 correspond to the three filters just mentioned. The Chebyshev filter can have a variety of different responses with different levels of gain variation in the pass band (known as pass-band ripple). The filter plotted has 3dB of pass-band ripple.

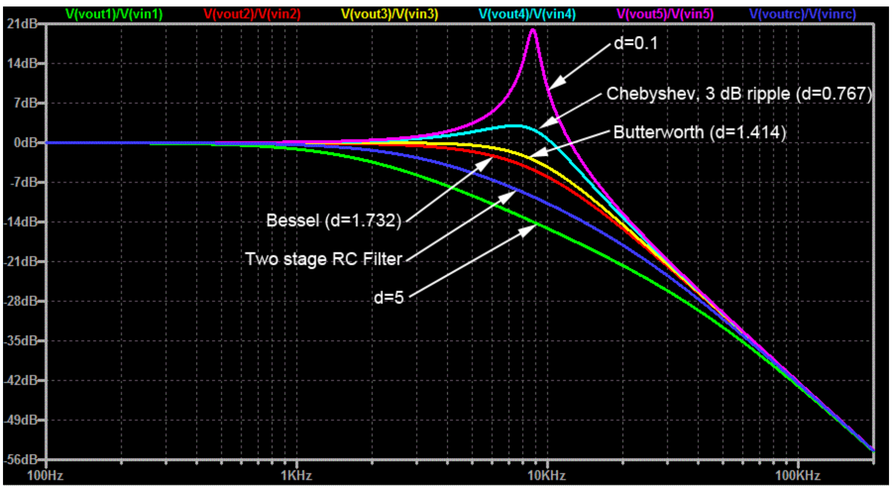


Fig.14. Various simulated frequency responses for the circuit in Fig.13 with difference resistance and hence damping values

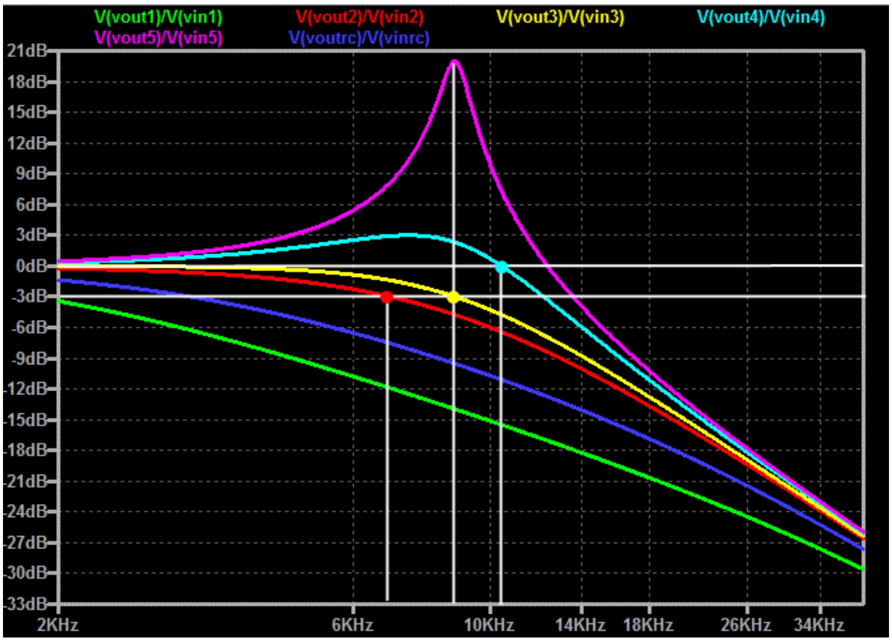


Fig.15. Detail from Fig.14 showing –3dB points for Bessel, Butterworth and Chebyshev filters

Fig.15 shows a zoomed-in part of the curves in Fig.14 close to the resonant and cut-off frequencies. The cut-off frequencies of the three useful low-pass responses are shown on the graph. The Bessel and Butterworth cut-off frequencies are at –3dB because their responses are flat at 0dB for low frequencies. The Chebyshev 3dB ripple filter cut-off is relative to the maximum pass band gain, which is 3dB, so in this case the –3dB point is where the response crosses the 0dB line. All three filters have different cut-off frequencies. The cut-off and resonant frequencies coincide for the Butterworth filter.

To finally answer james' question, the cut-off frequencies relative to the resonant frequency for a variety of common types of filter, implemented using the circuit in Fig.13, are given in Table 2. Table 3 shows the appropriate resistor value for the circuit in Fig.13 and the corresponding cut-off frequency for the same set of filters.

Table 2: damping and cut-off frequencies relative to resonance for a variety of RLC low-pass filters. * Indicates filter response shown in Fig.14 and Fig.15

Filter	**Damping (d or 2ζ)**	**Cut-off frequency relative to f_0**
Bessel*	1.732	$0.785f_0$
Paynter	1.564	$0.887f_0$
Butterworth*	1.414	$1.000f_0$
Chebyshev with 1 dB Ripple	1.045	$1.159f_0$
Chebyshev with 2 dB Ripple	0.895	$1.174f_0$
Chebyshev with 3 dB Ripple*	0.767	$1.189f_0$

Table 3: Resistor values and cut-off frequencies for the circuit in Fig.13 for various filter types

Filter	**R /Ω**	**Cut-off frequency/kHz**
Bessel*	314.6	6.88
Paynter	284.1	7.77
Butterworth*	256.9	8.76
Chebyshev with 1 dB Ripple	189.8	10.15
Chebyshev with 2 dB Ripple	162.6	10.28
Chebyshev with 3 dB Ripple*	139.3	10.42

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Wind-up flashlight – Let there be light!

WHILE walking on a remote dirt track in a tropical forest, I was overtaken by a violent tropical storm and nightfall. Being well prepared (or so I imagined), I pulled out my pen light flashlight, only to find that it rapidly faded and died – leaving me in complete blackness, in the midst of a frightening storm. From this experience, the idea for a better flashlight was born.

With new LED technology, it is now possible to build a flashlight that quite adequately lights the way 5m in front. Not only this, the power consumption is so small that is it is possible to power the LED not from batteries, but from a small super-capacitor, which allows rapid recharging with a few turns of a small generator. Also, unlike the standard flashlight bulb, which has a life expectancy of only days, a white LED promises years of unfailing service.

While its light output is modest in comparison with many modern flashlights, with a suitably focused lens, the wind-up flashlight will provide ample light around a camp table, for walking on a footpath, or for reading. The expected service from each full wind is as follows:

Reading light:	approx. 45 mins
Beam for walking:	approx. 7 mins

These times mark the point at which the voltage across the white LED falls from 100% to 95% – a barely perceptible drop in brightness. However, the time required to recharge the flashlight from 95% to 100% is a mere 10 seconds; see below for further details.

Flashlight operation

Fig.1 shows a block diagram of the wind-up flashlight. Power is provided by means of a generator based on a unipolar four-phase stepper motor. This type of motor was chosen for two reasons:

1) Such motors produce good DC voltage when rectified, at fairly low revs, thus obviating the need for complicated gearing.

2) They are readily and cheaply obtainable, especially from discarded 5-1/4 inch floppy disk drives, fax machines, or printers.

The AC voltage from each of the stepper motor's four windings is full-wave rectified, then stepped down by means of a simple, multi-diode regulator to about 5.2V, to feed a quarter-farad 'super-capacitor' reservoir. Unlike a battery, which gradually discharges, a capacitor releases a sudden surge of power, which becomes a weaker and steadier flow with time. Therefore,

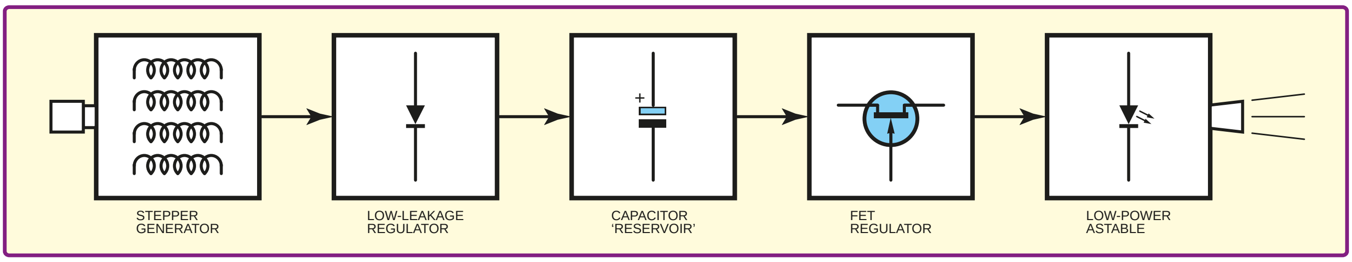


Fig.1. Block schematic of the wind-up flashlight

a crucial aspect of this design is the regulation of the reservoir capacitor's voltage. The super-capacitor regulator is based on an FET, which draws very little power and provides a very steady voltage from the rapidly falling voltage of the capacitor reservoir. Its conductance is controlled by means of a control voltage provided at its gate.

The final stage of the wind-up flashlight incorporates a very low power oscillator, which pulses the white LED to conserve power. Compromise was sought that reduces power consumption to a minimum, while not reducing light level to noticeably, or causing any visual disturbance to the pulsed light.

