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VOL. 42. No 2 February 2013

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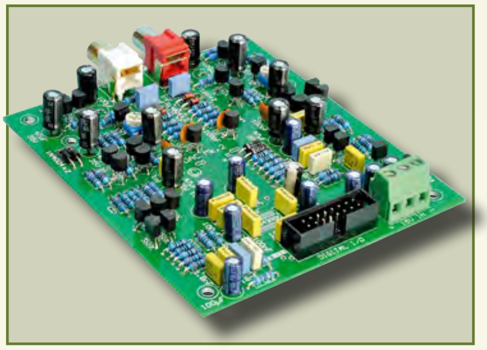

Our March 2013 issue will be published on Thursday 7 February 2013, see page 80 for details.

Projects and Circuits

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£11.95 (Code MK172)


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These educational electronic robot kits make a great introduction to the exciting world of robotics. Some require soldering. See website for details


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Cat. KC-5475

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Create your own eerie science fiction sound effects by simply moving your hand near the antenna. Easy to set up and build. Complete kit contains PCB with overlay, pre-machined case and all specified components.

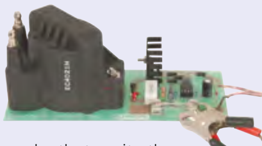
- PCB: 85 x 145mm

£27.25*

Jacob's Ladder High Voltage Display Kit MK2

Cat. KC-5445

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display. Kit includes PCB, pre-cut wire/ladder and electronic components.



- 12V car battery, 7Ah SLA or > 5A DC power supply required
- PCB: 170 x 76mm

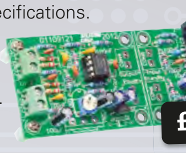
£15.75*

'The Champion' Audio Amplifier Kit with Pre-Amplifier

Cat. KC-5519

NEW 2013

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



- PCB: 101 x 41mm

£7.25*

"Minivox" Voice Operated Relay Kit

Cat. KC-5172

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

- PCB: 47 x 44mm

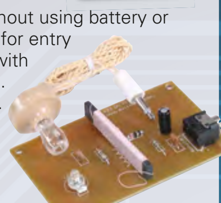
£6.00*

Crystal Radio Kit

£4.75*

Cat. KV-3540

Enjoy AM broadcasting without using battery or other power sources. Ideal for entry level students or hobbyist with little electronics experience. Includes circuit explanation. Kit supplied with silkscreened PCB, crystal, prewound coil, earphone and all components.



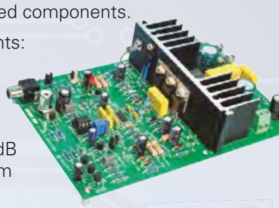
- PCB: 81 x 53mm

High Performance 250WRMS Class-D Amplifier Kit

Cat. KC-5514

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 see **KC-5517**
- S/N ratio: 103dB
- Freq. response: 10Hz - 10kHz, +/- 1dB
- PCB: 117 x 167mm



Also available:

Stereo Speaker Protector Kit to suit
KC-5515 £11.00

+/- 57V Power Supply Kit to suit
KC-5517 £11.00

£32.75*

Universal Stereo Preamplifier Kit

Cat. KC-5159

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

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

£6.25*

"The Champ" Audio Amplifier Kit

Cat. KC-5152

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

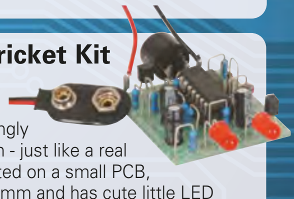
£3.00*

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

Clifford The Cricket Kit

Cat. KC-5178

Clifford hides in the dark and chirps annoyingly until a light is turned on - just like a real cricket. Clifford is created on a small PCB, measuring just 40 x 35mm and has cute little LED insect eyes that flash as it sings. Just like a real cricket, it waits a few seconds after darkness until it begins chirping, and stops instantly when a light comes back on.



- PCB, piezo buzzer, LDR plus all electronic components supplied
- PCB: 40 x 35mm

£6.25*

IR Remote Extender MKII Kit

Cat. KC-5432

Operate a devce using its remote control from another room. This unit is a two transistor two stage transmitter that has the benefits of being VERY COMPACT. The kit contains PCB, 9V battery and all components, and makes an ideal inexpensive beginners kit. Requires 2-wire cable **(WB-1702 £0.17 per metre)**

- PCB: 45 x 23mm

£10.00*

Miniature FM Transmitter Kit

Cat. KE-4711

Ref: Silicon Chip October 2006

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. This improved model features fast data transfer, capable of transmitting Foxtel digital remote control signals using the Pace 400 series decoder. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

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

£5.00*

The Super Ear Kit

Cat. KA-1809

This kit assists people who have difficulty in hearing high audio frequencies, or for those who want to hear more than their normal unaided ear. By amplifying these high audio frequencies, not only will conversations be made clearer, you will be able to hear noises not normally heard such as insects or a watch ticking, for example. Built into a small case and powered from a 9V battery makes this kit totally portable. Use it as a hearing aid or for a fun & educational purpose.

- Kit supplied with Case, Front label, PCB, 9V battery, and all electronic components.
- Headphones required.
- PCB: 56 x 26mm

Note: Not a replacement for a proper hearing aid.

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MK182 Velleman kit £11.43
Digital Record/Player
Non volatile flash memory, Single 20 sec recording via integral mic, 2W output to 8Ω speaker.
Power: 5Vdc 100mA
C-9701 Cebek Module £7.89
3rd Brake Light Flasher Kit
Works with any incandescent or LED rear centre brake light. Flashes at 7Hz for 5 or 10 times, adjustable retriggering.
Power: 12Vdc max load 4A
MK178 Velleman kit £6.30
Multifunction Up/Down Counter
An up or down counter via on-board button or ext input. Time display feature. Alarm count output. 0-9999 display.
Power: 9-12Vdc 150mA
K8035 Velleman kit £17.85
2 Digital Counter
Standard counter, 0 to 99 from input pulses or external signal. With reset input, 13.5mm Displays,
Power: 12Vdc 90mA.
CD-9 Cebek Module £12.99
Digital Clock Mini Kit
Red 7 Segment display in attractive enclosure, automatic time base selection, battery back-up, 12 or 24Hr modes.
Power: 9Vac or dc
MK151 Velleman kit £15.09
Nixie Clock Kit
Gas filled nixie tubes with their distinctive orange glow. HH:MM display, automatic power sync 50/60Hz
Power: 9-12Vac 300mA
K8099 Velleman kit £64.96
1.8W Mono Amplifier
Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
E-1 Cebek Module £5.87
Proximity Card Reader Kit
A simple security kit with many applications. RFID technology activates a relay, either on/off or timed. Supplied with 2 cards, can be used with up to 25 cards. Power: 9Vac or dc
MK179 Velleman kit £14.25
Mini USB Interface Board
New from Velleman this little interface module with 15 inputs/outputs inc digital & analogue in, PWM outputs. USB Powered 50mA, Software supplied
VM167 Module £26.80
20W 2 Channel Amplifier
Mono amplifier with 2 channels (Low & High frequecy), 20W RMS 4Ω per channel, adjustable high level. 22-22kHz, short circuit & reverse polarity protection.
Power: 8-18Vdc 2A
E-14 Cebek Module £22.11
Running Microbug Kit
Powered by two subminiature motors, this robot will run towards any light source. Novel shape PCB with LED eyes.
Power: 2 x AAA Batteries
MK127 Velleman kit £9.02
Thermostat Mini Kit
General purpose low cost thermostat kit. +5 to +30°C Easily modified temperature range/min/max/hysteresis 3A Relay
Power: 12Vdc 100mA
MK138 Velleman Kit £4.55
5W Stereo Amplifier
Stereo power stage with 5W RMS 4Ω, 30-18kHz, short circuit & reverse polarity protection.
Power: 6-15Vdc 500mA
ES-2 Cebek Module £21.54
200W Power Amplifier
A high quality audio power amp, 200w music power @ 4Ω 3-200kHz Available as a kit without heatsink or module including heatsink.
K8060 Velleman kit £12.85
Heatsink for kit £9.95
VM100 Module £38.54
Velleman Function Generator
PC Based USB controlled function generator. 0.01Hz to 2Mhz Pre-defined & waveform editor. Software supplied. See web site for full feature list.
PCGU1000 Velleman £118.38
12Vdc Power Supply
Single rail regulated power supply complete with transformer. 130mA max, low ripple, 12Vdc with adjustment.
FE-103 Cebek Module £13.16
MP3 Player Kit
Plays MP3 files from an SD card, supports ID3 tag which can be displayed on optional LCD. Line & headphone output. Remote control add-on. Power: 12Vdc 100mA
K8095 Velleman kit £39.99
Velleman PC Scope
PC Based USB controlled 2 channel 60Mhz oscilloscope with spectrum analyser & Transient recorder. 2 Scope probes & software included. See web site for full feature list.
PCSU1000 Velleman £249.00
1-180 Second Timer
Universal timer with relay output. Time start upon power up or push button. LED indication. 5A Relay
Power: 12Vdc 60mA
I-1 Cebek Module £12.92
DC to Pulse width Modulator
A handy kit to accurately control DC motors etc. Overload & short circuit protection. Input voltage 2.5-35Vdc, Max output 6.5A.
Power: 8-35Vdc
K8004 Velleman kit £9.95
Velleman PC Scope/Generator
PC Based USB controlled 2 channel oscilloscope AND Function generator. Software included. See web site for full feature list.
PCSGU250 Velleman £113.67
Cyclic Timer
Universal timer with relay output. Time start upon power up or push button. On & Off times 0.3-60 Seconds, LED indication. 5A Relay
Power: 12Vdc 80mA
I-10 Cebek Module £14.12
Audio Analyser Kit
A small spectrum analyser with LCD. Suitable for use on 2, 4 or 8Ω systems. 300mW to 1200W(2Ω) 20-20kHz Panel mounting, back-lit display. Power: 12Vdc 75mA
K8098 Velleman kit £31.65
RF Remote Control Transmitter
Single channel RF keyfob transmitter with over 13,122 combinations. Certified radio frequency 433.92MHz.
Power: 12Vdc 2mA (inc) For use with TL-1,2,3,4 receivers.
TL-5 Cebek Module £14.64
Light Detector
Adjustable light sensor operating a relay. Remote sensor & terminals for remote adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-4 Cebek Module £13.98
USB DMX Interface
512 DMX Channels controlled by PC via USB. Software & case included. Available as a kit or ready assembled module.
K8062 Velleman kit £47.90
VM116 Module £67.15
RF Remote Control Receiver
Single channel RF receiver with relay output. Auto or manual code setup. Momentary output, 3A relay
Power: 12Vdc 60mA For use with TL-5 or TL-6 transmitters.
TL-1 Cebek Module £28.25
Liquid Level Detector
A liquid level operated relay. Remote sensor operates relay when in contact with a liquid. 5A Relay
Power: 12Vdc 60mA
I-6 Cebek Module £13.08
USB Interface Board
Featuring 5 in, 8 digital outputs, 2 in & 2 analogue outputs. Supplied with software. Available as a kit or ready assembled module.
K8055 Velleman kit £24.80
VM110 Module £34.90
Keypad Access Control
An electronic lock with up to ten 4 digit codes. Momentary or timed (1-60ec/1-60min) output. Relay 5A
Power: 12Vdc 100mA Keypad included.
DA-03 Cebek Module £54.26
Thermostat
A temerature controlled relay. Adjustable between -10 to 60°C Sensor on remote PCB. Connector for external adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-8 Cebek Module £12.80
8 Channel USB Relay Board
PC Controlled 16A relays with toggle, momentary or timed action. Test buttons included, available in a kit or assembled.
K8090 Velleman kit £39.95
VM8090 Module £58.40
AC Motor Controller
A 230Vac 375W motor speed control unit giving 33 to 98% of full power.
Power: 230Vac
R-8 Cebek Module £12.14
Start / Stop Relay
Simple push button control of a relay. Either 1 or 2 button operation 5A Relay
Power: 12Vdc 60mA
I-9 Cebek Module £12.83
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Happy New Year!

If all goes according to plan – and I'm sure it will! – you should receive this issue around 3 January. So, on behalf of all the staff at *EPE* and Wimborne Publishing, I'd like to wish you a very happy and successful New Year. We'll certainly be working hard to keep you entertained, fascinated and busy with every facet of electronics.

This month brings an excellent collection of projects. From top quality digital audio electronics to a nice dollop of carpentry in the form of Julian *'Recycle It!'* Edgar's low-cost, but high-impact loudspeaker project. We conclude our popular *USB Data Logger* project with some great tips on using this compact device. Plus, we show you how to make a high efficiency floodlight using everyone's favourite optical component – the LED.

Last, but not least, I really hope you will enjoy *SemTest*, our PIC-controlled component checker. It comes with a whole host of 'bells and whistles', everything you could possibly want for checking the health of your discrete silicon. You can analyse those 'miscellaneous' parts we all seem to accrue as projects, repair jobs and assorted semiconductor flotsam and jetsom come our way. Plus, of course, it's great for checking parts as you build circuits – or to be more realistic, troubleshoot the odd problem which we all come across when wielding a soldering iron!

This early part of the year may be dark, grey, wet and cold (stop laughing, our sun-drenched friends in the Southern Hemisphere), but it's the perfect opportunity to get down to some serious design and construction work. Why not set yourself a target for 2013? – finally get to grips with PICs, build that low distortion amplifier you've promised yourself, or maybe just tidy up your workbench. OK, the last suggestion might be a bit ambitious, but there is nothing wrong with setting the bar high!

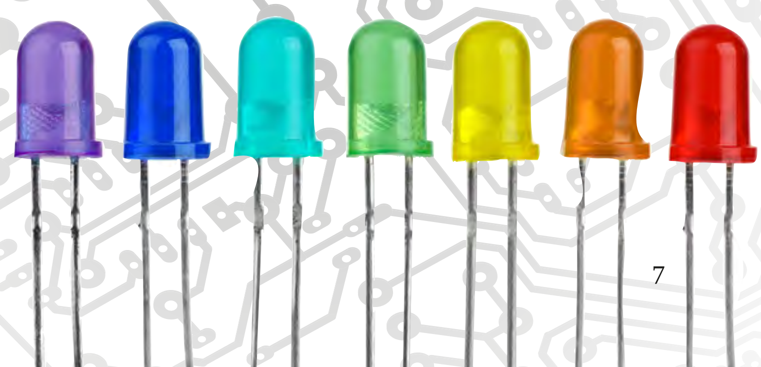
Whatever 2013 brings you in electronics, I hope you are successful and that *EPE* helps and inspires you to learn, build and have fun..

Keeping you informed – online subscribers

We have introduced a new and improved download system for the online version of the magazine. All existing digital subscribers will automatically be changed over to our new system, which is now available through PocketMags (**www.pocketmags.com**).

Only the January 2013 issue onwards will be available on this system, unfortunately we cannot offer earlier back issues, but these are available on CD-ROM from the editorial office.

If you have any queries then please feel free to email stewart.kearn@wimborne.co.uk.



NEWS

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

Electronics and IT in Cuba – by Barry Fox

The electronics industry is always looking for new markets, but there are very few countries that remain unexploited. Cuba is one big hope. But Cuba and the US fell out in 1959 when communist revolutionary Fidel Castro took over from hated dictator Fulgencio Batista, grabbing US companies and properties.

The next year, the US started a 'blockade' by making it an offence for any American to trade with Cuba or visit the country. In 1961, the US clumsily backed a botched invasion by mercenaries who landed on the beaches of the Bay of Pigs and were quickly routed. The following year saw the Missile Crisis, when Russia tried to put nuclear missiles on the island, just 90 miles from the US.

Since then, there has been a bitter stalemate, with many companies hoping for an end to the blockade so that they can start selling to Cuba. I recently spent a week in the capital Havana and the Bay of Pigs area, discovering what US electronics companies, like Apple, HP, Dell, IBM, Kodak, Lexmark and Motorola can expect when they finally land. In short, they are in for a severe culture shock. Although anyone on a package holiday may be cocooned from many truths, anyone exposed to day-to-day Cuba will find the infrastructure very primitive, much as it was in the Soviet Union and East Germany before the collapse of communism in Eastern Europe.

There are two Cuban currencies, the Cuban peso (CUP) of low value for locals, and Cuban convertible pesos (CUC) for tourists, with an exchange rate of 1.00 CUC = $1.00 USD. Currency cannot be converted outside Cuba, so anyone arriving at Havana airport off a long haul flight must first stand in long lines at the inadequately staffed exchange booths before being able to get a taxi into town (25 CUC).

On the phone

Foreign mobile phones connect to the Cubacel network (run by the government-owned ETECSA, Empresa de Telecomunicaciones de Cuba S.A.). Costs are high, so owners make only brief and to-the-point calls, much as it was in the early days of UK cellular.

My O_2 phone could not directly dial; I had to dial a code (*111*#) and wait for a call-back with instruction prompts. An Orange phone can dial direct, but calls cost £1.75 per minute to make and £1 per minute to receive. Texts cost 50p to send, but are free to receive. Sending a picture message costs up to £1.65, and data use costs a staggering £8 per MB.

Driving (in a 1954 Plymouth with Russian jeep engine) on the main dual carriage highway from the Bay of Pigs area to Havana there was no mobile phone signal for tens of miles, no roadside phones, few direction signs and few (if any) petrol stations. I saw no one using a satnav. TomTom has confirmed that there is not yet any mapping for Cuba.

On the net

Locals repeatedly complained about the cost and difficulty of using the Internet. 'We have to go to a hotel' said a bookseller, 'but it costs around 6 CUC for half an hour'.

'You can spend half an hour on line and achieve nothing' said an academic with Internet access in his home.

I ran a check at the famous Nacional hotel, where incidentally the room had a coffee machine with a European round pin mains plug, while all the mains sockets in the room were for US 110V flat pin plugs. My laptop found a Wi-Fi signal (from HP repeaters), but no Internet access.

The guest services paperwork offered no advice. After some trial and error I got Internet Explorer to display: 'Are you an existing user? Welcome to the Wi-Fi Network!!!!!!!!! Username: Password: Please contact your Network Administrator in case of problems.'

A small business centre, open only during the day, sold Wi-Fi logon details at 2.5 CUC for 15 minutes, 5.0 CUC for 30 minutes, 7.5 CUC for 45 minutes and 10 CUC for an hour.

Shopping for consumer electronics in Havana and trying to communicate is like time-travelling back to the Soviet Union and walled-off East Berlin

Black and white printing cost 0.5 CUC per page, with colour at 2 CUCs. As a pricing yardstick, a bottle of Cuban rum in a supermarket can be bought for less than 5 CUC.

'It is obligatory to present the passport, identity card or room number to access the Internet' a sign warned. We presented, logged on and found access painfully slow – so ran a series of broadband speed checks. These revealed the ISP to be Empresa de Telecomunicaciones de Cuba, with download speeds varying between 0.070, 0.047 and 0.039 Mbps and upload speeds of 0.011, 0.017, 0.025 and 0.057 Mbps. This is equivalent to a slow dial-up connection.

Only a handful of others were using the system, so I asked the business centre clerk if the speeds were always so slow. Yes, she said, without hint of concern or apology.

Opportunity awaits

During my week in Cuba I saw no locals using a laptop, tablet or smartphone and only one person (a tourist) listening to music on headphones. I did, however, see a few youngsters carrying portable 'boomboxes'.

I saw only one Apple product; an old iPod HDD playing a movie through a Real media player box connected to a TV in a roadside cafe.

I spotted only one consumer-size satellite dish, and that was mounted on a school roof. However, a taxi driver told me that in his housing block one resident had a DirectTV dish, brought in 'illegally' from the US. The owner had rigged shared video feeds to several other apartments whose owners shared the subscription cost.

Another taxi driver was listening to US satellite radio. He said a friend in Texas paid the subscription. Another local asked me to show him how to remove the SD card from the Sony digital camera he had got from a friend in Europe.

These examples typify the overall situation. Although some Cubans may have some modern electronics, it has almost always been imported on the grey or black market. Only a very few Cuban shops sell electronics and it is over-priced and decades behind the rest of the world.

So, the opportunities for approved imports are huge, if the trade barriers come down. Cuba's first priority will then be to build an IT infrastructure.

Tech giants humbled

It would be unwarranted hyperbole to say that Japanese electronics giants Sony, Sharp and Panasonic are finished, but they are certainly facing a 'difficult period'.

In November 2012, the ratings agency Fitch cut the firms' credit rating to 'junk' status; a humiliating first for these companies. This means that not only does Fitch believe these prestigious firms may default on their existing debts, but that borrowing will now be much more expensive for them.

Where willl the next 'Walkman' come from – Japan? Companies like Sony, Sharp and Panasonic need to rediscover their creative side to compete successfully

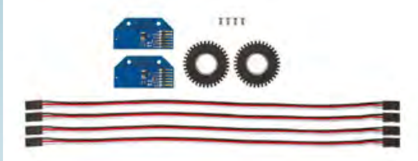
Panasonic has warned it expects a 2012 loss of $10bn, while Sony expects only a small profit after four years of losses.

Many Japanese electronics firms are facing a daunting four-pronged assault on their once dominant position. The all-important domestic economy has been stagnant for nearly two decades. The world's most important growth economy – China – has become a much more difficult place to sell and work thanks to nationalist and anti-Japanese sentiment over territorial disputes concerning tiny, but strategic islands in the South China sea.

Smaller nimbler countries, such as Taiwan and South Korea have eaten into their high-tech lead, and US companies like Apple and Google are making all the running when it comes to creativity and profitability.

Japanese companies such as Sony still have many strengths, but their period of dominance is long over, and they have had to accept powerful rivals. Whether this spurs them to a new golden era of popular world-beating products, or they resign themselves to being just another player remains to be seen.

Sensors from Parallax



The new toothed-wheel 36-position quadrature encoder from Parallax

Parallax has released a pair of useful new sensors: a 36-position quadrature encoder set and a proximity sensor.

The encoder provides rotational feedback for robot wheels. It was designed specifically for Parallax's 'Motor Mount and Wheel Kit', but can be used with your own custom robots or mechanical systems with half-inch axles.

The Si1143 Proximity Sensor is handy for non-contact gesture recognition in microcontroller applications. By measuring infrared light levels from the three on-board infrared LEDs, gestures in the up, down, left, right and centre select directions can be detected.

Both items cost $29.99 plus p&p, more details at: **www.Parallax.com**

ELECTRONIC LOCKS PICKED

Those never-seem-to-work the first time you use them electronic card keys, that hotels are so fond of, now have another reason to be unpopular. US business magazine Forbes *has reported that hotel rooms in the States with electronic locks have been broken into and then robbed.*

The locks were picked with relatively simple digital tools, despite public warnings from a software developer months earlier that particular systems were vulnerable. More on this story at: ***http://tinyurl.com/clautcb***

Avoiding termination

The Centre for the Study of Existential Risk may sound like a website from one of the more eccentric corners of the Internet, especially as it will look at the possible risk to humans, and indeed humanity as a whole from artificial intelligence, nanotechnology and robots. However, it is in fact a serious body, set up at Cambridge University by Martin Rees, the Astronomer Royal, Huw Price, professor of philosophy at Cambridge and Jaan Tallinn, a co-founder of Skype.

They wanted to create a joint initiative between a philosopher, a scientist, and a software entrepreneur to deal with pressing issues that require a great deal more scientific investigation than they presently receive. For more details, see: **http://cser.org**

SemTest

Part 1: By JIM ROWE

Check all those semiconductors in your collection with this easy-to-build test set!

How many discrete semis have you got in your collection? Hundreds? Thousands? Are they all good? Don't know? With our new Discrete Semiconductor Test Set you will be able to test a wide range of active components: LEDs, diodes, bipolar junction transistors, MOSFETs, SCRs and programmable unijunction transistors (PUTs), for gain (where applicable), voltage breakdown and leakage. You can even run tests on IGBTs and triacs!

OF COURSE, there are lots of semiconductor testers out there. These range from the handy pocket-sized instruments produced by Peak Electronic Design Ltd to large laboratory bench instruments made by Agilent, costing many thousands of pounds. The former group are not able to test the range of semiconductors that perhaps we would like, while the latter instruments are beyond our reach.

New design

So, we set ourselves the task of producing a new design that would be easy to drive.

I looked at an old design from the 1960s – a bunch of rotary switches, a 50µA moving coil meter and 'olde-worlde' point-to-point wiring. Still, it could perform most of the basic tests that were needed on the discrete semiconductor devices of the day.

After a while though, that old 1968 design made me shudder: all that point-to-point wiring – all those switches – no PCB – an analogue meter. Ahhhh! Definitely time for an upgrade. Plus, of course, it was designed long before MOSFETs were even thought of, and we would have to include them.

In the fullness of time (a silly expression glossing over the trials and tribulations – not to mention the blood, sweat and tears – of producing a completely new design), we came up with the *SemTest*. It's otherwise known as a *Discrete Semiconductor Test Set* – which is too much of a mouthful.

It's around half the physical size of the 1968 design and it's controlled by a microprocessor, with a 16 × 2 LCD panel used to display the device to be tested, the test to be run and the test results. There is a minimum of front panel controls: one rotary switch, one potentiometer and five pushbutton switches. The problem of catering for all the different semiconductor sizes and pinouts has been solved by employing an 18-pin ZIF (zero insertion force) socket. These sockets are normally used for programming microprocessors, but they are ideal for this application.

All the parts inside the case are accommodated on two medium-sized PCBs, which are connected together by three IDC cables.

However, before we jump into describing the circuitry of the *SemTest* in detail, we need to discuss the tests it can perform on each type of the most commonly used discrete semiconductors. After all, if you are contemplating building the *SemTest*, you will want to understand all the tests that it can run.

Diodes and LEDs

Testing diodes and LEDs sounds simple enough, but there are different sorts: standard silicon and germanium signal and rectifier diodes, Zener/avalanche diodes, Schottky barrier diodes, LEDs and diacs (bipolar breakover diodes, which are actually a 2-terminal thyristor). The new tester can perform basic tests on all of these devices.

A simplified version of the diode test circuitry used in the *SemTest* is shown in Fig.1. It's very straightforward, yet can be used to measure any of four basic diode parameters:

(1) V_F – the voltage drop when conducting in the forward direction

(2) I_R – the leakage current which flows when a reverse 'operating' voltage (OPV) of 10V/25V/50V/100V is applied via an appropriate series current-limiting resistance

(3) I_R – the current which flows when a higher 'breakdown' voltage (BV) of 600V is applied (again via a suitable series current-limiting resistor)

TESTS AVAILABLE ON THE DISCRETE SEMICONDUCTOR TEST SET

Device Type	Test Parameter	Extended description
Diodes, including zener & schottky (also Diacs)	I_R (BV)	Reverse avalanche current with BV (600V) applied*
	I_R (OPV)	Reverse leakage current with OPV (10/25/50/100V) applied*
	V_F (OPV)	Forward voltage drop with OPV (10/25/50/100V) applied*
	V_R (BV)	Zener/avalanche voltage with BV (600V) applied*
LEDs	I_R (OPV)	Reverse leakage current with OPV (10V) applied*
	V_F (OPV)	Forward voltage drop with OPV (10/25/50/100V) applied*
Bipolar Junction Transistors (NPN or PNP)	$V_{(BR)CBO}$ (BV)	Breakdown voltage with e o/c, BV (600V) applied*
	$V_{(BR)CEO}$ (BV)	Breakdown voltage with b o/c, BV (600V) applied*
	I_{CBO} (OPV)	Leakage current with e o/c, OPV (10/25/50/100V) applied*
	I_{CEO} (OPV)	Leakage current with b o/c, OPV (10/25/50/100V) applied*
	h_{FE} with I_B = 50µA (OPV)	Forward current gain with I_B = 50µA, OPV applied*
	h_{FE} with I_B = 200µA (OPV)	Forward current gain with I_B = 200µA, OPV applied*
	h_{FE} with I_B = 1mA (OPV)	Forward current gain with I_B = 1mA, OPV applied*
Mosfets (N-channel or P-channel)	$V_{(BR)DSS}$ (BV)	Breakdown voltage with g-s short, BV (600V) applied*
	I_{DSS} (OPV)	Leakage current with g-s short, OPV (10/25/50/100V) applied*
	I_{DS} vs V_{GS} (OPV) (g_{fs})	d-s current vs V_{GS} (0-12V), OPV (10/25/50/100V) applied*
SCRs & PUTs (also Triacs)	$V_{(BR)AKS}$ (BV)	Breakdown voltage with g-k or g-a short, BV (600V) applied*
	I_{AKS} (OPV)	a-k current with g-k or g-a short, OPV (1/25/50/100V) applied*
	I_{AK} with I_G = 50µA (OPV)	a-k current with I_G = 50µA, OPV (1/25/50/100V) applied*
	I_{AK} with I_G = 200µA (OPV)	a-k current with I_G = 200µA, OPV (1/25/50/100V) applied*
	I_{AK} with I_G = 1mA (OPV)	a-k current with I_G = 1mA, OPV (1/25/50/100V) applied*
	$V_{AK(ON)}$ (OPV)	a-k voltage drop when on, OPV (10/25/50/100V) applied*

*Both BV and OPV are always applied via appropriate current limiting series resistors

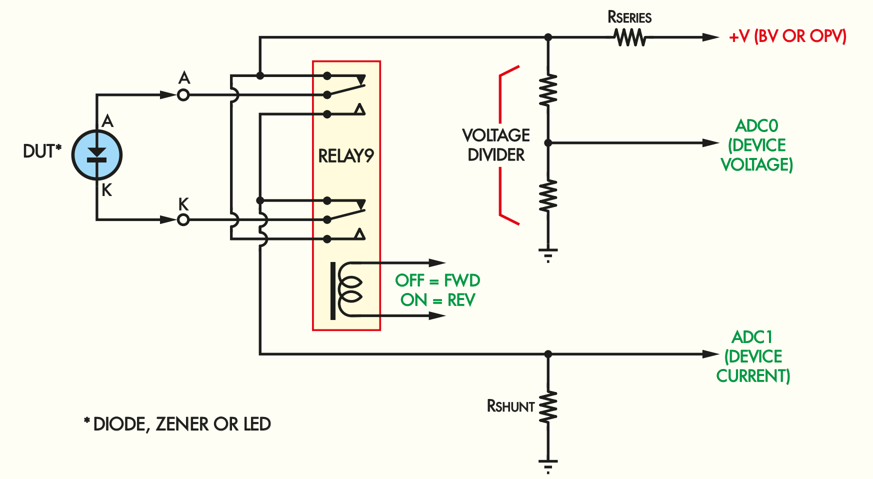


Fig.1: the basic diode test circuitry. It uses Relay9 to switch the polarity of the diode under test, a shunt resistor to allow current measurements and a voltage divider to interface with the microcontroller.

(4) V_R – the voltage drop when the diode is conducting in the reverse direction in 'avalanche' breakdown mode.

All four of these tests can be applied to test Zener/avalanche diodes, signal and rectifier diodes, Schottky diodes and even diacs. The last two tests are not available for testing LEDs as these devices can be damaged if sufficient current flows during avalanche breakdown.

In fact, before you do an I_R test on an LED, the tester warns you of possible damage if the lowest operating voltage of 10V is not selected.

The diode test circuit of Fig.1 uses RELAY9 to switch the polarity of the diode under test. When RELAY9 is off (not energised), the diode's anode (A) is connected to the test voltage source (+V) via series current-limiting resistor RSERIES.

Note that test voltage +V is switched between the operating voltage (OPV) and the breakdown voltage (BV) level by the microcontroller, which also changes the value of series resistor RSERIES to suit the various tests. In operation, the micro switches +V on only during the

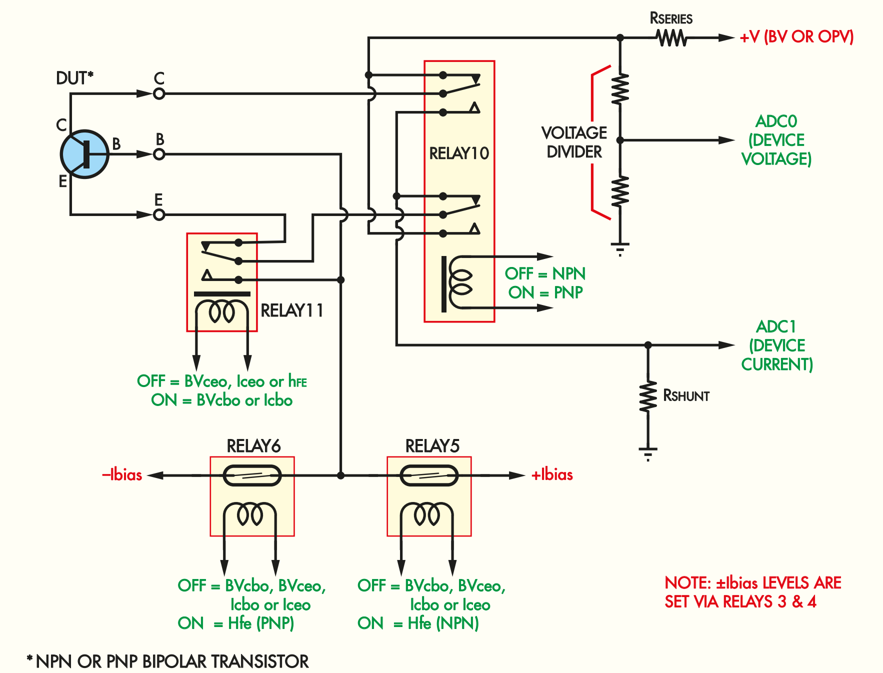


Fig.2: the basic test configuration for bipolar junction transistors (BJTs). It uses four relays to perform all of the basic tests normally required on *NPN* or *PNP* devices.

actual test and then off again at the end of the test.

For the 'reverse bias' tests, the micro energises RELAY9, which simply reverses the diode polarity so that the cathode (K) is connected to +V instead of the anode.

The rest of the diode test circuit includes a voltage divider, used to allow the micro to measure the voltage across the diode under test, by means of the micro's analogue-to-digital (A/D) converter input ADC0. The micro also switches the voltage divider's ratio to suit the voltage source used for each test.

Finally, there's a shunt resistor (R_{SHUNT}) connected between the cathode (or anode) of the diode and ground. The top of this resistor is connected to the ADC1 input of the micro so it can measure the voltage across R_{SHUNT} and then calculate the device current. Again, the value of R_{SHUNT} is switched by the micro; in this case, to suit the current range required for the selected test.

By the way, since the voltage drop across R_{SHUNT} effectively adds to the device voltage as measured via the voltage divider and the microcontroller's ADC0 input, this has the potential to introduce a small error in the device voltage measurement. This voltage drop across R_{SHUNT} is quite small, with a maximum of 2.0V for a 'full-scale' current reading of 20mA (or 200µA on the low range).

To eliminate this problem, the firmware automatically corrects the reading. It does that by subtracting 100mV for each 1mA of device current on the higher range, or for each 10µA of current on the low range (ie, it automatically subtracts the voltage across the R_{SHUNT}).

Testing diacs

Before we move on, let's look at how a diac can be tested with the *SemTest*. It should be connected to the diode A and K terminals (either way around) and first given the diode V_F test with the lowest (10V) setting for OPV. This will show you whether the diac is shorted (which will give a reading of no more than about 0.25V and a current of about 2.5mA) or 'OK' (which will give a reading of close to 10V).

If you do get a reading of very close to 10V, you can repeat the above test at 25V or 50V until the diac breaks over into conduction. Typical diacs break over at between 25V and 35V, with a current of less than 200µA.

When the diac does switch into conduction, the V_F reading suddenly drops to a much lower level – probably around 5V to 10V – while the current jumps up into the 3mA to 10mA region. If the diac behaves as described, you then do the test in the other direction: ie, switch back to the 10V setting for OPV and then test it with the I_R (OPV) test selected.

This will let you check the diac's operation in the reverse direction. You should again see it drawing a current of less than 200µA with only 10V applied, with the current jumping up to between 5mA and 15mA when you select an operating voltage of 25V or 50V, so that it 'breaks over' again.

A diac that gives these expected results in both tests is working correctly.

Testing transistors

Testing bipolar junction transistors or 'BJTs' is more complex than with diodes, because there are *NPN* and *PNP* types and they have three leads rather than two. Fig.2 shows the test configuration for BJTs. This uses four relays to perform all of the basic measurements normally required for *NPN* or *PNP* devices:

(1) I_{CBO} – the leakage current passed between collector and base, with a selected operating voltage (OPV) applied and the emitter open-circuit

(2) I_{CEO} – the leakage current passed between collector and emitter, again with a selected operating voltage (OPV) applied, but this time with the base open circuit

(3) $V_{(BR)CBO}$ – the breakdown voltage measured between collector and base, with the emitter open circuit, but with a breakdown voltage (BV) source applied via a series current-limiting resistor

(4) $V_{(BR)CEO}$ – the breakdown voltage measured between collector and emitter, with the base open-circuit, but with a breakdown voltage (BV) source applied via a series current-limiting resistor

(5) h_{FE} – the common-emitter forward current gain, measured at any of three base current levels (I_B = 50µA, 200µA or 1mA). The choice of base current levels is provided to cope with small and medium-power devices.

As you can see from Fig.2, RELAY10 is used for setting up the BJT circuit for testing either *NPN* or *PNP* devices. RELAY11 is used to perform the base/emitter switching for the various tests, while RELAY5 is used to switch on

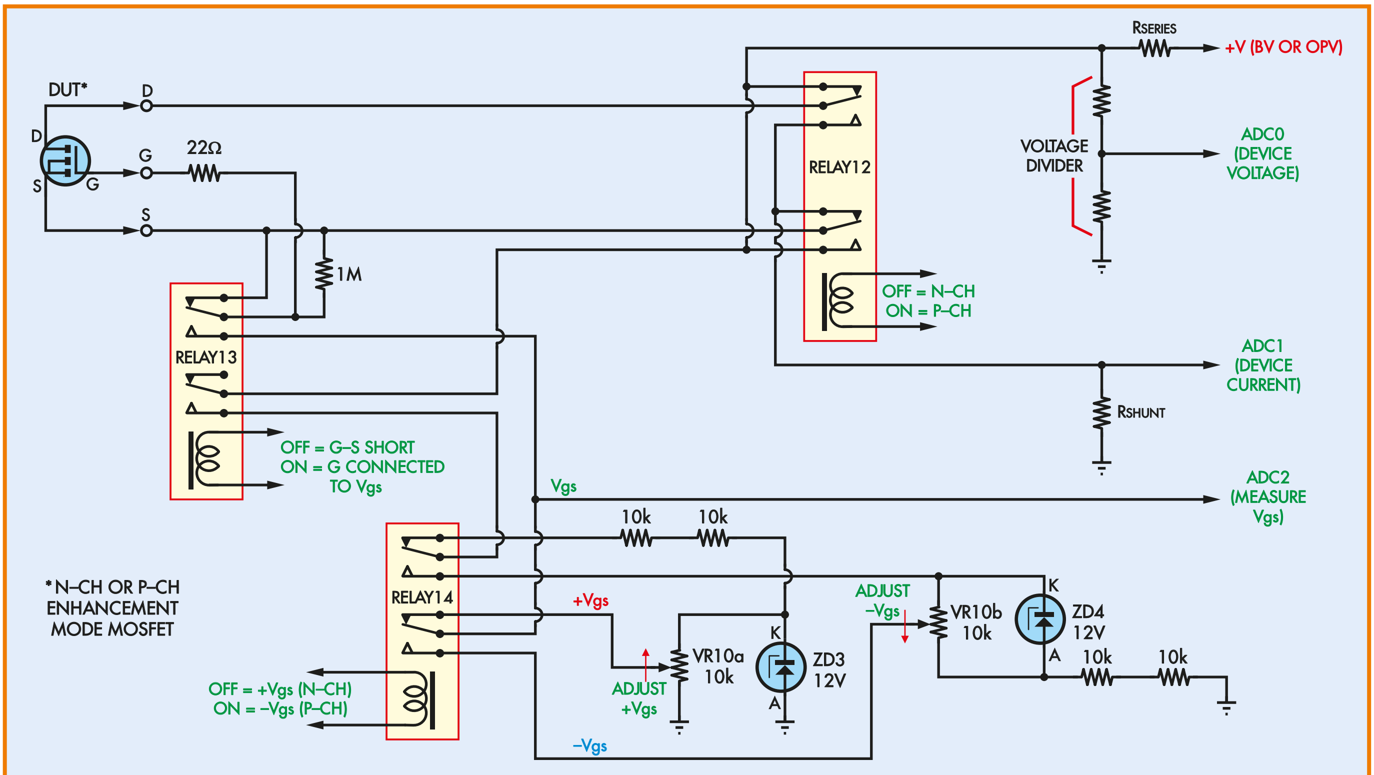


Fig.3: the MOSFET test circuit. Only three relays are used; these allow all the main tests normally required for both *N*-channel and *P*-channel MOSFETs. The positive V_{GS} (gate-source) voltage is derived from Zener diode ZD3 and varied by VR10a, while the 'negative' V_{GS} voltage is derived from ZD4 and varied by VR10b.

positive base bias current ($+I_{BIAS}$) for h_{FE} testing of *NPN* devices. RELAY6 is used to switch on negative base bias current ($–I_{BIAS}$) for h_{FE} testing of *PNP* devices.