The generator

A wide range of 12V unipolar four-phase stepper motors may be used for the generator. While such motors can be pricey when bought new (as much as £10-£15), when removed from old electronic equipment, the cost may be greatly reduced, quite possibly free. It's also worth noting that rarely has equipment failed due to stepper motor failure; they are reliable devices with little to go wrong.

Since the voltage produced is AC, this needs first to be converted to DC. Small unipolar four-phase stepper motors generally produce 5V, 25mA AC across each phase (or winding), or up to 30V DC when rectified and smoothed, depending on the load.

These motors usually have five leads, but sometimes six. In reality, no uniform colour coding for the leads exists. The author found no less than seven different colour-coding schemes. However, the identification of the leads is not difficult. Current flows in only one direction in the windings (hence the designation unipolar), and this considerably simplifies lead identification.

The first step is to find the motor's common lead or leads. A six-lead four-phase unipolar motor has two common leads, and these are most likely to be in the centre of two rows of three. It is easy to work out which is the common lead with a multimeter; just follow this process:

1) If there are six leads, measure the resistances across every combination of leads, but ignore any measurements that indicates open circuit (and infinitely great resistance).
2) Work out which leads were always involved where the lowest resistances were measured. These are the common leads.
3) Twist or solder these two leads together.
4) In the case of five leads, just one lead will be found to be consistently involved where the lowest resistances are measured. This is the common lead.

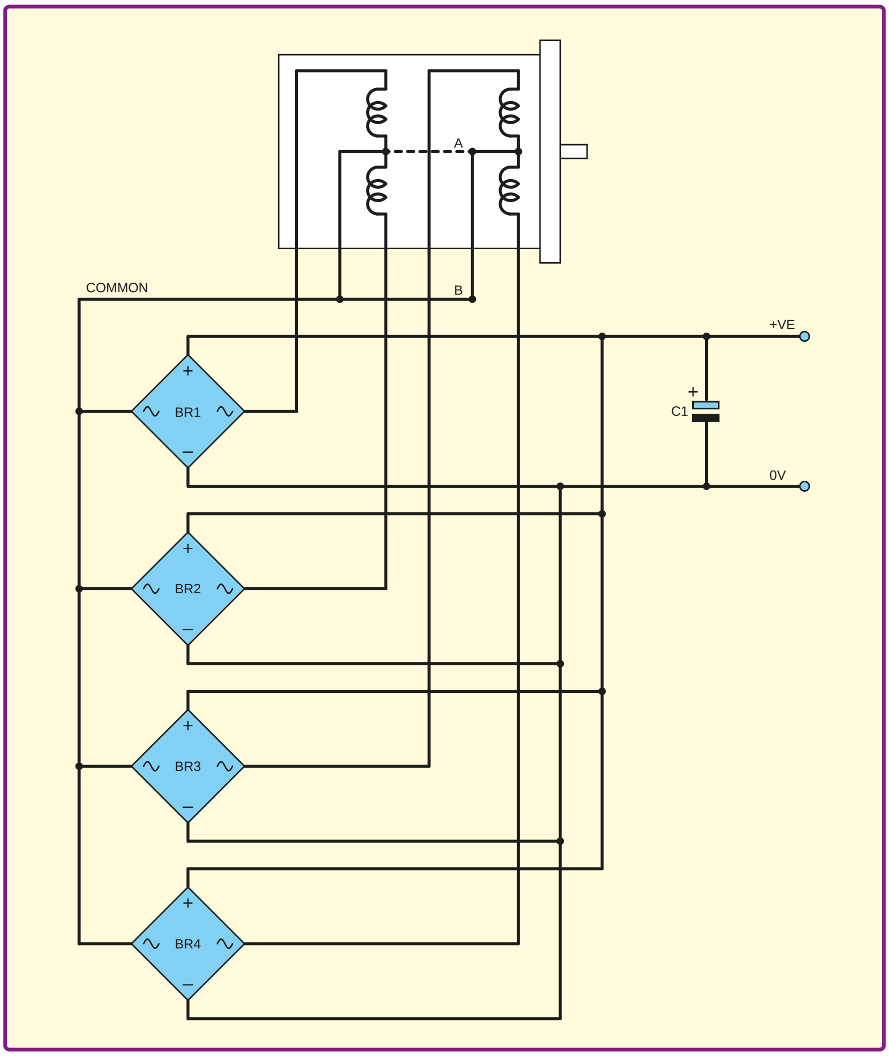


Fig.2. Full-wave rectification of unipolar four-phase stepper motor

Fig.2 illustrates how the windings of a unipolar four-phase stepper motor are full-wave rectified. The only difference between a five-lead and a six-lead stepper motor is that, in the case of the five-lead motor, the two common leads are wired together internally (shown by dotted line A) as opposed to externally (shown by black line B).

The 'reservoir'

The DC voltage from the stepper motor generator is smoothed by capacitor C1, then regulated by diodes D1-D8 (Fig.3). These diodes produce a forward voltage drop of around 5.9V, and conduct around 40mA maximum. D1-D8 would be equivalent to a 1W 5.9V Zener diode, if such a component existed. Diode D9 further drops the voltage to about 5.2V, and prevents reverse leakage of current.

A number of advanced micro-power regulators were tried in place of D1-D9, but all fell down badly on reverse leakage current. Although this was in most cases relatively small, the simple arrangement of D1-D9 extends the life of the flashlight roughly fivefold over high-tech equivalents.

C2 needs to be treated with care, and should under no circumstances be wired directly to the motor. (Charge current is up to 40mA.)

Circuit operation

The super-capacitor regulator is based around TR1, a FET. This holds a very steady voltage as the voltage of capacitor C2 falls.

The wind-up flashlight's reading-light setting adjusts the voltage to around 3.05V across C3, and the 'high beam' setting adjusts it to 3.8-3.9V, which is within acceptable limits for D14, especially as it is pulsed.

A FET was chosen for the task of voltage regulation, since, unlike a bipolar transistor, which is current controlled, it is voltage (or 'field-effect') controlled, and draws a minute current – a necessary feature of this application. A negative voltage applied to the gate creates a field effect, and 'pinches off' current travelling from drain to source, while a positive voltage at the gate increases conductance.

A steady reference voltage is provided at the gate from diodes D10 to D13. As the voltage across super-capacitor C2 drops, the gate becomes gradually more positive relative to the voltage at the FET's drain, thus providing a stable voltage across C3 as the voltage falls across C2.

Zener diodes are unsuitable here, since they are virtually unobtainable at the very low voltages required.

Instead, LEDs and silicon diodes are used in series, which provide small but fixed forward voltage drops.

The purpose of C3 is to maintain a steady power supply for oscillator IC1, and to reduce peak current passing through both TR1 and IC1. A very high value has been chosen for R2, and a very low value for C4, to keep power consumption to a minimum.

The oscillator circuit is a simple clock generator based on a two-input NAND Schmitt trigger. The importance of using the 4093 quad two-input NAND Schmitt trigger IC is that it has a very low supply current, and will operate effectively down to 3V, if not less. It also has an output sink current that is more than adequate for the present application. By way of experiment, I turned up the power of the wind-up flashlight 200% for 15 minutes, and no damage was sustained either by IC1 or D14.

Note that the component specified for IC1 is the Motorola MC14093BCP. The make of the IC does make a difference. Other makes may consume 30% more power, and may require a reduction in the value of C4 to prevent any visual disturbance of the pulsed light.

No ballast resistor is required for LED D14, since the regulator limits the effective current flow.

If an extreme brightness white LED is unobtainable, an extreme brightness coloured LED may be used in its place, although the light of such an LED will not be nearly as effective, or as pleasing to the eye. In either case, the wind-up flashlight's current consumption is in the region of 700µA on 'high beam'.

Construction

I built my wind-up flashlight circuit on a piece of 0.1-inch strip board (20 holes by 13 copper strips). Readers can of course adopt their own approach, and a PCB should be easy to design.

However you approach construction, do be careful to observe the correct polarity of the various components, and remember to leave space for off-board components and connections.

Casing

For my wind-up flashlight, I used a plastic case with slotted walls. Patience is required to fit all the parts into any specified case, but the resulting compact little flashlight is both handy and attractive. You might, however, wish to use a larger case for easier construction.

The motor is housed at one far end of the case, with its shaft pointing face downwards, and protruding through a hole in the case. If a stepper motor has been salvaged from a floppy disc drive, it is likely to have a large, bulbous head. In such a case, the head may be removed fairly easily with a hacksaw, or it may itself be used as a knob. If a knob is purchased, a retaining nut is recommended to prevent slippage.

A hole was drilled into the top side of the case to receive switch S1, which I decided should be a slider to prevent damage or accidental switching when packed into a suitcase or rucksack. It's probably best to prepare the hole for S1 after having established the position of the circuit board and lens.

Last, but not least, I cut a large hole for the lens at the opposite end to the motor.

The lens

The light of white LED D14 is a little diffuse, and ideally needs to be focused into a beam. While the wind-up flashlight could be built without a lens, this would compromise brightness.

In order to focus the beam, a convex lens with short focal length (short focusing distance) is required. A focal length of around 25-30mm (8× to 10× magnification) is ideal. At any rate, the focal length should not exceed the available space in the case.