Additional relays (RELAY3 and RELAY4, not shown in Fig.2) are used to switch both $+I_{BIAS}$ and $–I_{BIAS}$ between the various current levels.

As with the diode testing circuit, either operating voltage (OPV) or breakdown voltage (BV) can be applied to the transistor being tested, via series current-limiting resistor R_{SERIES}. Again, the micro switches the OPV/BV source on only for the actual test, and then off when the test is ended. It also changes the value of R_{SERIES} to suit each kind of test.

As before, there is a voltage divider across the device being tested, feeding the micro's ADC0 input so that the micro can measure the device voltage V_{DEV}. Again, the micro changes the divider ratio to suit each kind of test. The device current is also measured in exactly the same way as for diodes, with shunt resistor R_{SHUNT} used to effectively convert the device current into a small voltage for measurement via the micro's ADC1 input. The micro can also switch the value of R_{SHUNT} to provide two current ranges: 20mA and 200µA.

As before, the small voltage drop across R_{SHUNT} will effectively add to the device voltage measurement, introducing a small measurement error for $V_{(BR)CBO}$ and $V_{(BR)CEO}$. Again, the software corrects for this error by subtracting 100mV for each 1mA of device current on the higher range, or for each 10µA of current on the low range.

Testing MOSFETs

Testing metal-oxide semiconductor field effect transistors or 'MOSFETs' is not significantly more complicated than with BJTs, even though MOSFETs are a voltage-controlled transconductance device, rather than a current-controlled transadmittance device.

As with BJTs, there are again two types, in this case *N*-channel and *P*-channel devices, with different polarity requirements for both drain-source voltage and gate bias voltage. There's also a difference in terms of breakdown voltage and leakage current measurement, of course.

Note, however, that the *SemTest* is only capable of testing junction FET or 'JFET' devices in a limited sense, as these operate in depletion mode rather than in enhancement mode, as used by modern MOSFETs.

Whereas MOSFETs pass virtually zero drain-source current with zero gate bias, and need gate bias in order to pass significant drain-source current, JFETs work the other way around; they pass a significant drain-source current with zero gate bias and need gate bias to be applied in order to 'throttle back' the drain-source current. This means they require 'negative' gate bias, in contrast with the 'positive' bias needed by MOSFETs.

Despite this limitation, the *SemTest* is capable of testing JFETs for one quite important parameter: I_{DSS} – the drain-source gate current with the gate tied to the source (ie, the zero-bias channel current). This is done via the same I_{DSS} test used for MOSFETs (see below), the difference being, with MOSFETs the reading should be very low (usually well below 200µA), while for JFETs the reading will be relatively high (probably 10mA to 20mA).

The MOSFET test circuit is shown in simplified form in Fig.3, and it's relatively straightforward. Only three relays are used, but these allow the *SemTest* to perform all three of the

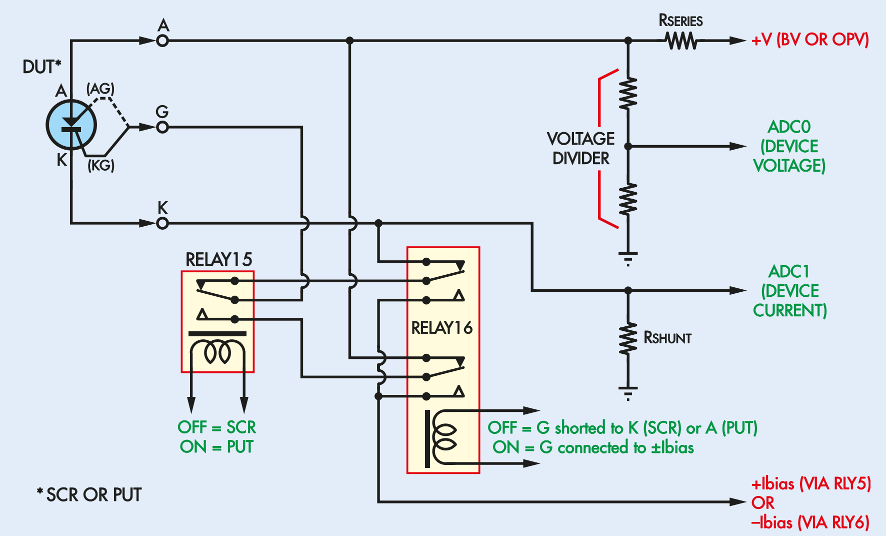


Fig.4: the test circuit for SCRs and PUTs uses two relays for switching and is similar to that used to test bipolar junction transistors (BJTs). It carries out five basic tests.

main tests normally needed for either *N*-channel or *P*-channel MOSFETs:

(1) I_{DSS} – the drain-source current with zero gate bias (ie, gate tied to source). This can be measured with any selected operating voltage (OPV) applied between drain and source, via a series current-limiting resistor;

(2) $V_{(BR)DSS}$ – the drain-source breakdown voltage, again measured with gate tied to source, but in this case with the higher voltage source (BV) applied between drain and source, via a higher-value current-limiting resistor

(3) I_D – the drain-source current which flows at any gate bias voltage V_{GS} (variable between 0V and approximately 12V), with any selected operating voltage (OPV) applied between drain and source. This allows the transfer characteristic of a device to be measured, and its transconductance worked out.

As you can see from Fig.3, the MOSFET drain-source voltage and drain current are measured in exactly the same way as for BJTs and diodes, using a voltage divider feeding ADC0 for the voltage measurement, and shunt resistor R_{SHUNT} feeding ADC1 for the current measurement. The OPV/BV switching and R_{SERIES} switching are managed by the micro as before, as is the voltage divider ratio and the value of R_{SHUNT}.

The main differences between Fig.3 and the earlier test circuits are in the gate switching circuitry, involving RELAY13 and RELAY14. The first of these relays carries out the primary gate switching, shorting the MOSFET's gate to the source for the I_{DSS} and $V_{(BR)DSS}$ tests when it is not energised, or connecting the gate to a bias voltage source V_{GS} when it is energised (for the I_D versus V_{GS} test).

RELAY14 then performs the job of selecting either a 'positive' V_{GS} source for *N*-channel devices, or a 'negative' V_{GS} source for *P*-channel devices.

The positive V_{GS} source is derived from the test voltage (OPV) via Zener diode ZD3 and varied by potentiometer VR10a, while the 'negative' V_{GS} source is also derived from OPV, but via ZD4 and varied by VR10b. The latter is only negative by comparison to the MOSFET's source terminal, which in the case of a *P*-channel device is connected to OPV.

This explains why VR10a is adjusted upwards from ground (0V) to increase $+V_{GS}$ (for *N*-channel devices), while conversely VR10b is adjusted downwards from the device source voltage (representing zero V_{GS}) to increase $-V_{GS}$ for *P*-channel devices.

Since VR10a and VR10b are the two sections of a dual-ganged 10kΩ+10kΩ pot, they are simply wired in converse fashion so that the effective gate-source voltage advances from zero as the pot is turned clockwise.

The micro is able to work out the effective gate voltage for any setting of VR10a or VR10b via the connection from the V_{GS} source, as selected by RELAY14, to a third ADC input of the micro (ADC2). But because this only allows the micro to measure the 'raw' gate voltage V_G, relative to ground, this means that for *P*-channel devices it also has to measure the source-drain voltage of the device and subtract the measured gate voltage from it, to calculate the effective gate-source bias ($-V_{GS}$).

With *N*-channel devices this isn't necessary, although the small voltage developed across current measuring shunt resistor R_{SHUNT} will reduce the effective gate-source bias for these devices, by the same factor of 100mV for each 1mA of current on the higher current range, or 10µA of current on the lower range.

As with the h_{FE} measurements for BJTs, the firmware automatically makes this correction.

What about IGBTs?

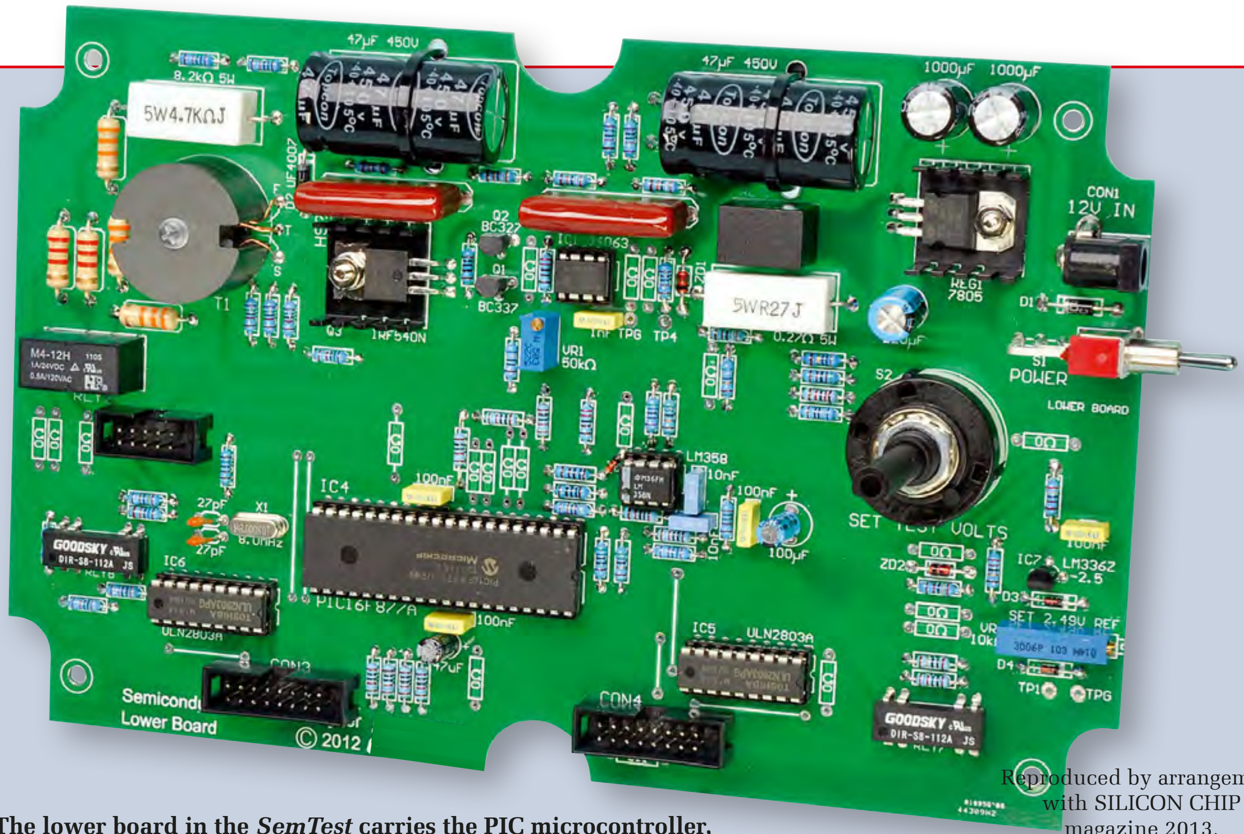
Although they're not widely used in general electronics, insulated-gate bipolar junction transistors or IGBTs are encountered in automotive ignition systems, fuel-injection controllers, high power inverters and AC induction motor drives.

They can be regarded as very much like an *N*-channel MOSFET and an *NPN BJT/PNPN* silicon-controlled switch combined, with a collector as the main positive electrode and an emitter as the main negative electrode. However, they have a gate electrode for voltage control instead of a base electrode for current control.

IGBTs are usually quite high-power devices, so the modest test currents available inside the *SemTest* mean that it isn't really possible to use it to fully characterise the performance of an IGBT.

However, you can perform basic tests on an IGBT by connecting it to the *SemTest's* MOSFET testing terminals (C to the drain terminal, E to the source terminal and G to the gate terminal). You then test it as if it were an *N*-channel MOSFET, making a mental conversion of the test results into the equivalent parameters for an IGBT.

For example, the voltage reading you get for $V_{(BR)DSS}$ will correspond to the IGBT's $V_{(BR)CES}$ (collector-emitter breakdown voltage with the gate shorted to the emitter), while the reading you get for I_{DSS} will correspond to the IGBT's I_{CES} (collector-emitter leakage current with gate shorted to emitter).



The lower board in the *SemTest* carries the PIC microcontroller, the power supply components and the test voltage selector switch.

You'll even be able to get an idea of the IGBT's gate threshold voltage $V_{GE(TH)}$, by using the MOSFET I_D vs V_{GS} test and finding the gate voltage where I_D (corresponding to the IGBT's collector-emitter current I_{CE}) begins rising from its I_{CES} 'off' level.

Testing SCRs and PUTs

The fourth main type of discrete semiconductor device that the *SemTest* is capable of testing is thyristors or silicon-controlled switches (SCSs) – in particular, SCRs (silicon-controlled rectifiers) and PUTs (programmable unijunction transistors).

Note that another name for an SCR is a cathode-gate SCS, while a PUT is more accurately described as an anode-gate SCS. They are both *PNPN* devices, and similar apart from the different gate connections. So, in that sense they are essentially just two different 'flavours' of SCS devices, like *NPN* and *PNP* bipolars or *N*-channel and *P*-channel MOSFETs.

As a result, the circuitry needed for testing SCRs and PUTs is not all that different from that needed for BJTs, as can be seen from the simplified circuit shown in Fig.4.

Despite its simplicity, this circuit allows the following measurements to be carried out on SCRs and PUTs:

(1) $V_{(BR)AKS}$ – the breakdown voltage for an SCR, with its gate tied to the cathode and a source of high voltage (BV) applied between anode and cathode via the usual current-limiting resistor R_{SERIES}

(2) $V_{(BR)AKS}$ – the breakdown voltage for a PUT, in this case with its gate tied to the anode and the high voltage (BV) applied between anode and cathode, again via R_{SERIES}

(3) I_{AKS} – the anode-cathode current for either an SCR or a PUT, with its gate tied to either the cathode (SCR) or anode (PUT), and with any selected operating voltage (OPV) applied between anode and cathode via a current-limiting resistor R_{SERIES}. In other words, the 'OFF' current of the device

(4) I_{AK} – the anode-cathode current for either an SCR or a PUT, with any selected operating voltage (OPV) applied between anode and cathode, and its gate connected to any of three sources of bias current: +50µA, +200µA or +1mA in the case of an SCR, or –50µA, –200µA or –1mA in the case of a PUT. These measurements allow you to gain a good idea of the device's triggering sensitivity

(5) V_{AK} – the anode-cathode voltage for either an SCR or a PUT when it has switched ON and is conducting. In other words, V_{AK} is the device voltage drop in its conducting state.

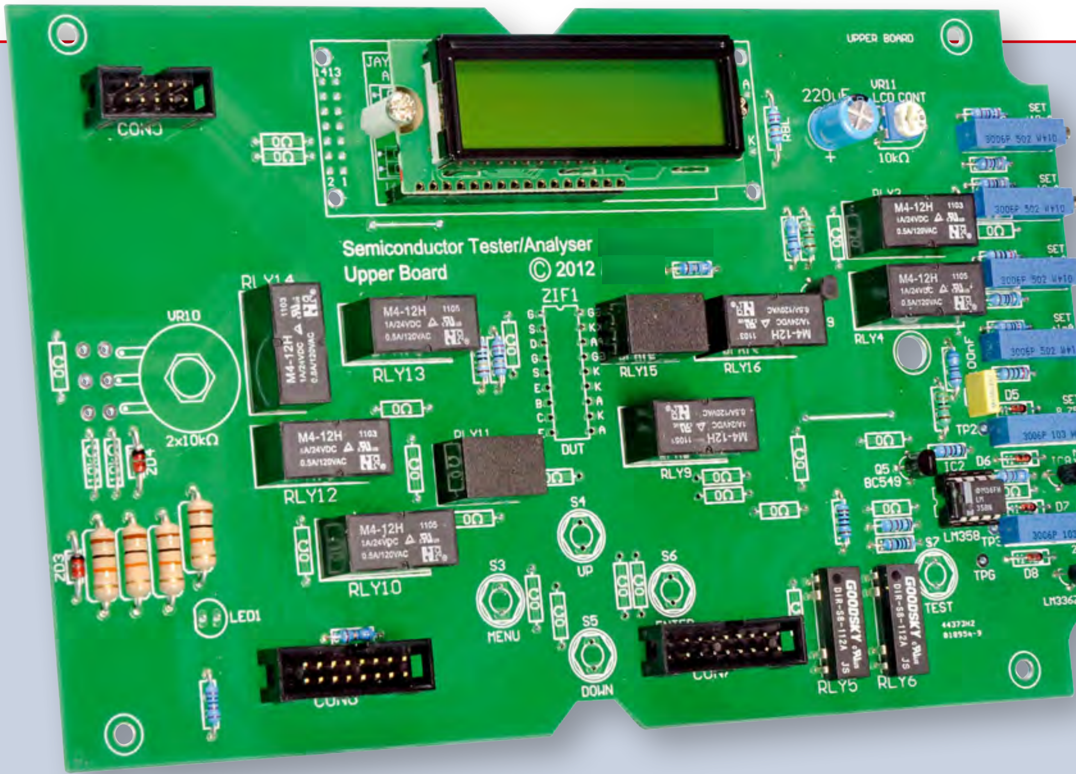
These measurements are really all that are needed to test and roughly characterise most PUTs and low-to-medium-power SCRs in general use. But please note that because of current limitations, the *SemTest* is *NOT* really capable of testing high-power SCRs – except in a basic 'shorted or open' sense.

Apart from anything else, the maximum gate bias current provided by the *SemTest* is only 1mA, which may not be enough to trigger a high-power SCR.

As shown in Fig.4, the device voltage and current measurement arrangements for SCRs and PUTs are exactly the same as for BJTs. The only real differences are with regard to gate switching, where RELAY15 controls the initial SCR/PUT switching and RELAY16 controls whether the gate is connected to the cathode (SCR) or anode (PUT), or to a bias current source (via RELAY5 or RELAY6, with the actual bias current level selected via RELAY3 and RELAY4).

Triac testing

Triacs are another common form of discrete thyristor device, more widely encountered than SCRs. They're used to control mains AC in many electrical appliances.



This view shows the partially-completed top board. It carries the LCD, the ZIF socket (not yet mounted) and most of the relays. It's connected to the bottom PCB via three IDC cables.

Because triacs are essentially gate-controlled AC switches, the only way to fully characterise their behaviour is in a tester which allows them to be tested under AC conditions. However, because a triac is very much like a pair of SCRs connected in inverse parallel, it's possible to use the *SemTest's* SCR/PUT tests to perform a full range of measurements on a triac.