The lens' diameter should be large enough to catch sufficient light from the LED. I used a 9× lens with a little more than 25mm diameter, which was found to be just wide enough. Lenses may also be twinned to obtain a shorter focal length.

It is important that both LED D14 and the lens (or lenses) should be mounted centrally, otherwise the flashlight will not produce a smooth beam of light.

You will need to establish the correct distance from the circuit board to the lens, so as to obtain a beam of ideal width. Through experimentation, I found that if the flashlight's beam was too narrow, it was of little use in illuminating a page, or the full width of a path. If it was overly wide, then too much light intensity was lost.

A good compromise may be found as follows: aim the wind-up flashlight at a white wall, from a distance of 2m. Adjust the distance between the circuit board and lens so as to yield a beam width of about 40cm diameter on the wall.

If, on the other hand, maximum brightness is the objective, position the lens so that a sharp image of the LED's lens surface is projected onto the wall.

Calibration

Check first whether the stepper motor is generating the required voltage. Spin the shaft briskly between your fingers. The shaft may be spun in both directions. A voltage rising above about 5.5V should be a sign of an adequately functioning generator.

To check that regulator D1-D9 is working correctly, measure the voltage across C2. Spin the motor's shaft briskly between your fingers. As the voltage rises across C2, you should measure a voltage close to 5V, but not rising higher than 5.3V.

Next, measure the voltage across C3 with S1 set to reading-light brightness. This should be around 3.05V. Then switch to 'high beam', which should be around 3.8V. In both cases, make sure that the flashlight is 'fully wound'.

The open 'high beam' setting may be increased to about 3.9V for a brighter beam with a slight loss of light duration, by substituting D10 with an orange LED.

If the voltages measured across C3 are not within 1-2% of 3.05V and 3.8V, as described, then resistor R1 may be altered within the range 1M to 10M to provide the correct reference voltages at TR1's gate – use a higher resistance for lower voltages, and vice versa. This changes the current flow through D10-D13, thus changing the forward voltage drops of the diodes.

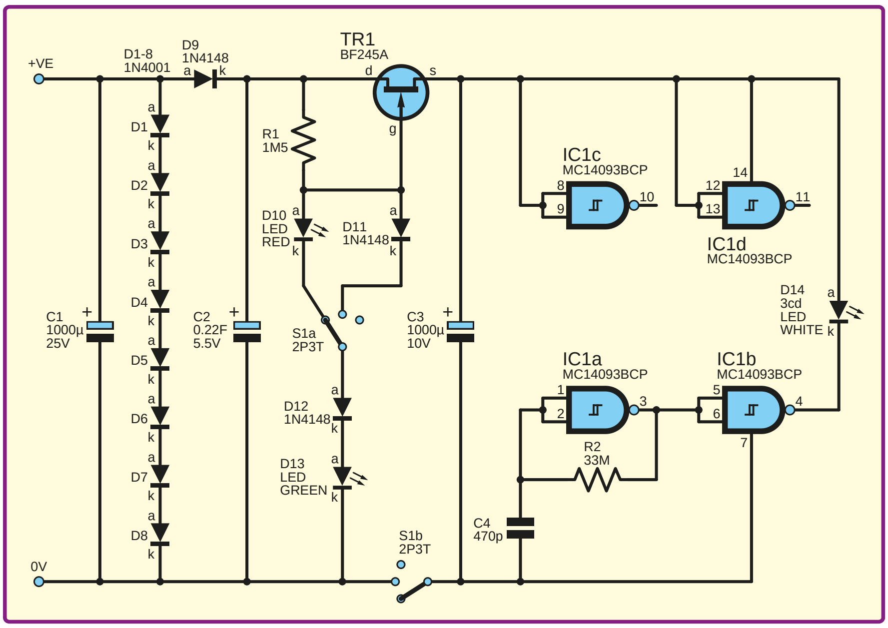


Fig.3. Circuit diagram of the wind-up flashlight

In the unlikely event that this does not bring the voltages within range, try replacing TR1 with another FET of the same type, or try different combinations of coloured LEDs and/or silicon diodes in place of D12-D13 – until the correct voltages are obtained.

If the BF245A FET is unobtainable, a rough equivalent is the BF244A or the 2N3819. Both of these were tested successfully. However, diodes D10-D13 would likely need to be modified, as described, to provide the correct voltages across C3.

The finished unit

Wind-up flashlight components list

Resistors
R1 1M5 1/4W carbon film (see text)
R2 33M 1/4W metal film

Capacitors
C1 1000µF 25V miniature radial electrolytic
C2 0.22F 5.5V memory back-up 'super-capacitor'
C3 1000µF 25V miniature radial electrolytic
C4 470p tubular foil polystyrene

Semiconductors
D1-D8 1N4001 (8 off)
D9, D11-D12 1N4148 silicon diode (2 off)
D10 Hewlett Packard 3mm diffused red LED
D13 Hewlett Packard 3mm diffused green LED
D14 5mm 3cd white LED, 20° viewing angle
BR1-BR4 W005 bridge rectifier 50V 1.5A (4 off)
TR1 BF245A N-channel JFET
IC1 Motorola MC14093BCP 4000-series IC

Miscellaneous
M1 12V unipolar four-phase stepper motor (see text)
S1 double-pole three-position vertical slide switch
Lens 8-10× magnification 25-30mm lens diameter
Small plastic case; for example, 89 × 57 × 44mm (see text)
Small knob with fixing nut
0.1-inch stripboard; for example, 20 holes by 13 strips
Solder pins, solder etc

In use

Switch on the wind-up flashlight. Turn the generator rotor briskly between index finger and thumb. LED D14 should reach full brightness within seconds.

Note, however, that the flashlight will not yet have reached full charge, and will quickly dim again if winding is halted. If C2 is completely 'flat', or has not been charged before, charge time may be up to a minute. With experience, you will obtain a feel for just how long is required to fully charge the flashlight. Once the wind-up flashlight is fully charged, a 10s wind should return it to full charge after the voltage across C3 has dropped to 95%.

The wind-up flashlight may also be given occasional 'in between' winds, which will keep it going almost effortlessly over time. In this case, a few seconds of wind every 10 minutes or so will keep it going indefinitely as a reading-light.

The wind-up flashlight may also be recharged when switched off, and holds its charge for about half a day before going 'flat'. It takes a few seconds to dim after switching off, due to the charge on C3. If C3 were separated from the load (IC1 and D14) when switching off, winding could cause C3's voltage to rise too high for safety.

Rev Thomas Scarborough, Cape Town, South Africa

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

Getting started with test gear

IN an ideal world, it would not be necessary for electronic project builders to have any test equipment unless they decided to embark on some project development of their own. Every electronic component would work perfectly and would never become damaged, and every project would work first time. In the real world, dud electronics are few and far between but might be encountered from time to time, and components that start out as fully functioning devices can be physically damaged or zapped by static charges. Odd problems can occur, and even projects that are built while paying due care and attention will not always work first time.

I suppose that in an ideal world, every project would work first time, but the challenge of building a working project would then be lacking. Overcoming difficulties and eventually winning through is a large part of the fun with any creative hobby. Having even a few basic items of test equipment to help deal with the occasional awkward project considerably adds to the interest value for most project builders. You gain a greater insight into the way circuits function, and things are moved onto a higher level.

Highs and lows

A battery of top quality professional test equipment is not an option for the vast majority of electronic project builders due to the high cost. With professional test equipment you can spend hundreds or even thousands of pounds on a single unit. This type of equipment is largely aimed at developing and testing complex electronic circuits. For things like simple component testing and basic voltage checks you can get by perfectly well with some low-cost test gear. The precision of professional quality test equipment will probably be lacking, but low-cost alternatives will still tell you what you need to know. With most simple checking you do not need a reading that is within 0.01% of the actual figure. In many cases you do not even need to know values to within one or two percent and a 'ball park' figure is often sufficient.

An important point to bear in mind with budget test equipment is that it tends to be much less rugged than the more upmarket alternatives. This is particularly the case with the items that are on offer at 'rock bottom' prices. The very low-cost units should still provide many years of service if they are used carefully, but it can be worth paying a little extra for equipment that is a bit tougher and that will probably provide additional features as well.

Another important point to bear in mind when buying test equipment is that a certain amount of technical knowledge is needed in order to fully utilise the equipment. An impressive array of professional test gear is of no help if you lack the expertise to use it. The more advanced the test equipment, the greater the technical knowledge needed in order to use it properly. It is best to start with some relatively simple units that can be mastered quite quickly, and then progress to more advanced equipment as and when necessary.

I think that most electronics enthusiasts would agree that the multi-range test meter, or 'multimeter' as it is often called, is the most useful piece of test gear, and it is the obvious first buy. As with many other types of electronic equipment, prices have fallen in recent years, and multimeters that would once have cost a week's wages can now be obtained for a few pounds. Even some professional units can be obtained at prices that are far from being in the 'arm and a leg' category. Since the usefulness of a multimeter is very high and the cost is quite low, it makes sense to obtain one sooner rather than later.

Getting needled

There are two distinctly different types of multimeter: analogue and digital (Fig.1). An analogue multimeter is relatively low-tech and has the readout provided by a meter that has a fine pointer and a scale. The digital variety has a digital readout that on modern units is normally provided by a monochrome liquid crystal display (LCD). The cheaper units typically have a three or three-and-a-half-digit display. A three digit display can handle numbers up to 999, whereas the crippled extra digit of a three-and-a-half-digit type extends readings to 1999.