For example, if you connect a triac to the *SemTest's* SCR terminals with its A1 electrode connected to the cathode terminal, its A2 electrode to the anode terminal and its gate to the gate terminal (where else?), you can do all the SCR tests described earlier, ie, $V_{(BR)AKS}$, I_{AKS} and I_{AK} for any of the three levels of $+I_{BIAS}$ and even $V_{AK(ON)}$. So you can give it a fairly thorough 'DC workout' in its main operating 'quadrant'.

If you then leave it connected in exactly the same way, but this time check it as if it were a PUT, you can thoroughly test it in a second quadrant. Finally, if you swap the A1 and A2 electrode connections so that A2 goes to the cathode terminal and A1 to the anode terminal, you will be able to test it in the other two quadrants, ie, by testing it again as an SCR and then as a PUT.

So, for a quick and dirty test, you just run the SCR tests on the triac for just one quadrant. If you want to test in the other three quadrants, you need to run the tests three more times, as just described.

The only limitation to this procedure is that the maximum gate bias current which the *SemTest* can provide is ±1mA, which, as with SCRs may simply not be enough to trigger high-power Triacs.

Summary

That should give you a good idea of the discrete semiconductor devices that our new *SemTest* is capable of testing and measuring. Next month, we will present the full circuit details and start the construction.

Standby for supercapacitors

TechnoTalk

Mark Nelson

Do you remember when lithium batteries were a novelty, combining hefty capacity with an amazingly long life? Well, it's time for lithium cells to step aside, as a new contender enters the arena. Mark offers a roadmap on energy storage trends, together with some advice on your consumer rights.

Batteries take a battering

WITH the growing amount of electronic gadgetry in our homes, you'd think we'd be buying more batteries. Not so, says leading market research company GfK, citing static sales and little likelihood of change any time soon. What's more, despite the focus on recycling and greater energy-efficiency, sales of rechargeable cells have not increased.

But there's another reason why we might soon be buying fewer batteries. What's more, it's a genuine 'disruptive technology' that goes by the name of 'supercapacitors'. These devices are not new by any means, but their plunging price definitely is. Back in 2001, a three kilofarad capacitor cost US $5,000 and now its cost is below $50.

Their relatively high energy/density is what makes them such excellent energy storage devices; it is also the reason why they are not employed as general-purpose electronic components, but specifically for energy storage, effectively a kind of rechargeable battery.

Up till now, applications for super-capacitors have been in 'energy smoothing' and high momentary-load situations, for instance in vehicles and home solar energy systems, where extremely fast charging is a valuable advantage. But all this is about to change with the burgeoning growth of multifunctional portable devices — not merely mobilephones that handle Internet, navigation, email and playing videos, as well as making phone calls and sending texts, but also Android-based cameras with Wi-Fi Internet capability.

Springtime for supercapacitors

Common to all these gadgets are power requirements that vary over time, with rechargeable batteries sufficing for some functions and separate lithium batteries handling occasional peak power rushes. Lithium cells boast good energy/density qualities, but they have the disadvantage that their 'energy content' is reduced significantly if you need to extract the energy quickly.

Supercapacitors do not suffer from this drawback and can deliver a considerable amount of energy at high power, enabling them to handle the particular tasks in which lithium batteries underperform. In comparison with rechargeable batteries, they endure higher number of cycles, can be charged and discharged a hundred times faster and can reach 20 years of useful life, since their performance does not suffer from the same degradation processes of rechargeable batteries.

All this means that supercapacitors are starting to stake out their own territory in the energy storage landscape. Prices have not yet fallen to bargain basement levels by any means, but as we buy more multifunction devices, a mass market for supercapacitors will emerge. By the end of this decade, up-front, costs will be far more competitive. The emphasis here is on the words 'up-front' because with a useful life of 20 years, the true lifetime cost of ownership is already attractive for critical applications.

If you cast your mind back to the time when lithium cells were exotic and expensive, the notion that they would one day be sold in convenience stores was unthinkable. There is no reason why this should not happen with supercapacitors.

Consumer rights conundrum

Buying electronic goods should be a pleasure, not a contest. But when your purchase ends in dispute, should your loss be the supplier's gain?

It all boils down to consumer rights, a subject on which few of us are experts. For this reason, the Office of Fair Trading is running a campaign to give consumers a better understanding of their rights, and how to take action if something goes wrong. You can find their website at: **www.oft.gov.uk/OFTwork/consumer-protection/campaign11-12/kycr/**

Before you dash off to see their tutorials, test your knowledge by giving your verdict on these three scenarios.

1. Your son's birthday is coming up and he's just as keen on electronics as you. As you are ordering some components for your own projects online, you include a soldering iron that will be his present. The company operates walk-in stores as well as the website, on which it says that goods can be returned to their stores.

So far so good. Unfortunately, your son has been dropping hints rather too freely, with the result that on his birthday he receives two irons: one from you and one from his uncle. The iron you bought online is now redundant, but when you visit one of the supplier's shops to hand it back, they tell you that they return money only when the customer has a right to a refund — for example, where the item is faulty and does not conform to contract. Do they have to give you a refund?

Yes. If their online terms and conditions state without further qualification that goods ordered online can be returned in-store, then they have to deal with your return.

2. As a freelance circuit developer your oscilloscope is a vital tool, so vital that when it dies you buy a replacement immediately at the local electronics superstore. Annoyingly, you need to return it a week later, because the display flickers off and on when you tap or jog the new 'scope. They accept that it's faulty, but they have no more of this model in stock and are not expecting a delivery until next week.

You need a 'scope immediately and demand they let you have a more expensive one as it's their fault, not yours, and you fulfilled your part of the bargain by paying for what you wanted and by returning it in good time. Do you leave the shop with the de luxe model?

No. Although the device was not of merchantable quality and you returned it in good time, the vendor is not obliged to give you a more expensive substitute (the legal term for this is 'betterment'). Your only entitlement is either a full refund or else a repair/replacement made in reasonable time.

3. You fancy an Android smartphone that is listed on a company's website, but when you place an order for it, they tell you they have run out of stock. However, they do have a different product that has nearly all of the same features, although it's not quite so compact. Are they allowed to send you this as a substitute?

Yes, they can send out substitute goods of equivalent quality and price if they explained in their pre-contract information that this might happen, and made it clear before you placed your order that they would meet the cost of returning the substitute product if you, the customer, did not want to accept it.

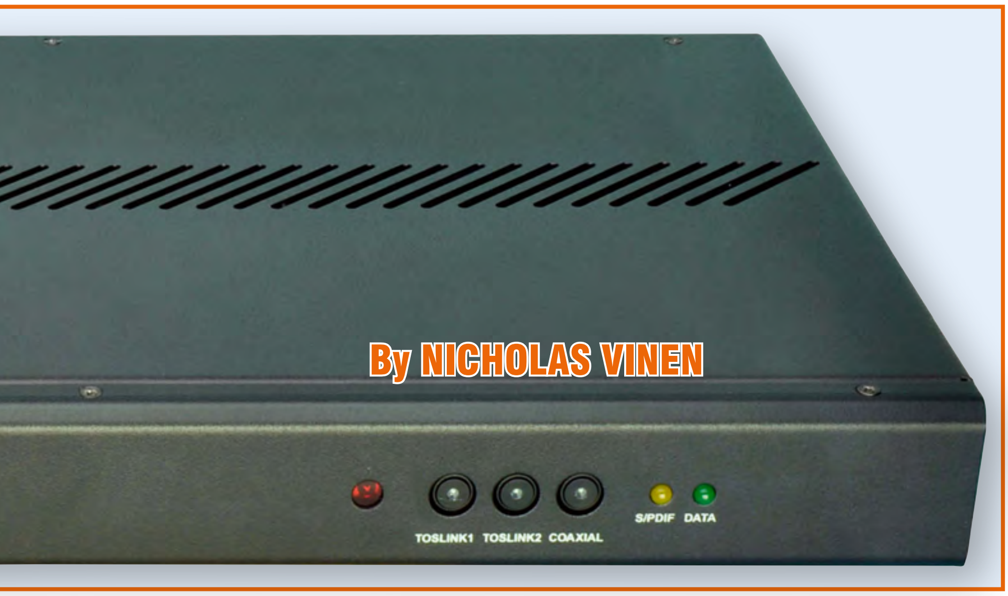
Crystal DAC

For the very best performance from 24-bit/96kHz recordings – uses the Crystal CS4398 DAC and a discrete transistor output stage

This new DAC board can be substituted for the original board used in our hifi Stereo DAC project (Sept-Nov '11) without any major changes, effectively replacing the Burr-Brown DSD1796 DAC IC with the high-end Cirrus Crystal CS4398.
Its harmonic and intermodulation distortion figures are significantly lower than before, although some people will have difficulty discerning the differences. Try it and find out for yourself.

THE INSPIRATION for this project upgrade came from the Marantz CD6003 CD player. Measurements using an Audio Precision System One analyser showed that it not only had a very low harmonic distortion figure for a CD player, but also, it was practically flat across the audible frequency band (20Hz to 20kHz).

We figured that this was partly due to its Crystal (Cirrus Logic) CS4398 DAC (digital-to-analogue converter) IC. This is mounted on a large PCB, among a forest of discrete and passive components. So we thought, hmmm . . . could we do something similar for our DAC design? We suspected Marantz were also doing some fancy digital processing using a



By NICHOLAS VINEN

DSP (digital signal processor) to get that level of performance, but that the CS4398 DAC must also be pretty good for such an excellent result.

New board

It turns out we were right on both counts. The CS4398 is very good, but Marantz seem to be doing some digital interpolation (possibly increasing the sampling rate to 96kHz or 192kHz) to keep the distortion so low. While our new DAC board does not have the benefit of digital interpolation, it is clearly superior to the previous design, especially when processing 24-bit/96kHz program material.

If you have already built the *Stereo DAC* project and would like to try out this new board, it's pretty easy. You just build the new PCB and swap it for the old one. We've designed it so that it's the same size and the critical parts are in the same locations. You then reprogram or swap the microcontroller on the input board, and Bob's your uncle.

Like the Marantz, we designed the filtering hardware using all discrete components (ie, bipolar transistors and passives).

There was some controversy on the Internet (unheard of!) over our choice of op amps in the original *Stereo DAC* design (*EPE*, Sep to Nov '11). This time, we have avoided using those 'evil' little black boxes, which should make the extreme audiophile cognoscenti happy.

The resulting circuit has a lot more components than it would if we had used op amps, but they are all cheap and commonly available. The resulting wide bandwidth compared to an op amp means that the output filtering works very well.

Performance

We tested both the original and new *Stereo DAC* designs extensively, using an Audio Precision System One analyser and the newer Audio Precision APx525 with digital processing. We also performed numerous listening tests, including blind A/B tests.

The first result that became clear from all this testing is that the original design really is very good. Its distortion and noise are low (including intermodulation distortion), its linearity is very good and it generally sounds excellent. However, the new *Stereo DAC* design measures even better, with lower distortion (especially at high frequencies), even lower intermodulation distortion and astounding linearity down to –100dB.

A comparison of the harmonic distortion between both channels of the original and the new *Stereo DAC* design is shown in Fig.1. These tests were performed on the same unit with just the DAC boards swapped, so they give an 'apples-to-apples' comparison.

Note that noise has been digitally filtered out of this measurement completely, for a couple of reasons. First, both DACs have quite a bit of high-frequency switching noise in their output (but a lot less than some DVD and Blu-ray players we've tested). This can mask the distortion if we set the bandwidth wide enough to capture harmonics of high audio frequencies.

Second, the 20Hz to 20kHz residual noise of both the original and new boards are similar. This also means that a THD+N comparison would tend to understate the reduction in harmonic distortion obtained with the new design.

As you can see, harmonic distortion with the CS4398 is substantially lower than the original design, both at high frequencies (above 3kHz) and low frequencies (below 100Hz). The differences between channels are due to asymmetries in the PCB layout, as well as mismatches between the two channels within the DAC ICs themselves (eg, due to resistor ladder tolerances).

Fig.2 shows the channel separation for both units. The lines labelled 'left' show how much signal from the right channel couples into the left and the lines labelled 'right' show the opposite. In both cases, channel separation is very good and is generally better than –100dB across the audio spectrum. The older design is slightly better in this respect, although the difference is largely academic.

Fig.3 compares the linearity of both DACs. This plot shows the deviation between the expected and actual output level for a sinewave at a range of levels between –60dB and –100dB. Both DACs perform extremely well in this test, but the CS4398 is especially good, with a maximum deviation of no more than 0.25dB at –100dB. Its deviation is essentially zero above –84dB, while the DSD1796 still shows some deviation up to –70dB.

Note that all of the above test results were obtained with the Audio Precision APx525 (which can test in the analogue or digital domain) using 24-bit 96kHz signals fed into a TOSLINK input of the *Stereo DAC* project.

Frequency spectra

The FFT frequency spectra for the updated *Stereo DAC,* with one channel in magenta and the other in khaki, is shown in Fig.4. This was computed with a one-million sample window, an equi-ripple algorithm and 8x averaging. The test signal is at 1kHz and the bandwidth is 90kHz.

The harmonics of the test signal are clearly visible at 2kHz, 3kHz and so on. Also visible is some 50Hz and 100Hz mains hum at around –120dB, as well as various intermodulation products of this hum with the fundamental and its harmonics.

Performance graphs

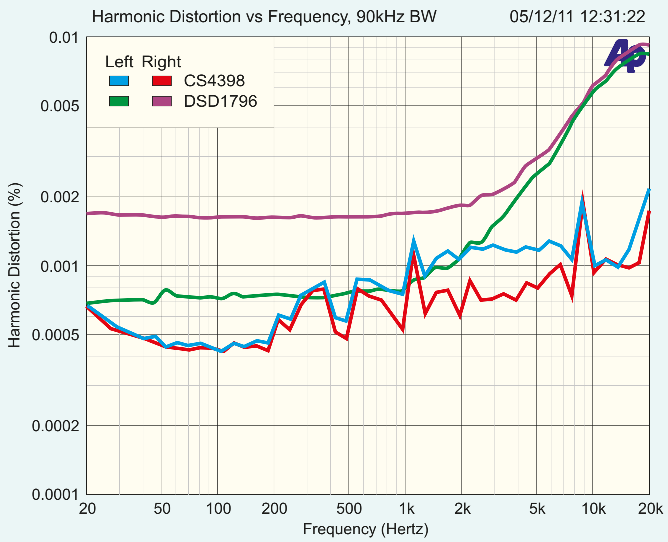


Fig.1: harmonic distortion (ignoring noise) versus frequency for the original (DSD1796-based) and new (Crystal CS4398-based) DACs. The new design has lower distortion overall, but especially above 2kHz. The channels differ slightly due to layout asymmetries and differences in the ICs themselves. The spikes at 1.2kHz and 9kHz are due to aliasing between the test and sampling frequencies.

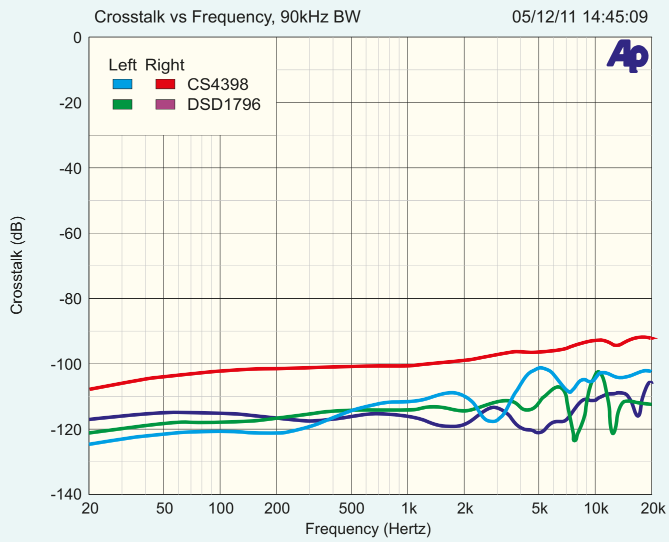


Fig.2: a comparison of channel separation (ie, crosstalk) for the original and new DAC boards. The original is slightly superior, but both are very good, with less than –93dB crosstalk at any frequency and separation of at least 100dB up to 1kHz. As is typical, there's more coupling in one direction (for the new design, left channel to right channel) than the other, again mainly due to asymmetry.

As we said earlier, both DACs are very good, but the updated design generally has better figures. We also ran the SMTPE intermodulation distortion test on both. This involves sending a 4:1 mix of 7kHz/400Hz sinewaves to the test device. These frequencies are then filtered from its output (400Hz with a high-pass filter, 7kHz with a notch filter) and the remaining harmonics measured. These will generally be the sum and difference frequencies of 6.6kHz and 7.4kHz, but possibly other harmonics too.

The old design gives an intermodulation distortion level of around 0.0018% (–95dB), while the new design gives 0.0006% (–105dB); a significant improvement.

Listening tests

The results of our listening tests were somewhat controversial. We used our *20W Stereo Class A Amplifier* (Oct 2008 – Feb 2009), a much earlier speeker project and the *3-Input Selector* presented last month, which was used to switch between the two *Stereo DAC* prototypes. The original prototype was set to a volume of –0.5dB and the levels matched almost perfectly, giving seamless switching between the two.

The two DACs were fed with digital audio from a Blu-ray player with separate TOSLINK and S/PDIF outputs.

Some 'subjects' could not tell the difference in sound quality between the two DACs, while others claimed to be able to hear a distinct difference between the two on certain passages, although the difference was not obvious on other passages. With complex choral music, two of the 'guinea pigs' were able to pick the updated DAC as sounding 'brighter'. On other types of music, a difference could be discerned, but we could not reliably pick which DAC we were listening to.

You'll have to make your own mind up about whether the new design gives an audible improvement. However, we can be certain that this upgraded DAC design gives far superior performance compared to virtually any CD, SACD, DVD or Blu-ray player on the market. And for those people who think that Blu-ray players are generally superior in terms of sound quality, our limited tests demonstrated that this is not necessarily true. Cheap Blu-ray players are just that – cheap!

Circuit description

The full circuit diagram for the new Crystal DAC board, is shown in Fig.5. IC1 is the CS4398 DAC chip, and this is wired to 16-pin IDC socket CON1. Its configuration is identical to that of the original DAC board, carrying the 3.3V supply from the control board, as well as audio data (pins 4, 6, 8 and 10) and serial control data (pins 7, 9, 11 and 13). There are also two mute feedback lines (pin 15 and pin 16), allowing the micro to sense output silence.

IC1 has a dual 3.3V and 5V power supply with multiple supply pins for each internal section. Both rails have 100µF bulk bypass capacitors. Each supply pin also has a 100nF bypass capacitor for lower supply impedance at higher frequencies (>100kHz).

VLS (pin 27) is supplied 3.3V to suit the audio serial data levels, while VLC (pin 14) is at 5V to match the microcontroller's I/O levels. To avoid switching noise feeding back into the 5V rail, which also powers analogue circuitry, a 100Ω stopper resistor is included.

VD (pin 7) is the supply pin for the DAC's digital core (digital filtering and so on). This runs off 3.3V, while the internal analogue circuitry (eg, op amps) runs off a 5V rail connected to VA (pin 22). This 5V rail is also fed separately to V_{REF} (pin 17) for the DAC reference voltage. Capacitors at FILT+ (pin 15) and VQ (pin 26) smooth IC1's internal reference voltages.

VQ is the quiescent output voltage and generally sits at half supply (ie, 2.5V). We aren't using the DSD (direct

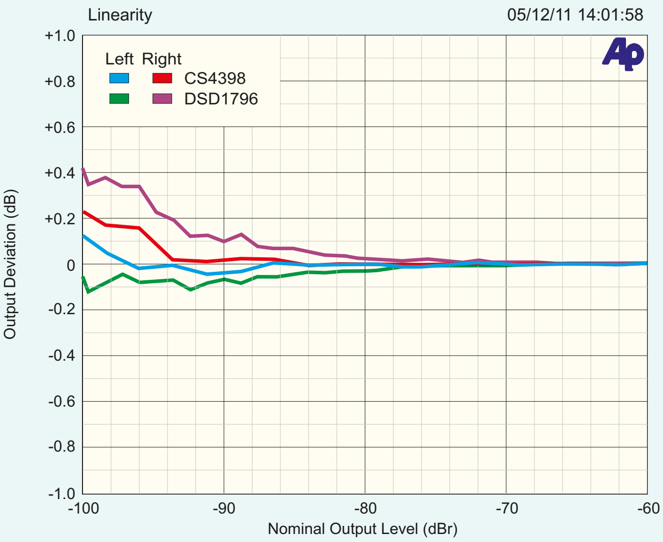


Fig.3: a comparison of the linearity of the original and updated DAC boards. Delta-sigma DACs typically have good linearity and in fact both are excellent. However, the updated board (with the CS4398) is the best of the two, with an astounding deviation of less than one quarter of a decibel at levels down to –100dB! (The dynamic range of CD-quality audio is just 96dB).