It is perhaps surprising that analogue multimeters are still available in these days of digital everything. However, analogue multimeters do have a few advantages. Where a high degree of accuracy is needed it is probably true to say that a digital multimeter is the better choice. The more upmarket analogue instruments have very fine needles and long scales that usually incorporate a mirror that enables parallax errors to be minimised. In terms of reading accuracy they are still unlikely to equal a three-and-a-half-digit display, let alone the four-and-a-half-digit types of some digital multimeters. However, as pointed out previously, you often only need to know whether a reading is 'in the right

Fig.1. A 20kΩ/V analogue multimeter on the right and a digital type on the left; both offer numerous ranges of voltage, current, and resistance measurement plus transistor and diode testing. The digital unit also has six capacitance ranges

ballpark'. With this type of testing, an analogue multimeter can be read at a glance, and a large number of checks can be completed very quickly.

An analogue instrument is also easier to use when dealing with slowly changing values. Suppose that a preset resistor must be adjusted to obtain a certain voltage at a test point. The pointer of an analogue multimeter will respond almost immediately to the changes, and will accurately track them, making it easy to set the required voltage. When using a digital multimeter this way, you tend to get a stream of confusing readings due to the low rate at which the display is updated. You have to adjust the control, wait for the reading to settle, adjust the control again, wait once more, and so on until eventually the appropriate reading is obtained. Any slowly fluctuating voltage is likely to give nonsense reading from a digital multimeter, whereas an analogue instrument will track the changes and display them clearly.

For voltage and current measurements, analogue multimeters are passive devices. In other words, there is no need for any batteries for these types of measurement, and there is no risk of being 'caught short' with batteries that have gone flat. Analogue multimeters usually require two batteries, but they are only needed for resistance measurement, and possibly for additional features such as transistor testing. Typically, there is something like a 1.5V battery for most resistance measurements, and a higher voltage type such as a PP3 9V battery for the highest resistance range.

Although analogue meters have some advantages, most of the multimeters on offer are of the digital variety, and most users opt for this type. Digital multimeters certainly have some advantages, one of which is that they are more rugged. The moving coil meter movement of an analogue multimeter is very delicate. The meter movements used in analogue multimeters are designed to respond to minute amounts of current, and most of them are physically quite large. This makes them especially vulnerable to physical shocks.

Going down

As pointed out previously, analogue multimeters are normally passive devices when measuring voltage and current, but there is a downside to this approach. The power needed to drive the meter movement is obtained from the test point. The problem with this approach is that the power tapped off by the meter can significantly load the voltage at the test point, giving a misleadingly low reading. Very sensitive meter movements are used to minimise loading effects, but there is a limit to the sensitivity that can be obtained while obtaining an adequate degree of ruggedness.

For DC voltage measurement there is a resistor in series with the meter, and the value of this resistor determines the full-scale voltage. The specifications of analogue multimeters usually quote a sensitivity of so many kilohms per volt. The budget types usually have a rating of one or two kilohms per volt, but for most units it is 20kΩ per volt. If, for example, a 20kΩ/V instrument is set to the 5V range, it will have a resistance of 100 kilohms, and 50μA will be drawn from the test circuit at the full-scale reading. The equivalent figures for a 1kΩ/V multimeter are 5kΩ and 1mA.

With both types, loading is unlikely to be of any significance for something like checking battery voltage or the DC voltage at the output of an amplifier. However, with the current trend towards micro-power circuits, even a 20kΩ/V multimeter is likely to give some misleading readings when making general voltage checks on a circuit. Digital multimeters have an amplifier at the input which provides a very high input resistance and very low load currents. The input resistance is typically in the range 10MΩ to 20MΩ, and is the same on all DC voltage ranges. Even with an input resistance as high as this it is still possible for loading to significantly reduce voltage readings on something like the bias circuit of a high input impedance buffer stage.

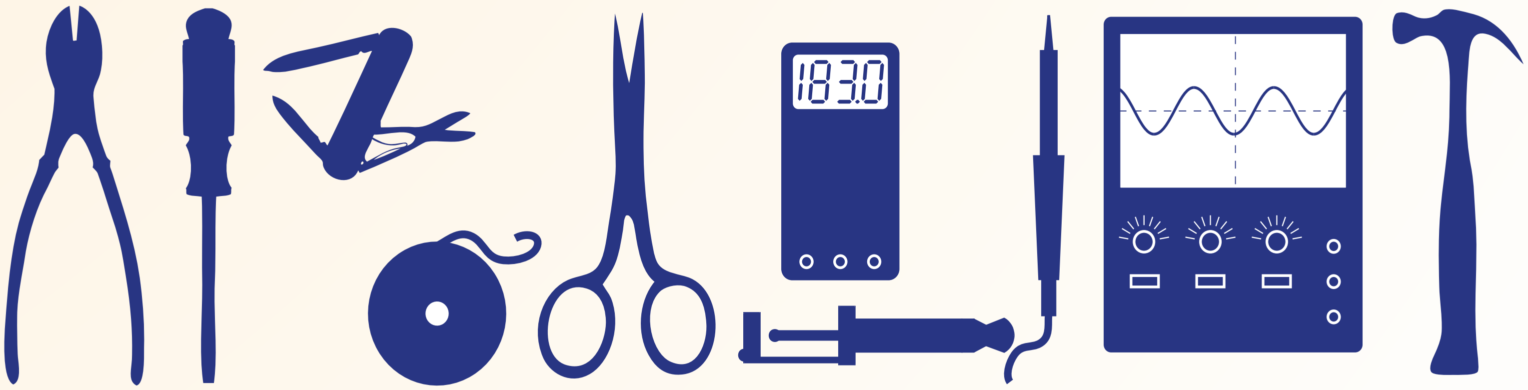
You need to keep your wits about you when making voltage measurements, especially when checking parts of a circuit with high value resistors.

Getting a buzz

Any multimeter should provide more than AC and DC voltage measurement, and DC current ranges. AC current ranges are often featured, but are not universal and will probably not be used much when they are available. There should be several resistance ranges, and this is something where digital units are definitely superior to the analogue type.

Resistance measurement using an analogue multimeter starts with the two test probes being connected together, and a control is then adjusted to zero the reading. Zero resistance is at what would normally be the full-scale reading, and the resistance scales read in reverse. They are also non-linear, with the scales getting cramped towards the high end of each range. Despite these drawbacks, it is still possible to obtain accurate results, but resistance measurement with a digital instrument is much more straightforward.

Analogue and digital multimeters often have further measuring ranges and features, such as continuity testing with a useful buzzer being



used to indicate continuity. There will often be facilities for testing diodes and measuring the current gain and leakage levels of transistors. Any additional features such as these greatly extend the usefulness of a multimeter.

Frequency measurement is sometimes provided, and although the coverage and accuracy are likely to be limited in comparison to a dedicated frequency meter, they can still be very useful. Many digital circuits have a clock oscillator, possibly with a divider circuit or two as well. A very basic frequency meter is usually sufficient to determine whether the clock oscillator is operational, and that the right output frequencies are being provided by any divider stages.

Temperature measurement is sometimes included, but requires a probe that might be an optional extra. This feature can be used to check that heatsinks are working efficiently, and that the more power-hungry semiconductors are not in danger of overheating.

Probing digits

A multimeter can be a bit limited in scope when dealing with logic circuits. It can be used to measure the voltages at static outputs, and the user can then determine whether the test points are at valid logic levels or hovering at an in between invalid state. The problem is that many points in a logic circuit will be pulsing. A voltage in the 'no man's land' between the logic 0 and 1 levels may genuinely indicate a fault, but it could simply be due to the test point rapidly switching between two valid logic levels.

A device called a logic probe (Fig.2) is a better choice for this type of testing. A logic probe is normally powered from the circuit being tested, and can accommodate supply voltages from about 3V to 18V. It will usually be switchable between TTL and CMOS logic levels. A few LEDs are used to indicate the state at the test point, with something like separate LEDs to indicate logic 0, logic 1, pulsing, and an invalid voltage level. Logic probes can be obtained at quite low prices, and should be regarded as an essential item for anyone who builds a lot of digital devices.

Some logic probes have a built-in pulser. In this mode the unit generates pulses at the appropriate logic levels, and it is normally used to replace the clock generator of the circuit under test. Connecting two outputs together is not advisable, and the chip that provides the clock oscillator must be removed before the pulser is used. A pulse generator is a more sophisticated version of a pulser, and it enables the duration and frequency of the pulses to be set over wide ranges and with a high degree of accuracy. The point of using a pulser in place of the normal clock oscillator is that the circuit can be operated at a much lower speed than normal. It can even be moved forward step-by-step, with checks being made along the way.

Market analysis

A logic analyser is a sort of upmarket version of a logic probe. In its most basic form there is a display that shows how the logic level at the test point varies over a certain period of time. Rather than just telling you that the test point is pulsing, it shows how long it spends at each logic state. Most logic analysers have several channels and can monitor several test points simultaneously. This enables the user to check that the right signals are being produced, and that the various parts of the circuit are properly synchronised.

An oscilloscope is the analogue equivalent of a logic analyser. It has a display that shows how the test voltage varies over a period of time. In other words, it displays the waveform at the test point, and most oscilloscopes can display two or more waveforms simultaneously. These days logic analysers and oscilloscopes can be standalone units or add-ons for a PC (Fig.3). Either way, they can be used to quickly sort out the problem with any faulty circuit of the appropriate type, and they can be very instructive when applied to circuits that are working. Unfortunately, they can be quite expensive.

At one time, an audio signal generator providing sine and squarewave output signals was a standard item of test equipment, as was a radio frequency generator. The function generator is the modern version of an audio signal generator. It uses digital techniques to generate a range of waveforms such as sine, square, triangular, pulsed and sawtooth types. The changing nature of electronics is such that signal generators remain extremely useful, but only if you have a specialist interest in audio or radio equipment.

Last, but by no means least, a bench power supply is a very useful item of test equipment. It saves the cost of running down expensive batteries while testing circuits, and in the case of mains powered projects it is safer to disconnect them from the mains supply and power them from a bench supply while carrying out tests. Highly sophisticated professional supply units are very expensive, but a more basic unit that provides something like a well stabilised 0V to -24V at a couple of amps or more is adequate for most purposes.

Fig.2. This logic probe can accommodate TTL and CMOS logic levels, and it has LEDs for high, low, and pulsing signals. It has a simple memory facility that enables a single brief pulse to be detected reliably

Pre-loved

A great deal of second-hand test gear is available, and much of it is at bargain prices. This enables sophisticated professional equipment to be obtained at what could well be a fraction of its original cost. Bear in mind though that second-hand professional equipment is likely to have received a large amount of use. This will not matter too much if it is only needed for light amateur use, and it keeps working. Unfortunately, repairs to this type of equipment can be impossible or very expensive. As with so many things these days, the cost of repair can be very much greater than the value of the repaired item.

Fig.3. These two units from Pico Technologies enable a PC to be used as a sophisticated oscilloscope. The one on the left is a dual channel type, and the one on the right gives up to four channel operation

READOUT

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

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Pot precision project

Dear editor
In the July 2012 issue of *EPE* you featured a *16-bit Digital Potentiometer* by Jim Rowe, which if used with a DC voltage reference source provided a good means of checking the calibration of DMMs. This was a most interesting project, but I found the accuracy of ±0.4% was not quite good enough for my needs, as I required an accuracy of about ±0.01% or better. As the original project used an R/R2 resistor ladder network made up of 0.1% tolerance resistors, its true accuracy varied depending on what voltage you set the output for.

The idea of using a PIC to generate a 16-bit binary number of the keyed in decimal voltage required was a good idea and gave a resolution of 0.15259mV per binary step when used with a 10V reference source.

However, the original project used 16 relays, 16 transistors, 16 diodes and 64 resistors (of which 32 were expensive 0.1% tolerance), all of which compromised the accuracy of the final output voltage. Also, the cost of all these components came to about £50.

For my project, I decided to replace all these with a 16-bit voltage output DAC (digital-to-analogue converter) chip. The one I used was the AD7846 from Analog Devices, which I purchased on eBay for about £5. Even if you were to purchase this chip from Farnell at a cost about £31 it would still represent a big saving compared to the original project costs. This chip has a number of advantages over the original circuit: its accuracy is stable over the whole range; it is very low power, only 100mW; and there is an option to configure the gain of the output to two, which then allows you to use a 5V reference source and still get the 0-10V output required. The other advantage of this is that the resolution is also increased by a factor of two.

To supply the 5V reference to the DAC I used a MAX6350EPA chip which has a tolerance of only ±0.02% or better without any trim resistor. If the Intersil X60008 Precision 5V reference chip were used instead, you could achieve an accuracy of ±0.01% or ±0.005%. However, this second option chip I found harder to source.

Finally, I decided to add an INA105 precision unity-gain differential amplifier configured as a buffer with a gain error of only 0.001% maximum on the output of the DAC. The end result is I now have a very accurate and stable voltage reference source for a fraction of the cost of one you can buy commercially.

When I finished this project I did some more research on the DAC used and found that it can also be configured for AC input voltage as a sinewave. This would allow me to use the same device for both DC and AC reference voltage purposes. I would be interested to hear your thoughts on this.

With regards to precision voltage reference ICs and DACs, I wonder if in the future *EPE* would consider doing an article on these, as I am sure it would be of interest to many of your readers.

Thanks again for a great magazine, I look forward to many more interesting projects.

Louis Scully, by email

Matt Pulzer replies:

Outstanding work Louis – few things are more satisfying than taking a project and adapting and improving it for your own purposes. We'll certainly consider your suggestion for a high-precision article.

Construction issues

Dear editor
I am starting construction on the O2 display from your October 2011 issue. In the article, it says that I will have to 'create vias', but how do I know where to create them. Also, since this board is double sided are all components soldered on both sides?

I will be constructing the wideband O2 sensor next to work on tuning my motorcycle. You have a great magazine, very informative and awesome construction projects.

Matt McCulloch, Industrial Engineer, Huntersville, NC, US, by email

Matt Pulzer replies:

Good question! First, if you want to create 'vias', as referred to in the text, then all you need to do is feed through the offcuts from resistor (or capacitor/transistor) leads and solder them both sides of the PCB.

Second, solder anything that pokes through to the underside, ie the non-component side.

Third, you only need to solder on the top side, the component side, if that connection has a PCB path to another connection. If not, then you can safely leave it unsoldered.

So, the emitter (top connection) of Q2 only needs to be soldered on the underside, but the base and collector need to be soldered on both sides.

I can see vias under the displays in the centre of the PCB; these can be made with the offcuts described above.

I must confess that I don't quite agree with the running order of soldering given in the text. I would be inclined to do all the vias first, then proceed in the following order, essentially working from the middle of the PCB out:

- *Vias*
- *Display sockets*
- *SIL resistor arrays*
- *IC socket*
- *Bargraph socket*
- *Electrolytic cap*
- *Regulator*
- *Other caps*
- *Switches*
- *Transistors*
- *Resistors*
- *LDR*

You need to make sure you can get access to everything to solder on the top side and working from the middle to the outside should ensure this.

A trial run with no solder and a cold iron might be a useful insurance policy here.

Max's Cool Beans

By Max The Magnificent

In previous columns, I introduced the concept of electromagnetic radiation (EM radiation or EMR), particle-based radiation, and ionising and non-ionising radiation. Now it's time to consider how radiation can affect electronic components and systems, and the techniques we can use in our designs to mitigate these effects.

Radiation and silicon chips

There are a a variety of 'single event effects' or 'phenomena' (SEE or SEP) that can be triggered by an individual radiation event. These include 'single event latchup' (SEL) conditions, 'single event upsets' (SEUs), 'single event transients' (SETs), and 'single event functional interrupts' (SEFIs). Two terms we often hear in this regard are 'radiation-hardened' (rad-hard), which refers to modifying the physical structure of a chip to mitigate against radiation-induced effects, and 'radiation-tolerant' (rad-tolerant), which refers to creating designs in such a way as to mitigate against radiation-induced effects.

In the case of an SEL, for example, the radiation event causes a short-circuit between the power and ground rails inside the chip. If an SEL condition occurs, the power has to be cycled (turned off and then on again). Two techniques used to reduce the likelihood of SELs occurring in the first place are to use trenches and to apply an epitaxial layer when creating the device.

If a radiation event 'flips' a register bit or memory cell (ie, changes its contents from a 0 to a 1, or vice versa), then this is referred to as an SEU, as illustrated in Fig.1.

Triple modular redundancy

One way to protect against an SEU is to use 'triple modular redundancy' (TMR) on the register element in question. This involves creating three copies of the register and then using a voting circuit to accept a majority (two out of three) vote, as illustrated in Fig.2.

If TMR is used, then – generally speaking – an SEU will automatically clear itself on the next clock cycle. If a radiation event causes a primitive logic gate to generate a pulse on its output, then this is referred to as a SET as shown in Fig.3.

If the SET has cleared before the next clock arrives (and assuming it doesn't violate the downstream register's setup or hold times), then there isn't a problem. However, if the SET is clocked into the downstream register and/or causes that register to enter a metastable condition, then the SET will be converted into an SEU.