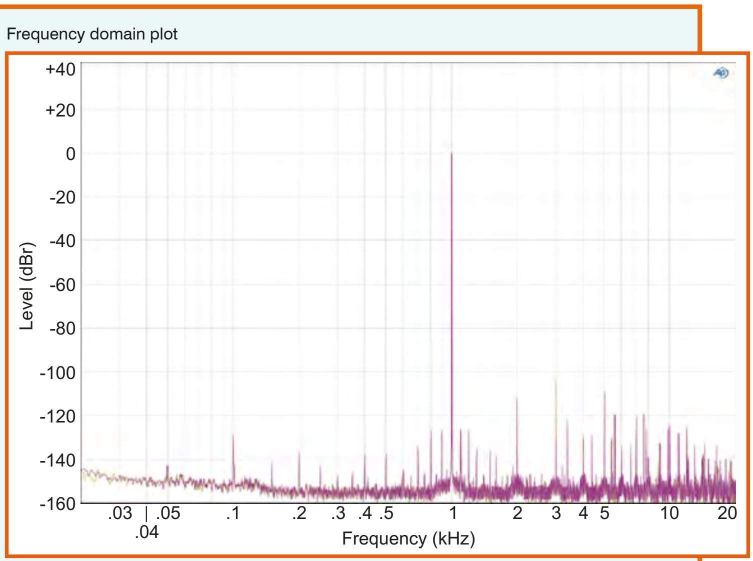


Fig.4: a frequency domain plot (ie, spectrum analysis) of the output of the updated DAC for a 1kHz sinewave. Eight FFTs were averaged to reduce noise. The harmonics are clearly visible at multiples of the fundamental (2kHz, 3kHz, etc) as well as mains hum at 100Hz. You can also see the various intermodulation products of the fundamental and its harmonics with 100Hz.

stream digital) input pins on the IC, so they are tied to ground.

The microcontroller's serial I/O pins connect to header CON1 via links LK1 to LK4. These are closely-spaced pads on the bottom of the PCB which can be bridged with solder. The CS4398 can operate without a microcontroller, and to do so, pin 9 to pin 12 are connected to either ground or VLC (+5V).

This arrangement allows those pins to be connected to configure the DAC correctly, even in the absence of a microcontroller. However, if this is done, many features of this design do not operate properly, such as volume control, automatic input scanning and muting. As a result, we suggest that constructors simply bridge LK1 to LK4 and reprogram the micro with the new software. All the features of the original design will then work normally.

Analogue filtering

The DAC IC we used previously (Burr Brown DSD1796) has differential current outputs, while the CS4398 has differential voltage outputs. That means we no longer need current-to-voltage converters; they are internal to IC1. However, we still need to filter the outputs to remove the DAC switching noise and convert the differential (balanced) signals to unbalanced, to suit the inputs of a typical amplifier.

We have used the recommended filter, a two-pole Butterworth low-pass arrangement, consisting of six resistors and five capacitors for each channel. These are shown just to the right of IC1.

The operation of this filter is quite complicated, since the two *RC* filters for each channel interact with each other. Let's look at the left channel; the right channel circuit is identical. The non-inverted output from IC1 comes from pin 23 (AOUTA+) and the inverted signal from pin 24 (AOUTA–).

The waveforms from each pin are (theoretically) identical but opposite in polarity; ie, one swings up when the other swings down, and *vice versa*. Both signals are attenuated, with a gain of around 0.45, by a pair of resistive dividers. While the division ratios are very similar, the actual resistor values differ: 620Ω/510Ω for the non-inverted signal and 1.6kΩ/1.3kΩ for the inverted signal.

These resistors also form single-pole, low-pass filters, in combination with the 18nF (non-inverted signal) and 6.8nF (inverted signal) capacitors. The attenuating resistors are effectively in parallel with each other, for a –3dB point of around 32kHz in both cases.

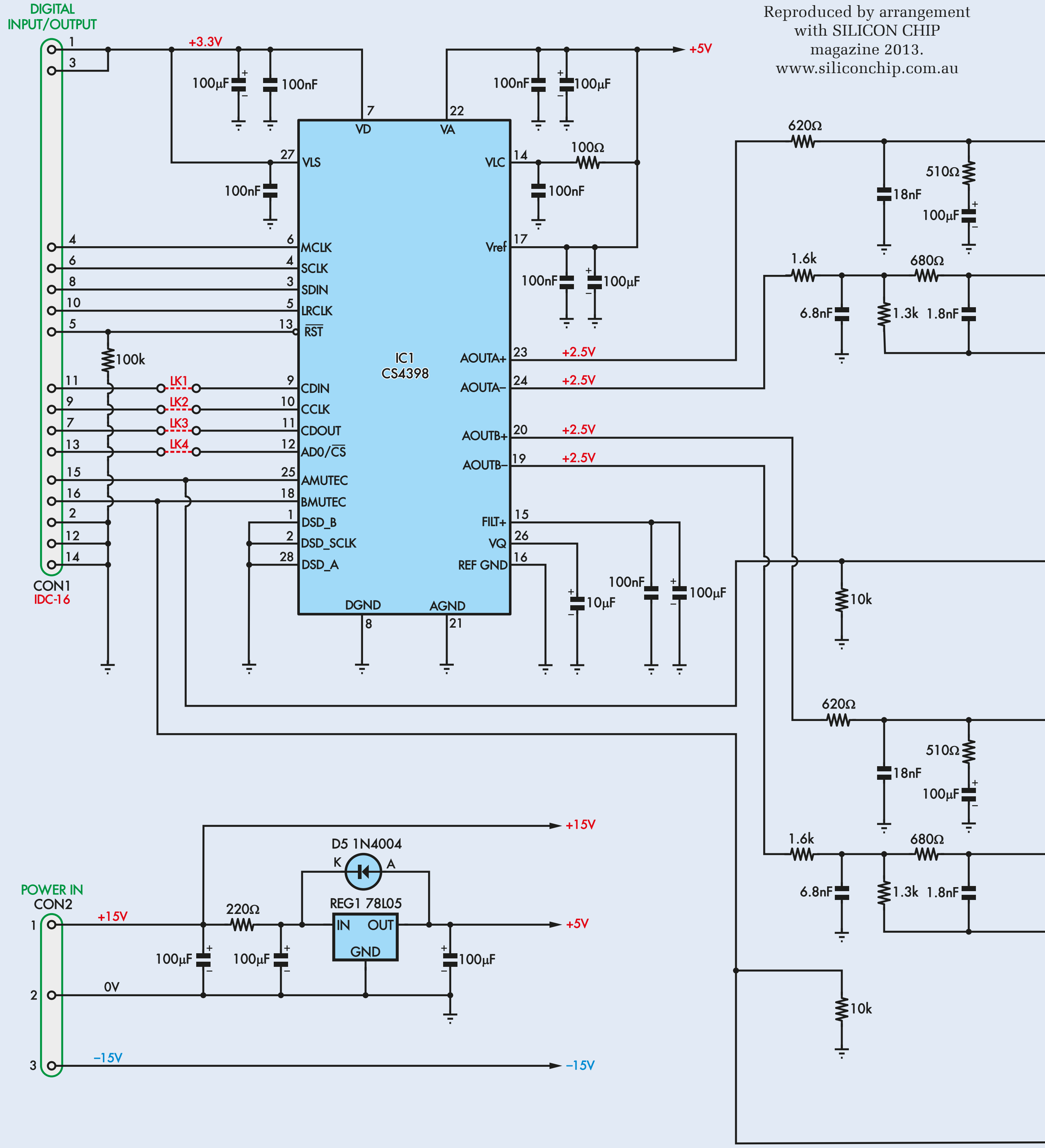
These are then followed by another set of *RC* low-pass filters – 270Ω/4.7nF for the non-inverted signal, and 680Ω/1.8nF for the inverted signal. In isolation, these have corner frequencies of around 130kHz.

Note that the bottom ends of the 1.3kΩ resistor and 1.8nF capacitor are connected to the output of the following differential amplifier, rather than ground. Because the output is out of phase with the inverted signal from pin 24 of IC1, this acts like a virtual ground. So there is twice the voltage across these compared to the non-inverted signal filter, hence the higher resistance values (keeping the current from each output approximately equal).

The overall filter response (determined by simulation) is –3dB at 45kHz, which is above the 30kHz or so you would expect if the filters operated in isolation. This is partly due to their interaction, and also partly due to the connection from the differential amplifier's output to the inverting signal filter. As we said earlier, it's complicated!

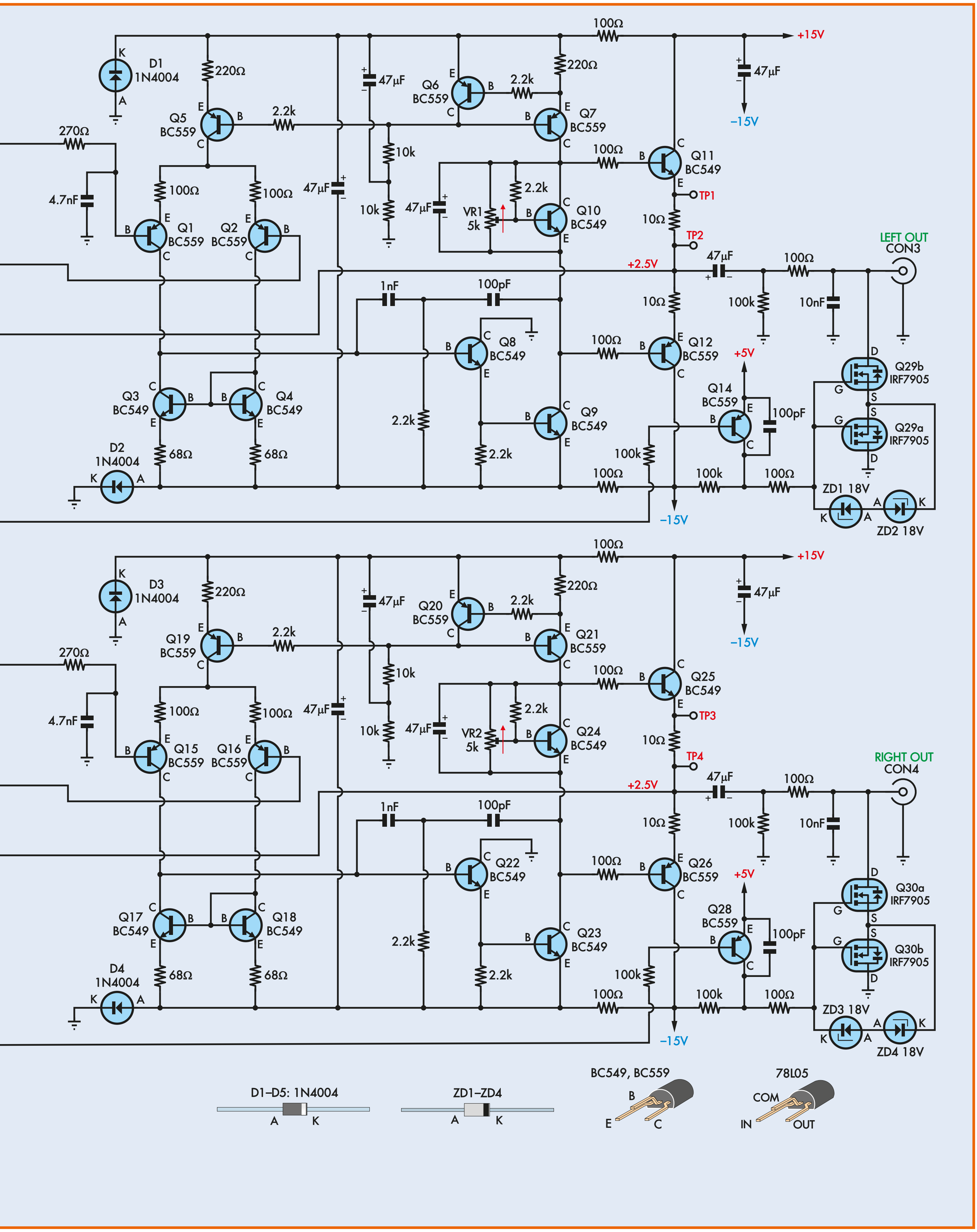
The resulting response is –0.1dB at 20kHz. Including the DAC's internal filtering and the additional filtering at the output, the overall response for the circuit is –0.25dB at 20kHz, which is quite acceptable.

The active filter gives around 13dB of attenuation at 100kHz, increasing



STEREO CRYSTAL DIGITAL-TO-ANALOGUE CONVERTER

Fig.5: the circuit is based on a Cirrus Logic (Crystal) CS4398 stereo DAC chip (IC1). This has differential outputs (pins 23 and 24, and pin 20 and 19) which drive discrete audio output stages based on transistors Q1 to Q12 in the left channel and Q15 to Q26 in the right channel. Q14, Q28 and dual N-channel MOSFETs Q29a-b and Q30a-b mute the outputs when there is no signal from the DAC. Power comes from an external ±15V supply, with REG1 providing a +5V rail for IC1.



+15V
–15V
100Ω
220Ω
47μF
D1
1N4004
Q5
BC559
2.2k
Q6
BC559
Q7
BC559
270Ω
4.7nF
100Ω
Q1
BC559
Q2
BC559
10k
VR1
5k
Q10
BC549
Q11
BC549
TP1
10Ω
TP2
+2.5V
LEFT OUT
CON3
1nF
100pF
100k
10nF
Q8
BC549
Q12
BC559
+5V
Q29b
IRF7905
Q3
BC549
Q4
BC549
Q14
BC559
Q9
BC549
Q29a
IRF7905
68Ω
D2
1N4004
ZD1 18V
ZD2 18V
D3
1N4004
Q19
BC559
Q20
BC559
Q21
BC559
Q15
BC559
Q16
BC559
VR2
5k
Q24
BC549
Q25
BC549
TP3
TP4
RIGHT OUT
CON4
Q22
BC549
Q26
BC559
Q30a
IRF7905
Q17
BC549
Q18
BC549
Q28
BC559
Q23
BC549
Q30b
IRF7905
D4
1N4004
ZD3 18V
ZD4 18V
D1–D5: 1N4004
ZD1–ZD4
BC549, BC559
78L05
COM
IN
OUT

at around 12dB/decade. This is ultimately limited by the bandwidth of the differential amplifier circuit, and so the filter is ineffective at very high frequencies (many MHz).

This means that the 1.8nF capacitor in the filter network can couple very high frequencies through to the output, but their level is too low to cause problems.

Discrete op amps

We noted earlier that we have used discrete transistors in this circuit, instead of op amp ICs.

Again referring to the left channel only, the base of *NPN* transistor Q1 is the non-inverting input of the differential amplifier, while the base of Q2 is the inverting input. Both transistors have 100Ω emitter-degeneration resistors to improve linearity.

Transistor Q5 (*PNP)* acts as a constant current source for the long-tailed pair, and this is set to around 3mA by a 220Ω resistor. *NPN* transistors Q3 and Q4 form a current mirror collector load, with 68Ω emitter resistors to improve current sharing.

The current into the base of *NPN* transistor Q8 is proportional to the difference in voltage between the two inputs (ie, between the bases of Q1 and Q2). Q8 and *NPN* transistor Q9 act as a beta-enhanced transistor (like a Darlington) and operate as a common-emitter amplifier. *PNP* transistor Q7 acts as a constant-current collector load at around 3mA.

Together, Q8 and Q9 form a trans-impedance amplifier, converting the current delivered to the base of Q8 into a voltage at Q9's collector. This voltage controls the output stage, which consists of transistor Q11 *(NPN)* and transistor Q12 *(PNP)* in a push-pull, emitter-follower configuration.

Transistor Q10 *(NPN)* forms a V_{BE} multiplier. This generates an adjustable bias (set by trimpot VR1), so that both Q11 and Q12 are conducting full time, giving Class A operation.

The 100pF and 1nF capacitors between Q9's collector and Q8's base provide frequency compensation. The two constant-current sources (Q5 and Q7) limit their charge and discharge currents, and so set an upper limit on slew rate and frequency, reducing gain at very high frequencies below the level required for sustained oscillation.

With this 2-pole compensation scheme, the 2.2kΩ resistor to the –15V rail increases the open-loop gain available at higher audio frequencies. At low frequencies, this resistor shunts much of the current passing through the 100pF capacitor so that it never reaches Q8's base, but at much higher frequencies, the capacitor's impedance is so low that it has no effect.

Transistor Q6 *(PNP)* provides the bias and negative feedback for current sources Q5 and Q7, keeping the voltage across their emitter resistors constant. Its own collector load is a bootstrapped constant-current sink formed from two 10kΩ resistors and a 47µF capacitor. This prevents variations in the supply rail from affecting the current regulation, as this would increase inter-channel crosstalk and reduce supply hum rejection.

The signal output appears at the junction of the 10Ω emitter resistors for Q11 and Q12. The output voltage has a 2.5V DC offset, which is removed by a 47µF DC-blocking capacitor with a 100kΩ bias resistor. The audio signal then passes through an additional *RC* low-pass filter (100Ω/10nF) before passing to the output RCA phono connector CON3 (CON4 in the right channel).

Since the output signal swing is about ±2.7V (1.9V RMS), the 100Ω resistor limits the short-circuit output current to 27mA. Otherwise, Q11 or Q12 would quickly burn out with a shorted output.

Muting

As suggested in the CS4398 data sheet, we have added muting circuitry to the outputs. This consists of a dual MOSFET for each channel, the MOSFETs operating as analogue switches. These short the output to ground when there is no signal from the DAC.

This suppresses any clicks or pops that may occur when the sample rate changes, or the DAC selects a different input and so on. It also makes the apparent signal-to-noise ratio appear to be better, by reducing the idle channel noise. But it doesn't actully affect the actual signal-to-noise ratio during playback, since the muting MOSFETs are then switched off.

These components are not strictly necessary, but don't add much cost or complexity to the circuit.

The example circuit in the CS4398 datasheet uses 2SC2878 *NPN* transistors rather than MOSFETs. These are a special type of bipolar transistor with an unusually high reverse h_{FE} of 150, compared to around 1-2 for a normal *NPN* transistor. So they can operate normally even with their collector and emitter reversed; in this case, when the collector voltage (ie, signal) swings below ground.

The 2SC2878 transistors are available but not widely so. By contrast, the dual MOSFETs we have used instead can be bought from many different sources.

The CS4398 DAC automatically determines the polarity of its AMUTEC and BMUTEC outputs (for the left and right channels, respectively) based on the external biasing arrangement. In this case, they have a resistive path to ground and so the chip drives them low to mute, and high otherwise.

When the mute output is low, current is sunk from the base of transistor Q14 *(PNP)* via the 100kΩ resistor, turning it on. Q14 then pulls the gates of Q29a and Q29b high to 5V via a 100Ω resistor. The 100Ω resistor creates a low-pass filter with the MOSFET gate capacitance, preventing voltage spikes due to stray inductance.

Features and specifications

Output level	1.9V RMS
Signal-to-noise ratio	–112dB
Idle channel noise	<–124dB
Channel separation	~100dB @ 10kHz (see Fig.2)
Harmonic distortion (see Fig.1)	<0.001% @ 1kHz, <0.002% 20Hz-20kHz
THD+N	0.0014% @ 1kHz
Intermodulation distortion	<0.001% (400Hz/7kHz 4:1)
Frequency response	–0.25,+0.05dB 20Hz-20kHz
Supported sampling rates	32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz

The two MOSFETs in each pair are connected source-to-source, with one drain connected to the output and the other to ground. As a result, the two parasitic body diodes are connected anode-to-anode so that regardless of the output signal voltage polarity, at least one is reverse-biased. If we had used a single MOSFET instead, the signal would be clipped to within one diode drop to ground when the body diode was forward-biased.

These diodes also clamp the sources of both MOSFETs to no more than 1V above ground. So when the gates are at +5V, both MOSFETs have a gate-source voltage of at least +4V. The on-threshold for the IRF7905 is no more than 2.25V, so they are turned hard on in this situation, shorting the output to ground.

When the AMUTEC mute output goes high, Q14 turns off, and so the gates of Q29a and Q29b are pulled to –15V via a 100kΩ resistor. This is well below the lowest output signal voltage of –2.7V, and so both MOSFETs switch off and the signal is unaffected.

When off, the MOSFETs do have some capacitance, due mainly to the drain-source capacitance which is at a maximum of about 350pF when the drain-source voltage is zero. However, most of the time, the two capacitances are in series and so there is effectively no more than 200pF additional capacitance at each output. This is swamped by the parallel 10nF capacitors, and so has no effect on distortion.

A pair of back-to-back 18V Zener diodes between the gates and sources of each MOSFET protects them from damage in the case of a voltage spike or static discharge. Due to the low currents normally involved, the Zeners will conduct below 18V, clamping the gate-source voltages below the 20V maximum rating.

The 100pF capacitor between the emitter and collector of Q12 helps keep it on when power is first applied, preventing start-up clicks or pops. Q12 is then held on by the resistors between its base and ground until the DAC IC begins actively driving the mute outputs.

Power supply

The ±15V supply for the amplifier circuitry is provided by an external power supply board (as used in the original *Stereo DAC*), wired to CON2. This powers the output stages directly, while the rails feeding the input stages are applied via *RC* filters. These filters each comprise a 100Ω resistor in series with each rail, plus a 47µF capacitor between the two rails.

This improves the channel separation by preventing supply voltage variations to the input stages due to current demands from the output stages. Diodes D1 and D2 in the left channel, and D3 and D4 in the right channel prevent the 47µF capacitors from pulling either supply rail to the wrong side of ground during power-up or power-down.

The +5V supply is derived from the +15V rail using REG1. Diode D5 prevents REG1 from being damaged if the +15V rail collapses faster than the +5V rail. The associated input/output capacitors ensure regulator stability and reduce output noise, while the 220Ω resistor reduces dissipation in REG1 and helps filter any ripple from its input supply.

Building it

All the component parts are mounted on a double-sided PCB, code 886, measuring 94mm × 110mm. This board is available from the *EPE PCB Service*. Please note it is NOT a plated-through-hole board and will require 'vias' (top-to-bottom links) and some components soldering to both sides. The printed circuit board (PCB) component layout is shown in Fig.6. The DAC IC (IC1) should be fitted first. This device is in a 28-pin TSSOP (thin shrink small outline package) with a 0.65mm lead pitch and is installed on the underside of the PCB – see Fig.7.

That's done by first placing the PCB copper-side up, with IC1's pads to the left and right (ie, with the board rotated 90°). That done, apply a very small amount of solder to the upper-right pad with a clean soldering iron (use a medium to small conical tip).

Next, pick up the IC with tweezers and position it near the pads with the correct orientation (ie, with its pin 1 dot positioned as shown on Fig.7). That done, heat the tinned pad, slide the IC into place and remove the heat.

Now check its alignment carefully, using a magnifying glass if necessary. It should be straight, with all the pins over their respective pads and an equal amount of exposed pad on either side. If not, reheat the solder joint and gently

Parts list – Crystal DAC

1 double-sided PCB, code 886, 94mm × 110mm
1 16-pin PCB-mount vertical IDC connector (CON1)
1 3-way mini PCB-mount terminal block, 5.08mm pitch (CON2)
1 white PCB-mount switched RCA phono socket (CON3)
1 red PCB-mount switched RCA phono socket (CON4)
M3 nuts and flat washers (may be required to adjust new PCB height to suit holes in existing case)

Semiconductors
1 CS4398 Stereo DAC IC (IC1) (Element14 1023397)
1 ATMega48 programmed micro (or reprogram existing micro) – see software panel
2 IRF7905 dual N-channel SMD MOSFETs (Q29,Q30) (Element14 1791580)
1 78L05 5V linear regulator (REG1)
14 BC559 *PNP* transistors (Q1-Q2, Q5-Q7, Q12, Q14-Q16, Q19-Q21, Q26, Q28)
12 BC549 *NPN* transistors (Q3-Q4, Q8-Q11, Q17-Q18, Q22-Q25)
5 1N4004 1A diodes (D1-D5)
4 18V Zener diodes, 0.4W or 1W (ZD1-ZD4)

Capacitors
9 100µF 16V electrolytic
10 47µF 35V/50V electrolytic
1 10µF 16V electrolytic
6 100nF MKT
2 18nF MKT
2 10nF MKT
2 6.8nF MKT
2 4.7nF MKT
2 1.8nF MKT
2 1nF MKT
4 100pF NP0/C0G

Resistors (0.25W, 1%)

7 100kΩ	2 510Ω
6 10kΩ	2 270Ω
10 2.2kΩ	5 220Ω
2 1.6kΩ	17 100Ω
2 1.3kΩ	4 68Ω
2 680Ω	4 10Ω
2 620Ω	

2 5kΩ mini sealed horizontal trimpots

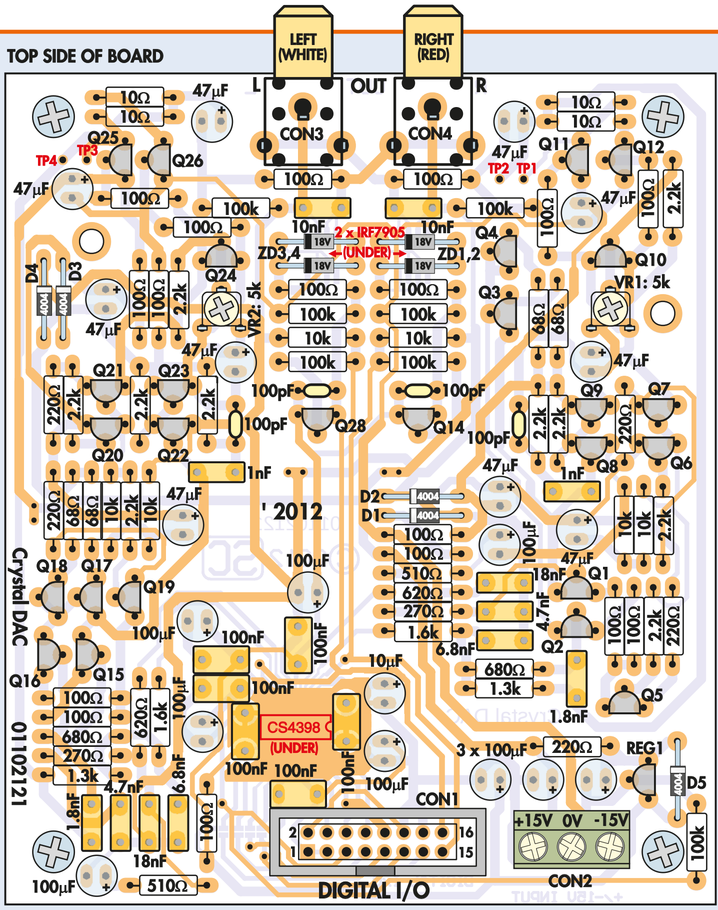
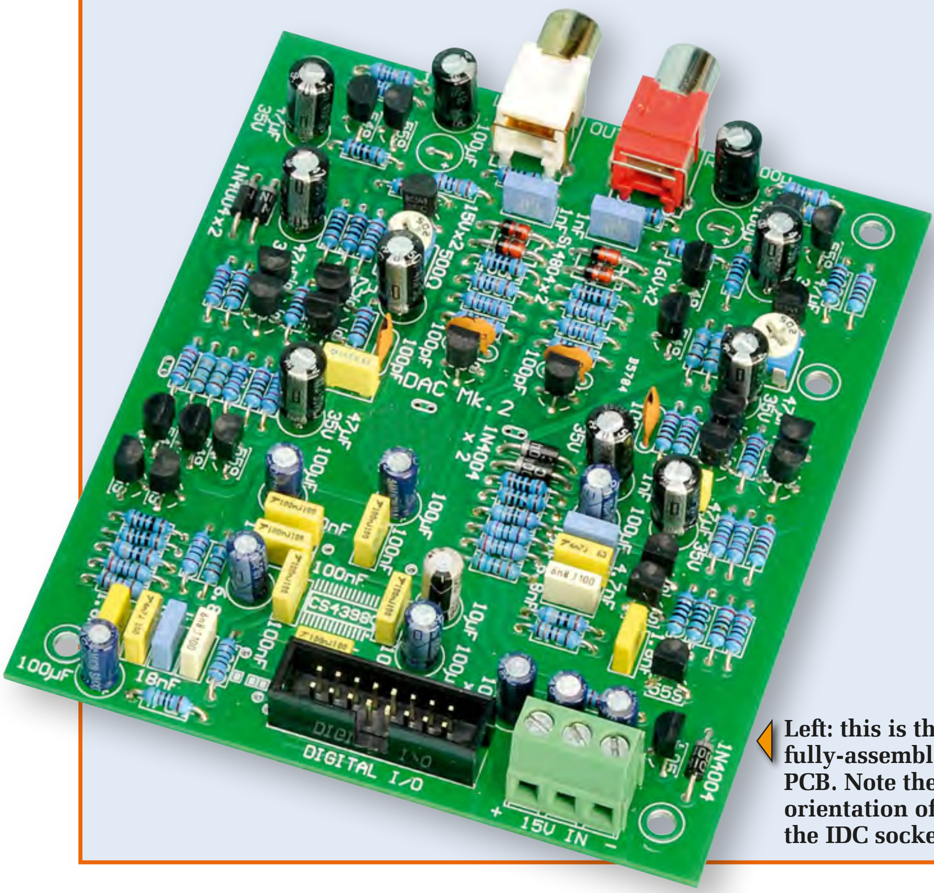


Fig.6: follow this layout diagram to install the through-hole parts on the PCB. Take particular care with the transistors. There are two different types (BC549 and BC559) – don't get them mixed up.



Left: this is the fully-assembled PCB. Note the orientation of the IDC socket.

nudge the chip in the right direction until its position is perfect.

The diagonally opposite pin should now be soldered, after which you can solder the remaining leads. Don't worry about solder bridges; they are virtually inevitable and can easily be fixed. The most important job right now is to ensure that the solder flows on to and between all leads and pads.

Once the soldering is complete, apply a thin smear of no-clean flux paste along the leads, then remove the excess solder using solder wick. Once the flux is heated to boiling point, this should happen quickly. Be sure to trim the end off the wick if it gets solder-logged.

You should now make a final inspection to ensure that there are no remaining solder bridges and that the solder has not 'balled' on to a lead without flowing on to its pad. If there are still bridges, clean them up with more flux and solder wick.

For further information on soldering SMD packages, refer to: *How to Solder Surface-Mount Devices*, July 2010.

MOSFETs Q29 and Q30 go in next. These are also SMDs, but they come in SOIC-8 (small outline integrated circuit) packages with much wider leads and greater pin spacing than the DAC chip. The leads can be soldered individually, although it's a good idea to add a small amount of flux paste and use solder wick to remove excess solder when you have finished. This also helps to reflow the solder, ensuring good joints.

Again, be extra careful with the orientation. The MOSFETs may not have a dot to indicate pin 1. Instead, SOIC packages normally have one bevelled edge and pin 1 is located on that side.

Links

The next step is to bridge the solder pads for links LK1 to LK4 (see Fig.7). This connects pins 9 to 12 of IC1 to CON1, and it's simply a matter of soldering across the four pairs of closely spaced pads. However, be careful not to bridge adjacent links or to bridge to the 0V and 5V pads on either side of the four links.

Note: if you want to test the board without reprogramming the microcontroller, leave these links open and connect pins 9 to 12 to either 0V or +5V, as detailed in the accompanying panel.

Through-the-hole

The larger through-hole parts can now be installed, starting with the resistors, diodes D1 to D5 and Zener diodes ZD1 to ZD4. Do check each resistor with a DMM before installing it, as some colours can be difficult to read. It's also a bit of a hassle to remove an incorrectly-placed part from a PCB.

If you do need to remove a resistor or diode, first cut the lead off one side, near the body. That done, heat the pad on the opposite side and gently pull the body until it comes away. Finally, grab the remaining lead with pliers, heat its pad and again pull it out.

Once the part is out, you can then clear the holes with a solder sucker. Other parts can be removed in similar fashion – cut away the body and then remove the leads one at a time.

Check that each diode (and Zener diode) is oriented correctly before soldering its leads. The 78L05 regulator (REG1) can now go in. Orient it as shown, and bend its leads with pliers to match the holes on the PCB.

Now for the transistors. There are two different types, BC549 *(NPN)* and BC559 *(PNP)*, so don't get them mixed up. Crank their leads so that they mate with their copper pads, then push them down on to the PCB as far they will comfortably go before soldering their leads.

Follow with the two horizontal trimpots, then mount the ceramic and MKT capacitors. That done, solder the electrolytic capacitors in place. These are all polarised, so be sure to orient them correctly.

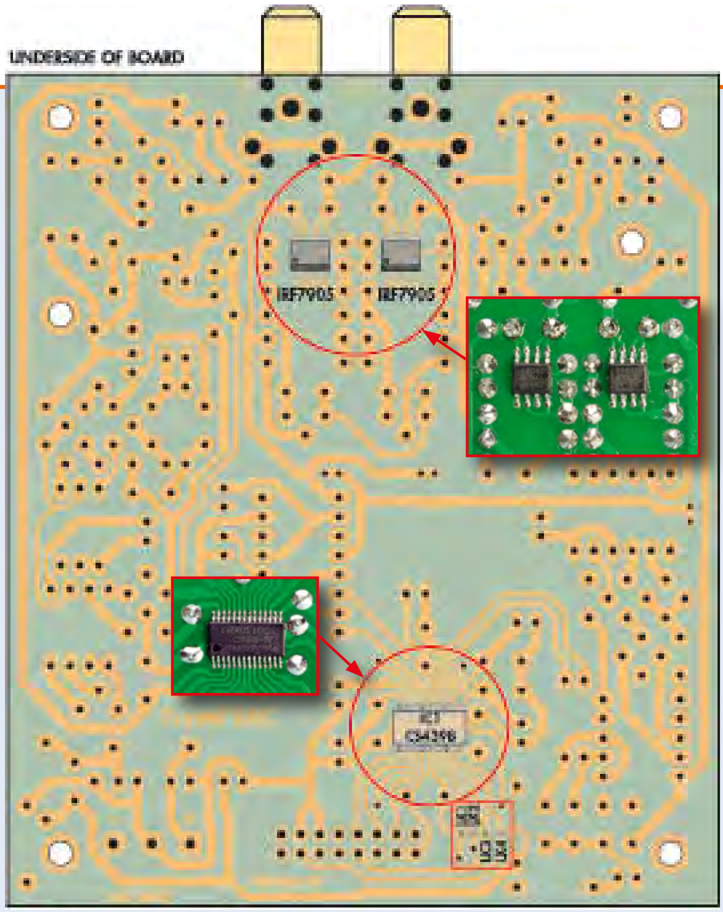


Fig.7: this diagram shows how the SMD parts are installed on the bottom of the PCB. Note that you also have to install solder bridges for links LK1-LK4, but temporarily leave these out if you want to test the completed board without reprogramming the microcontroller – see text and panel.

Making a connection

That just leaves the four connectors (CON1 to CON4). Make sure that the DC socket is installed with its notch towards the edge of the PCB and that it is pushed down fully before soldering its pins. It's best to solder two diagonally opposite pins first and check that it's sitting flat before soldering the rest. Similarly, terminal block CON2 must go with its wire entry holes towards the edge of the PCB and must be flush against the board.

Be sure also to push the RCA phono sockets down as far as they will go before soldering their pins. The red socket is mounted on the right-hand side, as shown on Fig.6, while the white (or black) socket goes to the left.

Chassis mounting

Once the assembly is complete, the PCB can be mounted in the chassis. Assuming you built you *Stereo DAC* from a kit, it's just a matter of removing the old DAC board and mounting the new one in its place (the mounting holes are in the same locations).

Note, however, that you may need to install some washers under the spacers to get the RCA phono sockets at the correct height. If so, install these between the spacers and the bottom of the case. **If you put the washers under the PCB, they could short some of the component leads to earth.**

The connectors are also in essentially the same locations, so the new PCB should slot straight into any case that's already in use for the original *Stereo DAC*.

Reprogramming the micro

You will now need to either reprogram the Atmel microcontroller on the Input PCB or replace it with a micro that has the new software. The hex file (**0110212A.hex**) is available for download from the *EPE* website. **If you don't have an Atmel programmer, you can purchase a programmed micro – see the blue software panel.**

Input board modifications

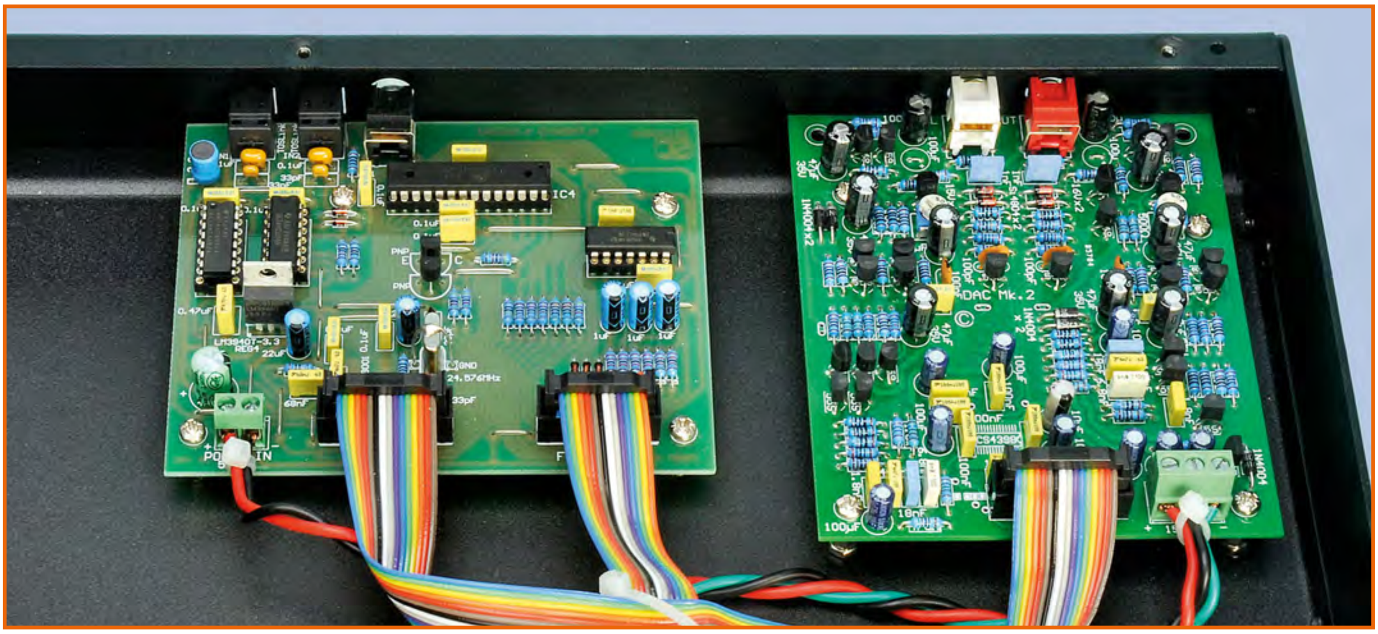
There are other changes we suggest you make to the input board. First, the original design had 33pF capacitors between each TOSLINK receiver's output and ground. These were recommended in the datasheet for the Jaycar ZL3003 16Mbps TOSLINK receivers we used originally. However, we subsequently found that these capacitors caused some TOSLINK receivers to oscillate under no-signal conditions.