One way to mitigate against an SET is to delay the output from the combinatorial logic so as to 'stagger' the

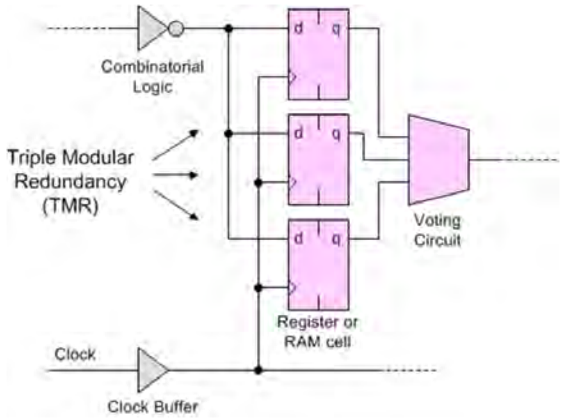

Fig.2. Mitigating the effect of an SEU using TMR (triple modular redundancy)

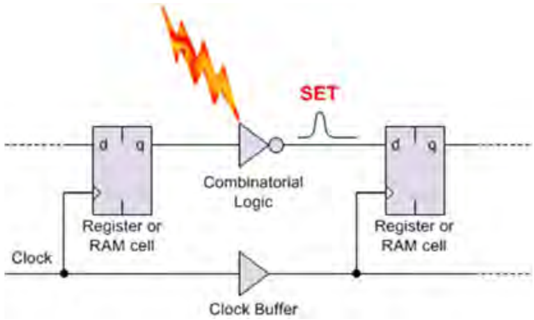

Fig.3. A single event transient (SET)

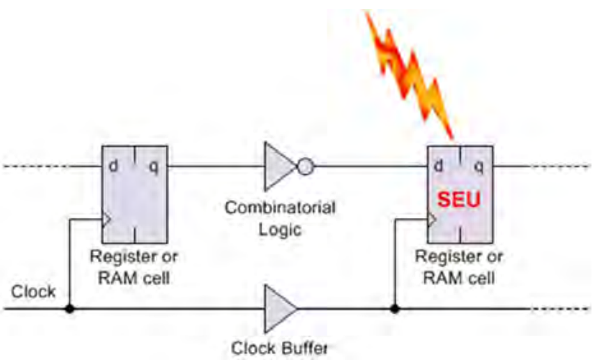

Fig.1. A single event upset (SEU)

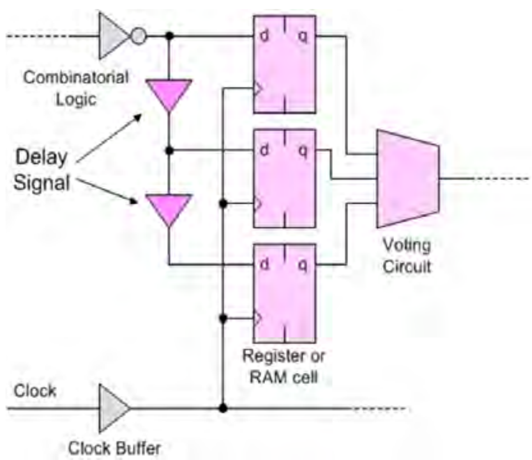

Fig.4. Using delay blocks to protect against SETs

way in which it reaches the inputs to the TMR registers as shown in Fig.4.

Other areas of concern are SETs occurring in buffers in the clock network, and SETs and SEUs causing transitions into invalid states – or invalid transitions between good states – in finite state machines. Also, we should note that there are all sorts of other techniques, such as the use of ECC (error-correcting code) memory and 'memory scrubbing' that we simply cannot cover in sufficient detail in an introductory column of this nature.

But wait, there's more...

Sad to relate, we've only touched on the various ways in which radiation can affect our designs. For example, sufficiently active radiation events can degrade the crystal matrix and modify the switching thresholds of transistors. Also, radiation can result in charge being trapped between the silicon (Si) and silicon dioxide (SiO_2) layers. These effects build up over time, which is why we tend to talk about the absorbed dose or the total ionising dose (TID). The TID is a measure of the amount of energy deposited in a medium by ionising radiation per unit mass. All of these effects can result in reduced speed and higher power consumption, so it is important to design for predicted worst-case conditions.

The bad news is that, as the size of the structures on silicon chips continue to shrink, the effects of radiation become more noticeable. In the not-so-distant past, the only systems we had to worry about in the context of radiation were those targeted for things like high-flying aircraft or satellites and deep space probes. By comparison, in the not-so-distant future, even products intended for use in terrestrial applications will have to be designed with radiation in mind. The good news is that design engineers who understand these issues, and the ways in which one can mitigate them, will be in high demand – great news for anyone involved with electronics who studies radiation!

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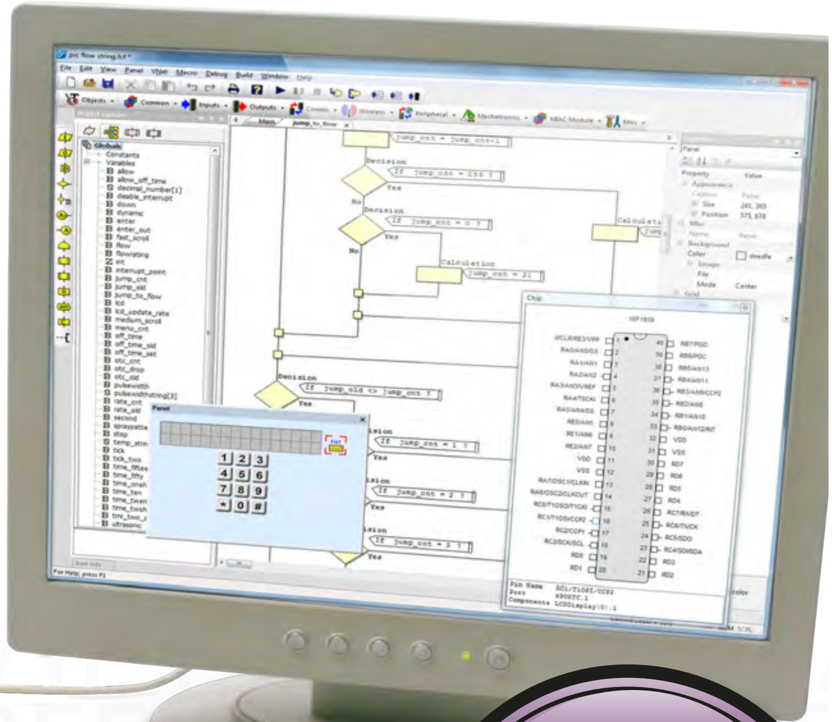

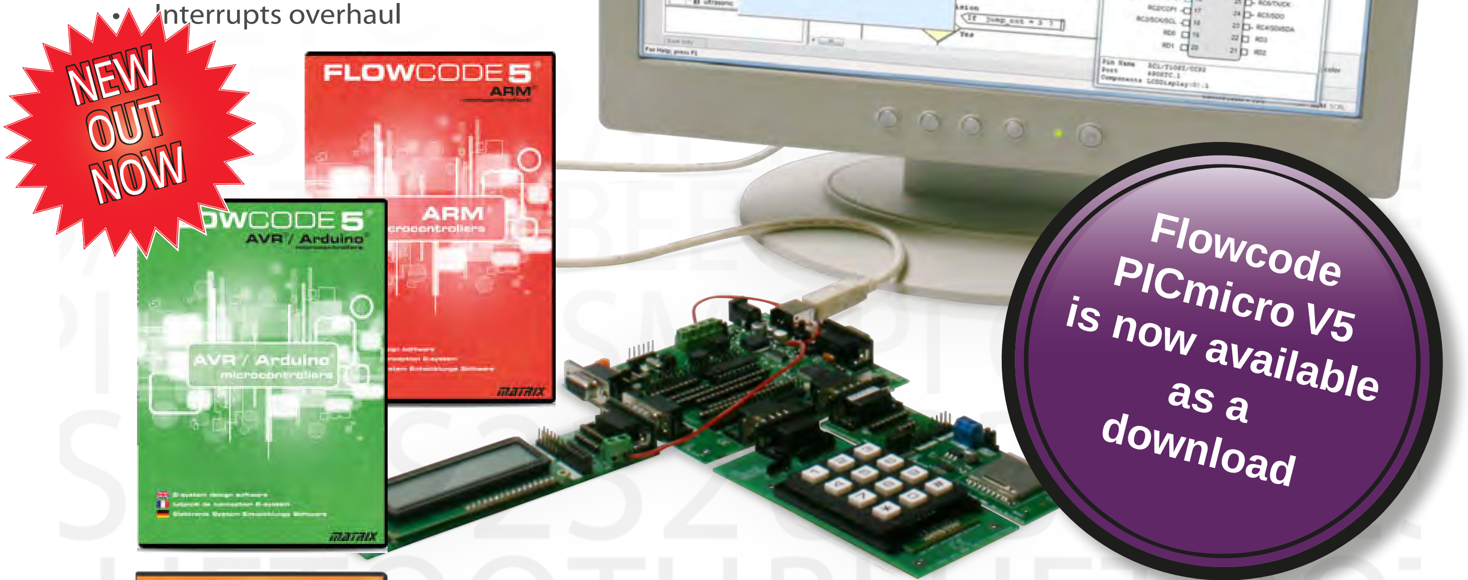

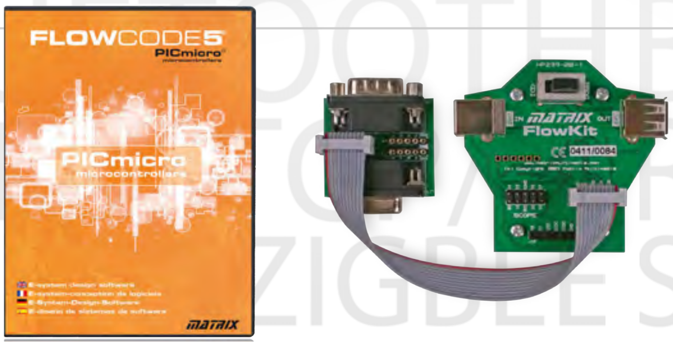

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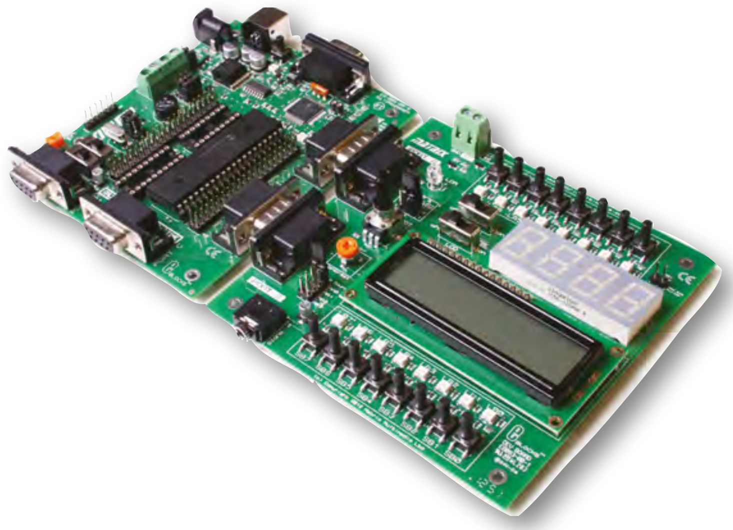
This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers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

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



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

SOFTWARE

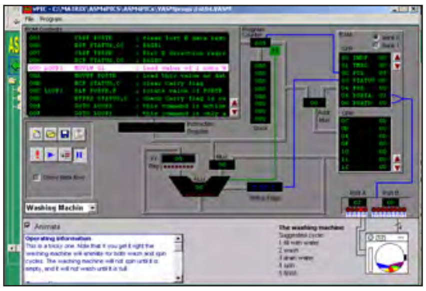
ASSEMBLY FOR PICmicro V4

(Formerly PICtutor)

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

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

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

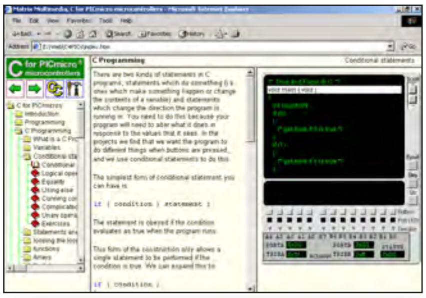


‘C’ FOR 16 Series PICmicro Version 4

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

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



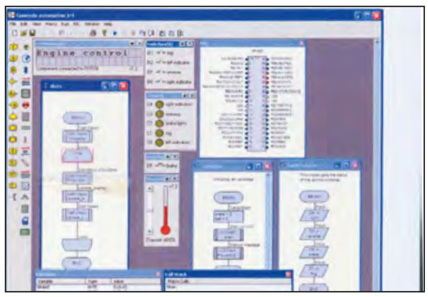
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V5 (see opposite page)

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

- Requires no programming experience
- 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:

(Order form on next page)

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

Hobbyist/Student	£58.80	inc VAT
Professional (Schools/HE/FE/Industry)	£150	plus VAT
Professional 10 user (Network Licence)	£499	plus VAT
Site Licence	£999	plus VAT
Flowcode Professional (Schools/HE/FE/Industry)	£199	plus VAT
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Flowcode Site Licence	£999	plus VAT

CIRCUIT WIZARD

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

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

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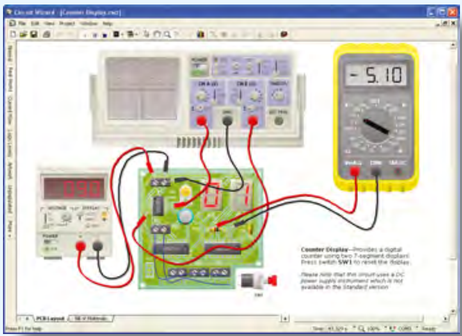

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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

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

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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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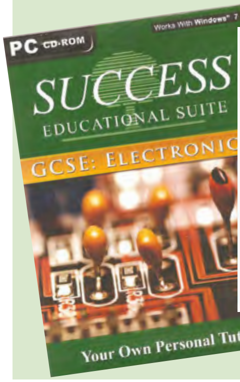

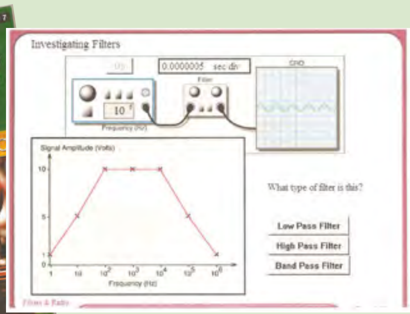

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NET WORK

by Alan Winstanley

On the Tube

IT'S been said that the Internet is becoming more like the Wild West every day – it's developed into quite an anarchic and lawless medium, where anything goes with barely a gun-toting Sheriff in sight. The web grew as a silo of information that lacked the instantaneous interactivity that its users craved. Facebook and Twitter came along at the right time, offering social networks that were superimposed onto the underlying world-wide web. Now users could post their own daily experiences, images or thoughts, direct from a mobile phone app, to enlighten their friends or the public at large.

YouTube is part of a web surfer's staple diet, and a quick search for favourite music (for example) will soon suggest videos of long-lost music tracks with links to more of the same; so it's easy to immerse oneself in YouTube for a little while. So-called 'personalised recommendations' are all about second-guessing what they think will appeal to you, so whether it's a YouTube movie or an eBay product based on your recent browsing history or personal profile, it seems like the entire Internet wants to develop an artificial intelligence and get inside your mind.

As YouTube is owned by Google, it's leveraged by the Internet-marketing industry in order to enhance a website's search engine rankings, so it's not surprising that a vast commercial presence has rushed to get itself online too. Thanks to cookie technology, many websites get to know that you have visited a particular website and they themselves spawn an array of adverts based on your recent history: absolutely every website that I visit (including YouTube) is currently displaying an image of the new office chair that I bought online more than a week ago. In fact I'm sitting in it!

Google makes its money by offering free services such as email, search or YouTube, and then it proceeds to monetise them with advertising. Gmail spawns context-sensitive adverts and YouTube videos often lead with an advert that can be dismissed after a few seconds. But it's free, and that's all that matters for many folks: strangely, everyone is becoming more aware of safeguarding their privacy online, but no-one seems to care that Google has 'read' their posts or private emails before battering them with contextual adverts.

Many enthusiasts from every corner of the world share their favourite videos online and YouTube is a goldmine of archived footage. A Google account is required to log in, and then it is straightforward to upload video from hard disk, mobile phone or webcam and all popular formats are supported. For movies more than 15 minutes long, additional user verification checks are undertaken. Although copyright-protected material such as music videos, TV programs or adverts should not be uploaded without permission, this stricture seems to be widely disregarded. YouTube has gained some notoriety for making it easy to upload videos of bullying, harassment, violent behaviour and other forms of abuse. It's possible to enable 'Safety Mode' to help protect users from seeing that kind of material, but it's not 100% reliable. The Report Abuse link is at **http://www.youtube.com/reportabuse** and the Contact page lists ways in which such content can be handled, see **http://www.youtube.com/t/contact_us**. Such is the influence of YouTube on younger or more impressionable users that YouTube even claims to work with suicide prevention agencies to reach out to vulnerable individuals whose videos have been 'flagged' or reported.

Footage galore

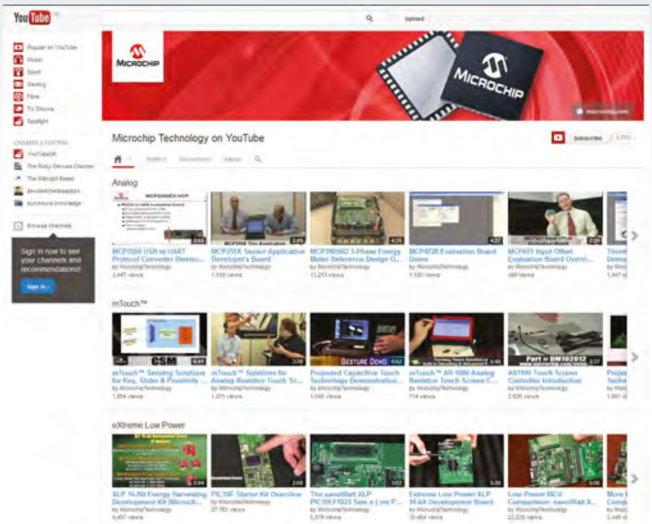
For typical *EPE* readers, hobbyists and radio enthusiasts of all ages, YouTube has much to offer and I've selected just a few that you might find appealing. Fascinating videos include the manufacture of thermionic valves by Mullard at **http://bit.ly/14DIDak**. Or there's a 1943 vintage Westinghouse video called 'Electronics at work', see **http://bit.ly/12mxyGj**. A wonderfully evocative 1967 video produced by Fairchild Semiconductors was uploaded at **http://bit.ly/1a6mwLR** which in 30 minutes describes the design and manufacture of those new-fangled integrated circuits – with not a hairnet nor static-safe handling in sight!

Linux users will appreciate the documentary relating the origins of Linux on **http://bit.ly/15rsIN7** presented by Linus Torvalds, and Unix users might enjoy **http://bit.ly/157KgeY** from the AT&T Archives. Windows users might chuckle at Steve Balmer introducing Windows 1.0 at **http://bit.ly/15rsPbG** and Mac users will appreciate Steve Jobs' introduction of the iPhone in 2007 at **http://bit.ly/1a6mXpf** (Part 1) and Part 2 at **http://bit.ly/13Gdcy8** – search YouTube for subsequent parts. Part 1 of a Steve Jobs and Bill Gates interview (search for more) is at **http://bit.ly/1aT6XKg** which was a gentlemanly get-together.