At first, we recommended increasing the capacitor values to 100pF. The problem then was the TOSLINK inputs could no longer reliably receive data with a 96kHz sample rate. As a

Software

All software program files will be available from the *EPE* website at **www.epemag.com**.

Although we do not supply pre-programmed microcontrollers, you can purchase the programmed micro featured in this project from: **parts@siliconchip.com.au**



The new DAC Board (top, right) is a drop-in replacement for the older board. Be sure to connect both the I/O cable and the supply leads *before* applying power, otherwise you could damage the DAC chip.

result, we removed these capacitors altogether from our unit (there were no ill effects) and were then able to test it at 96kHz.

So, if you want to use the DAC with 96kHz data, first check that you have TOSLINK receivers capable of 16Mbps. The aforementioned Jaycar ZL3003. If you do swap them over, be sure to check that the link selecting 3.3V/5V operation is in the correct location.

You must then remove the 33pF (or 100pF) capacitors at the outputs of the TOSLINK receivers. While you are at it, be sure to change the 300Ω resistor across the S/PDIF input socket (CON1) to 82Ω.

Setting up and testing

The new DAC Board can now be tested, but first a warning: never apply power to the unit without both CON1 and CON2 (on the DAC board) wired up. If you do, you could damage IC1. Check also that the power supply polarity to CON2 is correct before switch-on.

Before switching on, turn trimpots VR1 and VR2 fully anti-clockwise, then back clockwise about a quarter of a turn. That done, apply power and check the voltage between test points TP1 and TP2 using a DMM. You don't need PC pins; just push the probe tips into the test point holes.

The reading should be below 10mV. If it's higher, switch off and check for faults. Also, check the voltage between TP3 and TP4; it should also be less than 10mV.

Assuming these readings are OK, monitor the voltage between TP1 and TP2 and slowly turn VR1 clockwise until you get a reading of about 20mV. That done, repeat this procedure by monitoring TP3 and TP4 and adjusting VR2.

This sets the quiescent current through the output transistors in each channel to around 2mA. That's sufficient for them to operate in class-A mode for any load of 1.3kΩ or more.

For lower load impedances or highly capacitive loads, the circuit will automatically switch into class-B mode. If for some reason you want to drive a 600Ω load in class-A mode, increase the quiescent current to 6mA by adjusting VR1 and VR2 for 60mV between the associated test points.

There's no thermal feedback between the V_{BE} multipliers and output stages, but at these current levels, transistor self-heating is low and thermal runaway should not occur. Changes in ambient temperature will be compensated for though, as it will affect all transistors more or less equally.

Finally, connect a signal source and check that the sound is undistorted. It's also a good idea to check that the volume control, scanning, muting and so on are all working correctly. This will confirm that the microcontroller can communicate with the DAC IC (IC1).

Once up and running, its operation is identical to the original *Stereo DAC*. ***EPE***

Testing the PCB without reprogramming

Communications between the DAC (IC1) and the microcontroller on the other board (via CON1) go via links LK1 to LK4, which are closely spaced pairs of pads on the underside of the PCB. These are normally shorted with solder.

We could have used permanent tracks instead, but this way, it's possible to test the DAC board without having to reprogram the microcontroller. This is because the CS4398 has multiple different configuration modes, and the simplest involves tying pins 9 to 12 either high to +5V (VLC) or tying them low (0V). These are the same pins used for serial communications and they are connected to LK1-LK4.

Most constructors should just short the four links as shown on the overlay diagram, then reprogram the microcontroller. However, if you want to test the new board out first, you can instead connect pins 9 to 11 of IC1 to the small, nearby 0V pad and pin 12 to the adjacent 5V pad. In this mode, many DAC features do not work properly (eg, the volume control, input scanning and muting), but you can at least verify that the new board is functioning and use it in a limited manner.

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Light level rivals halogens – at MUCH less power!

10W LED Floodlight

Design by Branko Justic* Words by Ross Tester

LEDs have come a long, long way in recent times. Who would have thought that you could have an LED floodlight, with a brightness that rivals the incandescent lamps of yesterday? This compact LED floodlight is efficient, simple to build and cheap!

AS governments announce their restrictions and even bans on incandescent lamps, one of our first thoughts was 'what are we going to do for floodlights?'.

Mainly powered by halogen lamps of 150W and 500W ratings, these floodlights have become incredibly popular in domestic, industrial and public lighting installations.

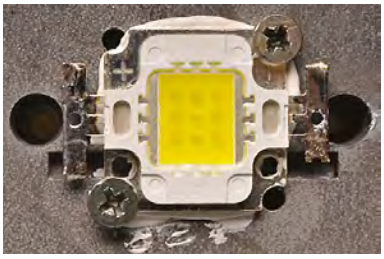
Until recently, there wasn't a viable alternative to the halogen lamp, often called a 'QI' lamp, which stands for quartz iodine (the construction and gas inside). But with the recent spectacular developments in LEDs, there is now a very effective replacement for power-hungry halogen lamps.

Strike a light

To get this into perspective, halogen floodlights comparable in size to this LED floodlight generally use 150W lamps; 15 times the power! Their light output varies depending on type, but a typical figure is about 2300 lumens, or about 15 lumens per watt (2300/150). And that really only happens with a new lamp, as light output drops with age.

The light output from this LED floodlight output is not as high, at 720 lumens and therefore, 72 lumens per watt.

OK, so that's about one third the light output of the halogen, but almost five times as efficient.



A close-up view of the LED array, already mounted in the lamp case. You can quite clearly see the 3x3 pattern of LEDs in the centre.

But, as we show in our measurements, even those figures can be quite deceiving! (See the panel 'How bright?').

LED array

The majority of high-power LEDs these days are made from a number of individual LEDs forming an 'array'. In this case, it's a 3x3 matrix of pure white LEDs, each one rated at 1.2W. The net result is a single LED light source rated at roughly 10W (there are some losses).

The array itself measures about 1cm square, but with mounting, the whole assembly measures about 2cm square – still pretty small compared to a halogen lamp. Attached to each side are tabs for soldering power leads.

The good news is that if you opt for a kit, the LED array is already fitted to the lamp housing (which acts as a heatsink) and a reflector drops into place around the LED array. So the hardware side is easy!

Driver circuit

The downside of an LED, especially an ultra-high-brightness type, is that you cannot simply connect power to it. LEDs need to be 'driven' by an appropriate supply or they will burn out very quickly.

With low-power LEDs, it's easy; a suitable current-limiting resistor will do the job. But high-power LEDs need a driver circuit to suit the type of LED/number of LEDs. And this project has the answer to this question as well: a tiny (30mm × 23mm) PCB, which contains the constant current driver circuit.

It's a simple circuit, but quite adequate for the purpose. Many (probably most) high-power LED drivers use a switch-mode driver, but they are more complicated and usually generate some (and some a lot!) radio-frequency interference, which must be suppressed.

This two-transistor circuit, shown in Fig.1 doesn't have this drawback, yet still manages about 80% efficiency, when used with a 12V source. It has only two connections, power in and power out and it can be connected in series with the positive or negative side of the LED array.

Ideally though, it should be in the *negative* side (ie, between the LED array and the negative supply) because that way the collector of the main regulator transistor (a *PNP* TIP42C) will not need to be insulated from the lamp housing (the collector and the lamp housing will both be at the negative potential).

How it works

As mentioned, the TIP42C is the current control transistor, biased on by a BC327 (Q2). It works in the following way: the base-emitter junction of Q2 effectively monitors the voltage developed across the two 1.2Ω resistors connected in parallel. These act as a sensing resistor for the current passed by the TIP42C (Q1) and therefore, the LED array.

Since the two resistors in parallel give an effective resistance of 0.6Ω, and the base-emitter junction of Q2 has a nominal voltage across it of 0.6V, this sets the emitter current of Q1 to 1A – exactly what we want for this array.

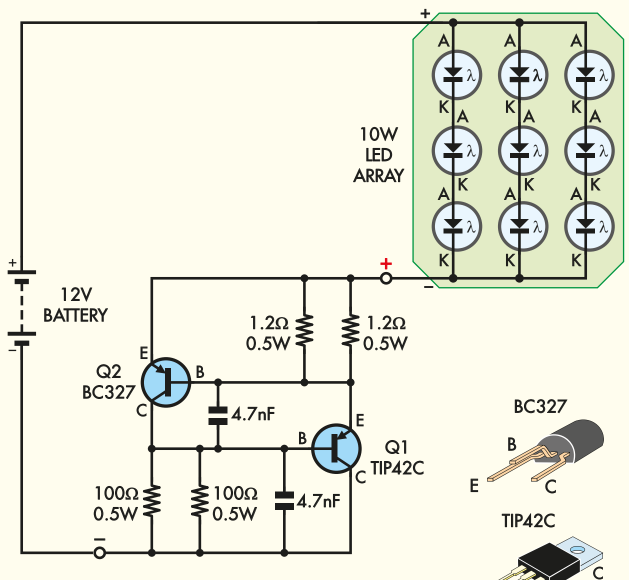
You may ask why there are two 100Ω resistors connected in series with the collector of the BC327? There is no magic in this; these two values provide sufficient base current for the TIP42C under all voltage conditions to which it is likely to be connected.

You may also wonder why we present an analogue regulator when we could use a highly efficient switching regulator?

The photo doesn't really do it justice: it's so bright, it's dazzling!

Most switchers are voltage regulators, and we need a current regulator for this application. The analogue current regulator has several advantages; cheaper, smaller and simpler. And in any case, we are not too worried about efficiency which, as already noted, is above 80%.

That means that it will dissipate between 2W and 3W, but that is not an issue, since we have a good heatsink available in the form of the lamp housing; fastening the TIP42C to the case will provide the cooling required.



10W LED DRIVER

Fig.1: the driver circuit, which is a simple constant-current regulator, drives the 3 × 3 LED array with a current of about 1A.

Parts List – 10W LED Floodlight

- 1 PCB, code 885, available from the *EPE PCB Service*, size 30mm × 23mm
- 1 hardware pack, consisting of lamp housing, gland, cable and pre-mounted 3 × 3 LED array
- 1 two-way screw terminal block, PCB mounting
- 1 TIP42C *PNP* power transistor (Q1)
- 1 BC327 *PNP* transistor (Q2)
- 2 4.7nF ceramic capacitors
- 2 100Ω 0.5W resistors
- 2 1.2Ω 0.5W resistors
- 1 length 2-core insulated power cable (to suit)
- 1 M3 × 10-15mm screw with nut and washer.

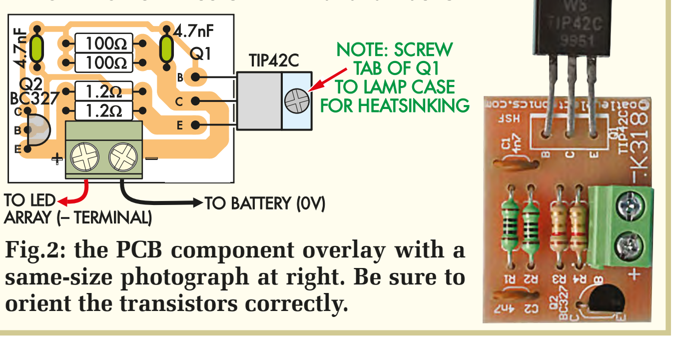


Fig.2: the PCB component overlay with a same-size photograph at right. Be sure to orient the transistors correctly.

In this and the photo at right, we've disassembled the lamp housing to show how it all goes together. The reflector 'drops into' the space above the LED array – but be careful that it doesn't short the two solder connections (on each side of the array). If there is any doubt, we'd be inclined to put a washer or two under the reflector where the screws hold it in place.

This photo shows the disassembled lamp housing from the rear. Note that in this shot, neither the holes for the PCB mounting screw nor the cable gland have been drilled (the cable gland hole can be seen in the pic at left). The blue item second from front is the reflector, again seen in the photo at left. Don't be tempted to leave out the gaskets – they keep the whole thing waterproof when used outside.

Some current regulators of this configuration can be prone to oscillation, so 4.7nF capacitors are included between the collector and base of both transistors.

Construction

The *Floodlight* circuit is built on a small printed circuit board (PCB) measuring just 30mm × 23mm. This board is available from the *EPE PCB Service*, code 885. The PCB component overlay (Fig.2) clearly identifies the location and where appropriate, the orientation of polarised components. Of the latter, there are only two, the transistors, and of these, only one might cause any confusion.

This is the TIP42C power transistor (Q1), which must be soldered into the board with maximum length of legs emerging, then folded down 90° so that it can be screwed to the case/heatsink. It should be obvious which way around it goes, even if you don't identify the legs: when laid flat, its metal tab should be in direct contact with the case.

The other (smaller) transistor is soldered in so its orientation matches the overlay on the PCB.

Leave the PCB-mounting terminal block until last, if only because it's big. Solder this in so that the lead access is to the edge of the PCB.

The LED array

As noted earlier, the LED array should be supplied already mounted in its heatsink (complete with heatsink compound), with two terminals ready for soldering the power leads on. The '+' and '–' terminals are clearly marked, though may not be immediately obvious in some light. Ensure that you get them correct and you don't make the joins too high.

PCB mounting

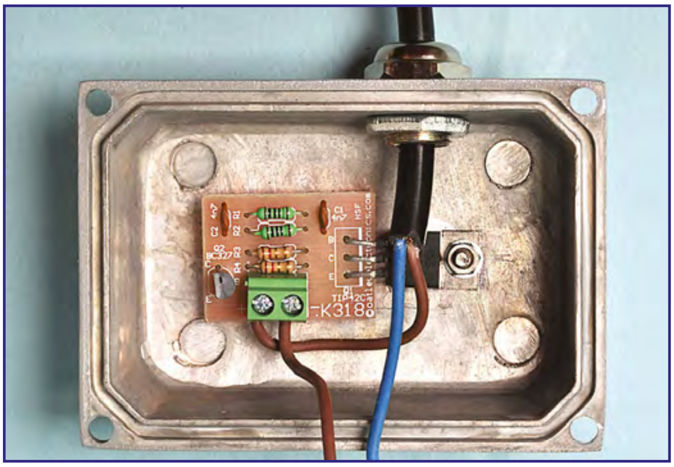
As mentioned earlier, the driver PCB can be mounted between the +12V (power) terminal and the LED array, or between the LED array and the 0V power terminal.

Because the metal tab of the power transistor (collector) is connected to 0V anyway, it makes sense to mount it in the negative line. Therefore, the case itself will be at 0V and no insulating washer will be needed between the collector tab and the case.

Obviously, if you do want to mount the PCB in the positive line, an insulating washer and bush *will* be required if you want to avoid having the case at +12V.

The photo on the next page shows how the PCB is mounted flat in the rear portion of the case. A single 3mm screw and

Comparison between the 10W *LED Floodlight* featured here and a typical mains floodlight fitted with a 150W QI lamp. These unretouched photos of my fishpond (ignore spiders on bird net!) were shot within moments of each other late at night, at the same speed and aperture (2sec, *f*4.0), with lamps in the same spot. Inset top right are the images of the two floods. Voltage on the LED was 12.4V, while the mains voltage on the QI was 237V. Incidentally, the QI attracted many more fish than the LED!



The PCB mounts in the 'bottom' of the rear of the lamp housing by means of a single screw and nut through the tab on the power transistor. There is an insulating washer in this photo – this is only necessary if you want to mount the driver PCB between +12V and the LED array. Place some dollops of neutral-cure silicone sealant underneath the PCB to prevent any short circuits to the case.

nut through the power transistor tab is all that is necessary to hold the board in place (there are no mounting holes on the PCB itself). The hole for this screw will need to be drilled in the case, but position is not overly important, as long as the PCB fits. To prevent the bottom of the PCB shorting to the case, place a few dollops of neutral-cure silicone sealant underneath the PCB.

A waterproof cable gland (which also requires a hole drilled through the case) secures the 12V power cable. You should use 2-core mains flex (red and black) for the 12V power supply cable. If you do use 3-core mains cable, the green/yellow is not used; the brown lead is used as the +12V lead and the blue becomes the 0V.

How bright is it?

Halogen floodlights are popular because they are so bright; much brighter than 'traditional' incandescents and streets ahead of anything fluorescent – that might be about to change!

Late at night on a fishpond we set up two mini floodlights – the one described here and a standard 150W halogen. These luminaires are roughly the same physical size, hence the choice.

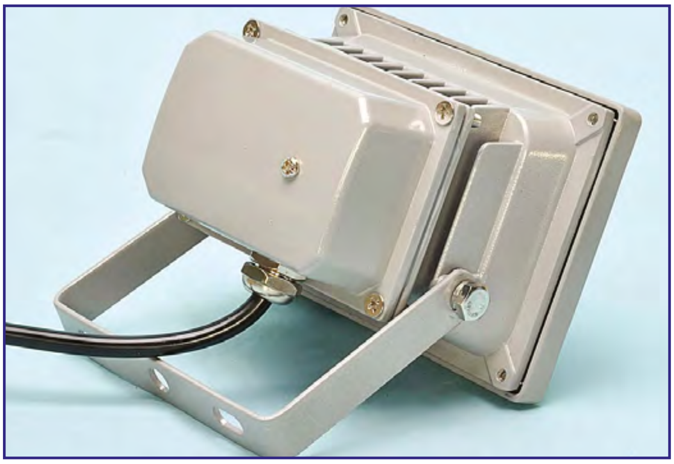
The first observation was just how yellow the halogen was in comparison to the LED – and we had always thought that the halogen lamps gave a nice, white light, especially compared to standard incandescents (see photos opposite for comparison).

But the second observation really surprised us. Using our Nikon DSLR as a light meter, we measured the output from both at the same distance and axis. To ensure accuracy of reading, we set the speed to 1/1000s and filled the frame with the floodlight from a distance of 2m.

Guess what! The in-camera meter read exactly the same with both floodlights. That's to within plus and minus half a stop.

Given the fact that the LED Floodlight draws 10W and the halogen 150W, that's a pretty powerful message!

Finally, after about 15 minutes (the time it took us to make the measurements), the LED Floodlight was warm, but not uncomfortably so. The halogen floodlight? Anyone got any eggs to fry?



Here it is completely assembled and ready for use. It's close to the same size as a 150W halogen floodlight, but has the advantage of using much less power. Another big advantage over halogen lamps is that LEDs aren't fussed which way you angle them (halogen lamps need to operate very close to horizontal for longest life). The bracket on the rear can be rotated to suit any mounting position.

Wiring up

Remove about 150mm of outer insulation from the cable and cut off (but retain) all but about 40mm of the red *(brown)* wire. Bare about 5mm of wire from both the red *(brown)* and black *(blue)*, pass the cable through the gland so there is about 15mm or so of outer insulation inside the gland.

Connect the short red *(brown)* wire to the '+' terminal on the PCB.

There are two holes already drilled in the lamp case which line up pretty well with the two terminals on the LED array. Pass the black *(blue)* wire through the hole which lines up with the terminal on the LED array and carefully solder it on. The length of red *(brown)* wire which you previously removed goes through the other hole and solders to the '+' terminal on the LED array. Make sure there are no stray strands of wire which can short to the case.

The other end of this red *(brown)* wire connects to the '–' terminal on the PCB. That's right, the '–' terminal. All you need do is connect to a 12V power source, preferably with a switch to turn on and off.

And that's it: the lamp housing comes with a rotatable bracket if you wish to mount the *LED Floodlight* permanently. With a rather modest current draw of just over 1A, a solar-backed battery supply makes a lot of sense – and the amount of light you get would be rather more than other 'solar' systems. ***EPE***

Where from, how much?

This kit comes from Oatley Electronics who hold the copyright on the PCB design. A complete kit of parts which includes all those components listed in the parts list is available from Oatley Electronics for around £20.00 + P&P. Contact Oatley Electronics via email (sales@oatleyelectronics.com) or via their website (www.oatleyelectronics.com).