YouTube 1967 film from Fairchild Semiconductor describing new integrated circuit technologies

Apart from searching for topics, you can also search YouTube by location or contributor or any other keyword. For example, you can see a summary of all of Microchip Technology's YouTube videos at **http://www.youtube.com/user/MicrochipTechnology**.

If you have a camcorder, it doesn't take much to put together a video of a subject that's dear to you, and YouTube will stream HD if the video was made in that format. For many, YouTube



Microchip's YouTube presence contains scores of informative videos

becomes an important part of their hobby or interest. On my Smart TV I saw a YouTube video of my local church bells being rung, which was a marvellous insight into a 1,000-year-old church tower. YouTube material often gives a new insight and is crammed with contributors eager to share their knowledge with you. So, if you want some practical advice, or check some reviews, news clips, nostalgic TV ads or much more besides, head over to YouTube to get a new perspective on your search experience.

A Streetview Named Desire

Google is now in the hot-seat as regards its own privacy rules, which they updated to make them more relevant to Google's myriad of online services, including user tracking and advertising. The search giant is doubtless trembling at the thought of legal action from the UK's Information Commissioner, who states that *'the update of [Google's] privacy policy ... raises serious questions about its compliance with the UK Data Protection Act. In particular, we believe that the updated policy does not provide sufficient information to enable UK users of Google's services to understand how their data will be used across all of the company's products. Google must now amend their privacy policy to make it more informative for individual service users... Failure to [improve] compliance with the Data Protection Act by 20 September will leave the company open to the possibility of formal enforcement action.'*

Google does many things because it can. Google's 3D road panorama Streetview has found very many practical uses, as well as enabling Internet users to nosey around a neighbourhood from the comfort of their own homes or mobile phones. Thieves or burglars can likewise check out their intended targets remotely. However, privacy issues have long been of great concern to ordinary citizens. In the case of Streetview, Google will state, disingenuously in my opinion, that its camera cars are doing nothing wrong because anybody can walk the route and see for themselves anything that's in public view from the highway. Yet their panoramic cameras stick their noses over garden fences and hedges, and pry into people's gardens. Number plates are recognised and automatically pixelated – usually. Google narrowly escaped a fine from the UK ICO because their cars slurped Wi-Fi data as they trundled around. It was fined $7 million (about an hour's earnings) in the USA and a risible €145,000 in Germany for the same reason.

A recent and very British thing happened in a Sainsbury's supermarket recently when, it was reported, a checkout operator refused to serve a customer who was busy talking on her mobile phone. This sparked a national TV and radio debate about showing respect and displaying general civility to one's fellow man. Many observers thought the checkout clerk was justified in her action, although the reverse situation, when the checkout operator is too busy gossiping to colleagues or another customer while ignoring the paying customer completely, is also common enough, so it works both ways.

Searching for Glass

How will Sainsbury's checkout staff – or anyone else for that matter – manage when Google's latest innovation breaks cover? Google Glass is a forthcoming wearable computer in the form of sci-fi-style spectacles with a difference: it sports a miniature image projector that shines a head-up display onto a lens. Currently only intended for the USA, it offers audio through a bone-conduction transducer, 802.11b/g Wi-Fi and Bluetooth compatibility, alluding to the need to pair with an Android mobile phone to get GPS and SMS functionality. It can surf the web and memory is synced with Google Cloud.

Google Glass breaks the mould for mobile data display. It has a 5MP camera, bone-conduction audio, Wi-Fi and Bluetooth built in

Glass has a built-in forward-facing 5MP camera that also shoots 720p video. The entire design is currently undergoing trials, but to give an idea of what Google has in mind, early screenshots showed a simplified sat.nav type display on a lens with on-screen guidance built in; voice recognition of commands such as 'take a picture' or 'record a video' or reading a message; a Siri-type service where you ask Google simple questions in plain English and the answer is shown on-screen. Through its Internet connectivity it will offer video conferencing or translations or beam airport travel data directly to your head-up display, or send live footage while you view the recipient in your display, webcam style. Google Glass updates itself automatically and a range of Glass apps is promised. An early video impression of how Glass looks and feels is at **http://www.google.com/glass/start/how-it-feels/**

An early example of Google Glass satellite navigation. A mobile phone Bluetooth connection provides GPS and SMS

Glass will doubtless challenge the rules of common courtesy and etiquette even more. Every pub and restaurant is crammed with people who spend more time looking at their phones than looking at their guests or workmates. Although it's becoming the norm to behave that way, if you're talking to a Google Glass wearer then how will you know that you have their attention, or are they secretly googling online or reading their text messages instead? How rude will a Glass wearer seem to the uninitiated? How do you know you're not being secretly filmed (perhaps with live footage being transmitted without anybody's consent)?

It's a sign of things to come when on the day that I wrote this, a world first was reported when a Glass tester/wearer captured on video a fist-fight and subsequent arrest in New Jersey, and he decided to ... upload the video to YouTube. Like Streetview, Glass will push the boundaries, and many new privacy implications are now arising for which there are currently no answers.

I hope you enjoyed reading this month's *Net Work*. You can email the author at **alan@epemag.demon.co.uk** or write to the editor at **editorial@wimborne.co.uk** for possible inclusion in *Readout*, and you could win a valuable prize!

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FREE CD-ROM

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

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

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

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

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

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM Order code ETI2 CD-ROM £9.50

ELECTRONICS TEACH-IN 3

The three sections of this book 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 various circuit design and application problems – everything 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 free cover-mounted CD-ROM is 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), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

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. There is also a MW/LW Radio project in the series. The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages Order code ETI3 £8.50

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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

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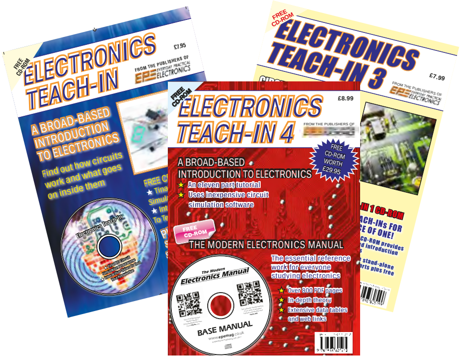

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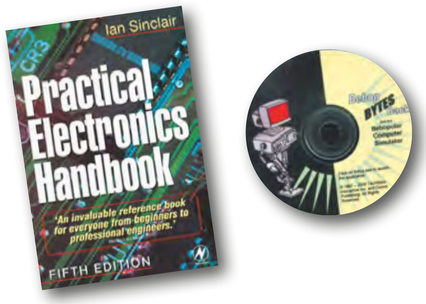

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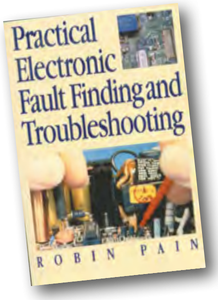

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All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

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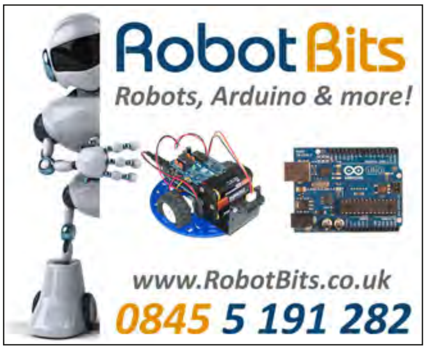

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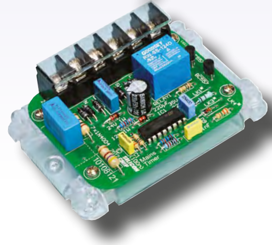
Next Month

Content may be subject to change

High-Temperature Thermometer/Thermostat

Need to measure or control temperature over a very wide range? Now you can do it with this compact unit, which hooks up to a K-type thermocouple. It drives a relay which can be used to precisely control the temperature in ovens, kilns, autoclaves, solder baths or at the cold end of its measurement range, fridges and freezers.



Timer For Fans And Lights

This simple circuit provides a turn-off delay for a 230VAC light or a fan. It can be used to make a bathroom fan run for a set period after the switch has been turned off or it can be used with a pushbutton to turn a light on for a specific time. The timer circuit consumes no standby power when the load is off.

LED Musicolour: Light Up Your Music, Part 1

Now you can have a kaleidoscope of colour that continually changes in time to music. It consists of 16 strings of LEDs, which are individually controlled by 16 frequency bands. Louder signals in each frequency band causes its respective LED string to be brighter. Use it for a Christmas light show, a disco or just for fun when playing music.

Teach-In 2014: Raspberry Pi

Mike and Richard Tooley are back! Yes, October sees the exciting return of the latest Teach-In series. Teach-In 2014 is designed for electronics enthusiasts wanting to get to grips with the immensely popular Raspberry Pi and also for computer buffs eager to explore electronics for the first time. Features will include projects, lessons, tips and tricks – all will be revealed next month.

OCTOBER '13 ISSUE ON SALE 5 SEPTEMBER 2013

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