*** Branko Justic is manager of Oatley Electronics.**

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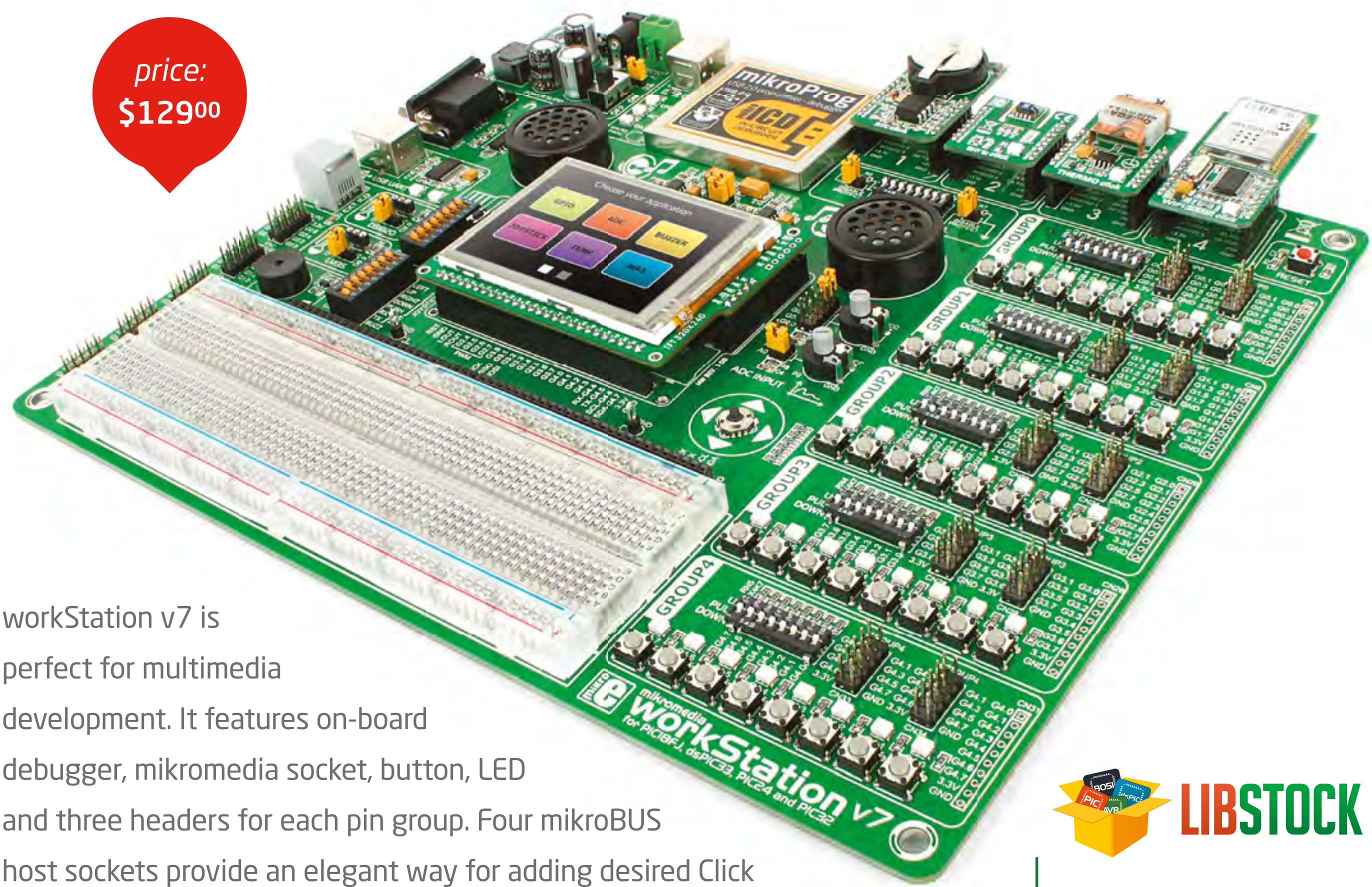

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Built-in Speakers!

By Julian Edgar

Do you want unobtrusive speakers in your house? One approach is to build the speakers into the walls and floor. It sounds radical, but if you are already doing some renovating, it's quite achievable. Julian Edgar shows how he did it in his house.

An effective way of getting good sound from a small speaker enclosure is to use a ported box. This will typically produce deeper bass and be more efficient than a design using a sealed enclosure. With this in mind, I decided to build custom ported enclosures that fitted within the walls.

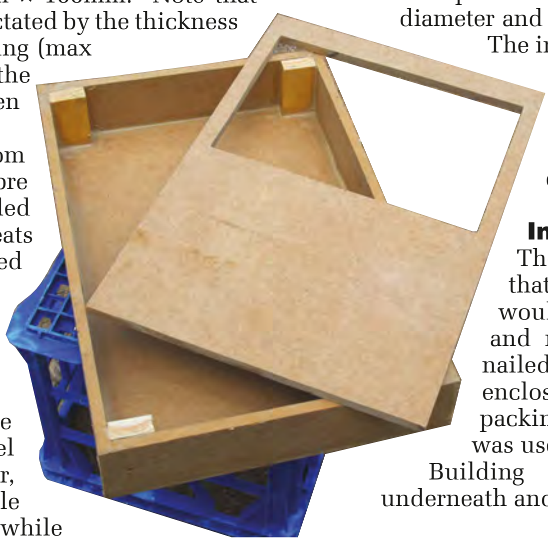
The starting point was a pair of older Wharfedale Atlantic speakers I already had. In standard form, each Atlantic uses three 8-inch drivers and a tweeter. The two lower drivers are housed in their own ported enclosure, and the mid/bass unit in a separate upper enclosure that is also ported. (The ports are on the back of the box.)

The upper enclosure has a volume of about 15 litres – a pretty good size for a custom-built in-wall enclosure. I removed the mid/bass units, tweeters and crossovers from the Wharfedales, and built them into a pair of new 15 litre enclosures, sized to fit in the walls.

Wall box construction

To provide an internal volume of about 15 litres, the wall box dimensions are about 540mm × 380mm × 100mm. Note that the depth was dictated by the thickness of the wall framing (max 100mm), and the width by the distance between adjoining studs (400mm).

The boxes were assembled from 9mm-thick medium density fibre board (MDF) using butt joints, nailed and/or screwed into place. Pine cleats (40mm × 20mm) were then placed at the internal corners of the box. Water clean-up building adhesive was used on all joins.



Wadding

To give clearance for the grille frame, I used a recessed front panel to mount the Wharfedale woofer, tweeter and the port. The woofer hole was cut with an electric jigsaw, while the port and tweeter openings were made by holesaws. Internal surfaces of the enclosure were covered in a single layer of polyester quilt wadding, held in place with building adhesive.

Lots of of glue was used on all joins, so that it squeezed out as the panels were screwed or nailed together. A wet finger was then used to smooth this glue along the seams, better sealing them.

Internal port

The ports of the Wharfedale donor speakers were 50mm in internal diameter and 85mm long. However, a port of this size in the in-wall enclosures would put the internal end of the port too close to the back wall of the box. To achieve the required clearance, I formed new ports of the same diameter and length from curved PVC plumbing sections.

The internal ends of the ports were 'bell-mouthed' by being heated until the plastic softened and then forced down over an inverted small ceramic bowl. Part of the bell-mouth needed to be ground away to provide clearance to the back wall of the enclosure.

In the wall

The existing wall plasterboard was cut back so that the joins between old and new plasterboard would be located over timber studs (verticals) and noggins (horizontals). A new noggin was nailed between two of the existing studs – the enclosure was then placed on it, sitting on two packing pieces. Additional MDF board packing was used on one side of the enclosure.

Building adhesive was then liberally applied underneath and on both sides of the box, effectively gluing

the box in place between the studs. The front face of the box was located flush with the wall surface.

Plastered

To fill the gaps, plasterboard was cut to size and glued in place. Finishing plaster was then trowelled over all the joins and then sanded smooth. The drivers were removed, the enclosure and wall painted, and then the drivers re-installed.

To obtain paintable, professional looking metal grilles, I bought the cheapest 8-inch in-wall speakers I could find online. When the speakers arrived, I removed the cheap drivers and crossovers, and then cut out the internal plastic panels with an electric jigsaw. This resulted in plastic frames and metal grilles that could be easily installed within the recessed front panels, giving a professional finish.

Finished

The sound quality from the wall speakers is excellent. Driving the speakers from a frequency generator shows that there is good response down to about 70Hz, and audible response down to about 50Hz. At the other end of the spectrum, the sound goes well above my hearing ability – but my 8-year-old son can hear 20kHz being reproduced.

Note that the location of the wall speakers is very important – testing showed that good results came from a speaker location near the ceiling, but when the speakers were located half way between the ceiling and floor, the sound was much poorer. For many people, the sound quality would be fine with just these speakers installed – but I also wanted lots of bass, which meant more speakers, this time located under the floor.

Floor speakers

My house uses a wooden floor with an under-floor crawl space, accessible through a small door about 50cm square. There's less than sitting-up room under the floor – but that still leaves space for some large underfloor speaker boxes!

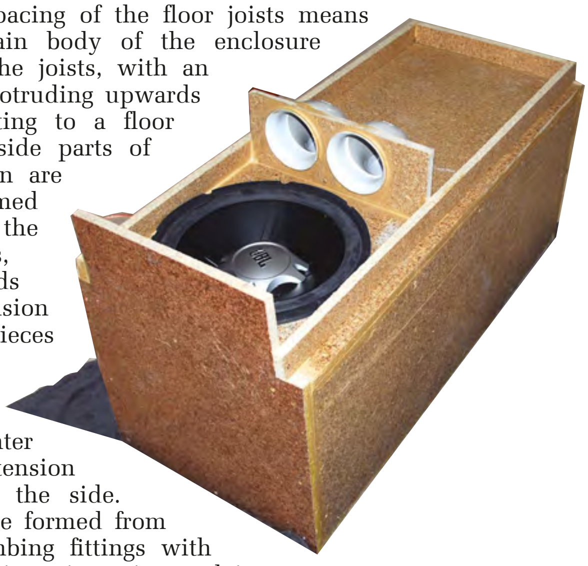
GT5-15

I decided to build two underfloor enclosures, each equipped with a 15-inch JBL woofer – the GT5-15. These drivers have a continuous power handling of 300W and a resonant frequency of 27Hz. With full Thiele-Small parameters for these drivers available, various enclosure designs could be modelled – I use BassBox Lite software.

The software indicated that with a 200-litre enclosure volume and two ports, each 100mm in diameter and 330mm long, I could expect a –3dB point of just under 21Hz! However, more difficult than the modelling was building enclosures that would fit through the access door and would acoustically connect to a floor-mounted grilles.

Completed

One of the two finished underfloor enclosures is shown here. The spacing of the floor joists means that the main body of the enclosure sits under the joists, with an extension protruding upwards and connecting to a floor grille. The side parts of the extension are largely formed *in-situ* by the floor joists, while the ends of the extension comprise pieces attached to the box.



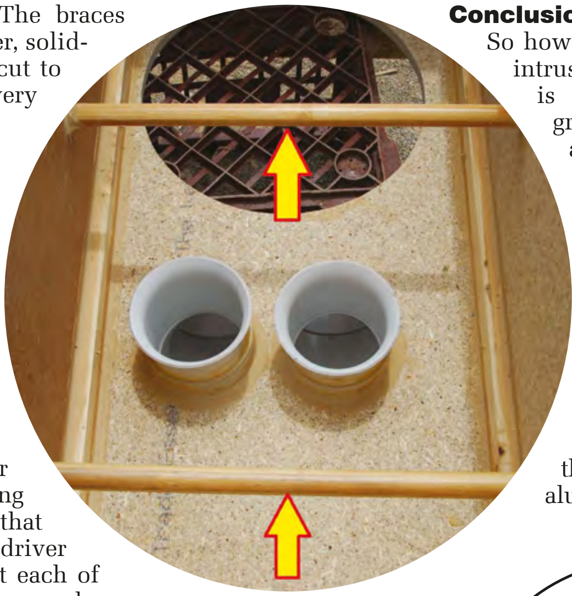
The two ports enter one of the extension pieces form the side. The ports are formed from curved plumbing fittings with flared extension pieces inserted in each end. The speakers are driven through simple inductor crossovers.

When tested with a frequency generator, there is audible bass down to 25Hz, and strong bass from about 35Hz. (In fact, the bass response may go lower than that, but perhaps I am unable to hear it – I can excite ornaments in other rooms of the house at about 18Hz!)

Braces

The enclosures are made from 19mm-thick MDF flooring. Butt joints (rather than mitres) were used; however, full-length cleats were added to strengthen every butt join. These cleats were made from 40mm × 20mm pine. Every joint was both glued and screwed, with the screws connecting to the cleats rather than to the MDF board. As with the wall speakers, the ends of the ports were flared.

To reduce panel vibration, two internals braces were used (arrowed). These connect the largest side panels, with one brace one-third of the way along the panel, and the other two-thirds along the length. The braces were made from 25mm diameter, solid-cored bamboo broom handles cut to appropriate length – these are very stiff.



Internal filling

All internal walls were covered with polyester quilt wadding, glued into place with building adhesive. In addition, two larger pieces of wadding were rolled and then inserted into the box, one at the end furthest from the driver and the other immediately below the driver.

I chose not to use a speaker terminal, the cable simply being run out of a hole in the box that was then sealed. The JBL driver was held in place by screws at each of the provided holes; in addition, a polymer sealant was applied under the lip of the frame. Soft rubber strips were placed on the surfaces that contact the underside of the floor.

Final grille

To provide an opening through which the drivers could fire, holes were cut in the floorboards. Because the floor was to be tiled, cement sheets had already been laid on top of the timber – so the holes were cut through both the sheets and the floorboards. Tiles were later laid around the holes.

Powder-coated steel floor grilles were then placed over the holes. The grilles are removable, sitting in the recesses only under their own weight. Self-adhesive felt strips were placed under the grilles so that they wouldn't rattle.

Jacked

To place the enclosures into position, they were slid along the ground on long, narrow piece of scrap particle board, until they were located directly under their respective floor grilles. Each enclosure was then lifted, with bricks at each end being used to hold the enclosure above the ground. A brick was then nestled into the dirt under the middle of the enclosure, a piece of strong timber placed under the enclosure and a surplus scissors-type car jack placed between the brick and the added timber support.

The enclosure was raised by the jack until the rubber seal of the extension piece contacted the underside of the floor, and then adjusted up another 5mm or so to give positive contact. The jacks stay in place: with heavily greased threads, they will be useable should the enclosures ever have to be lowered for repairs or replacement.

Conclusion

So how well does it all work? Well, firstly the intrusion of the speakers into the room space is effectively zero. The wall and floor grilles, while they can obviously be seen, are unobtrusive and blend in well with the decor. (Cue: wife acceptance factor comments!)

And the sound? Considered in terms of the cost and the fact that the speakers are completely hidden, the system sounds quite fantastic. Treble is transparent, mid-range uncoloured and upper bass tight. Bass and lower bass are faithful and 'there' – the system sounds full-bodied and natural at different loudnesses. Crank it up and the biggest problem is stopping the room's aluminium window frames from rattling!

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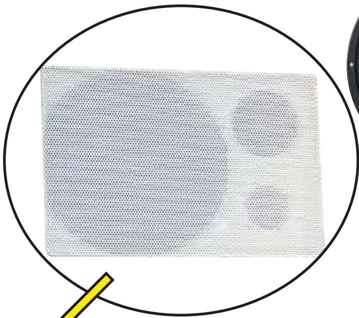

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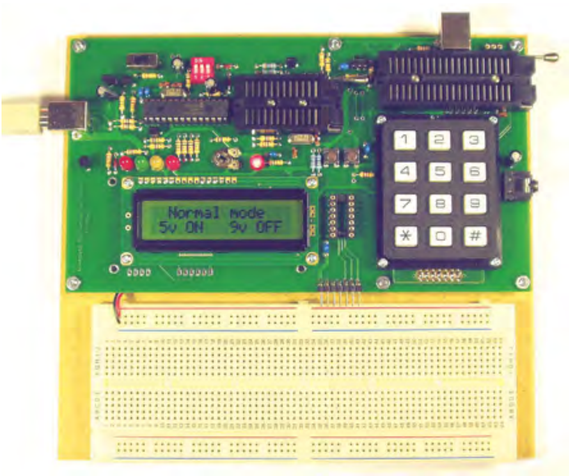

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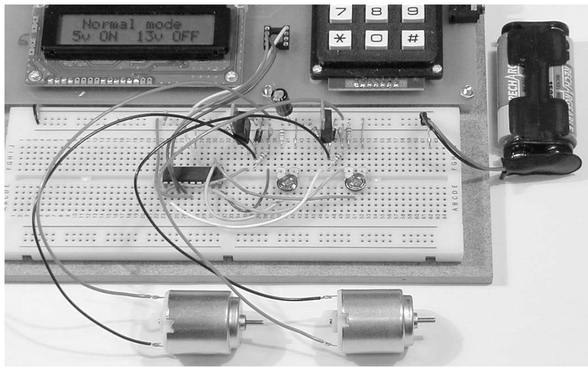

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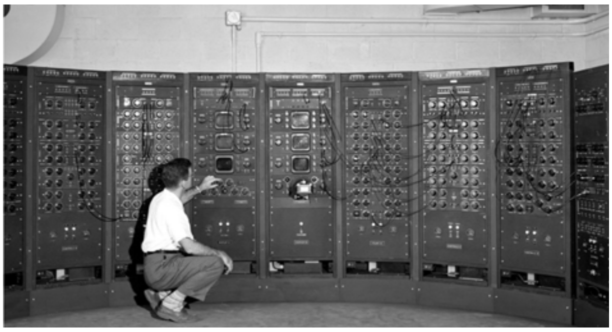
Max's Cool Beans

By Max The Magnificent

Things are racing along so fast with regards to electronics in general and computer systems in particular that my head is spinning.

It's all in the cards...

It's really not so long ago that I was at university working on my BSc in control engineering. Well, admittedly it was in the late 1970s, but that really isn't all that long ago in the grand scheme of things. Believe it or not, we did a lot of our real-world modeling experiments using a humangous analogue computer, similar to the one shown here (no, that's NOT me in the picture!).



The university did have a digital mainframe computer, but that was in a special building across town. We would capture our programs in the FORTRAN programming language by writing them down in our logbooks with a pencil. Then we would use a Teletype machine (like a mechanical typewriter) to transfer the program to 80-column IBM-style punched cards. Then we would carry our 'card deck' (from 'deck of cards,' get it?) over to the computer building.

Someone on the reception desk would take the deck and say 'Come back next Tuesday.' When you did return, you were anticipating a computer printout showing you a plot of your results. Instead, you were presented with your original cards wrapped with an elastic band and augmented with a small piece of paper bearing a message along the lines of 'SYNTAX ERROR, MISSING COMMA LINE 2.'

Good grief! If they could detect a missing comma, why couldn't they add it in for you? So you went back to your building, retyped that card adding the comma, returned to the computer building, and started all over again. Sometimes it took an entire semester to get the simplest program up and running.

My memory isn't what it used to be

My first job was with International Computers Limited (ICL) in West Gorton, Manchester. I was a junior member of a team designing CPUs for mainframe computers. This was a fantastic position and I learned a lot, but after a year or so two of the managers left to form their own company and they invited me to join them. My mother was horrified when she discovered that I was leaving a company like ICL (in which she could see a life-time career progression for me) to join an unknown startup. Now she tells everyone that it was the best decision she ever made for me (at 82, she has a mind like a trap; her memory is so good that sometimes she remembers things that haven't even happened yet!).

I was number six in the new company. I arrived the day after the desks and chairs, so the other guys all said that I was a lucky ******* (person). The firm's computer was a rinky-dinky PDP 11/23 manufactured by the Digital Equipment Corporation (DEC). Next to this computer was a cabinet the size of a small fridge, which housed the hard disk drive and its associated power supply and cooling systems. This drive was actually formed from a number of platters mounted one above the other with gaps between for the read/write heads. If you wished to remove the disk for any reason, you used something that looked like a glass wedding cake cover with a handle on the top.

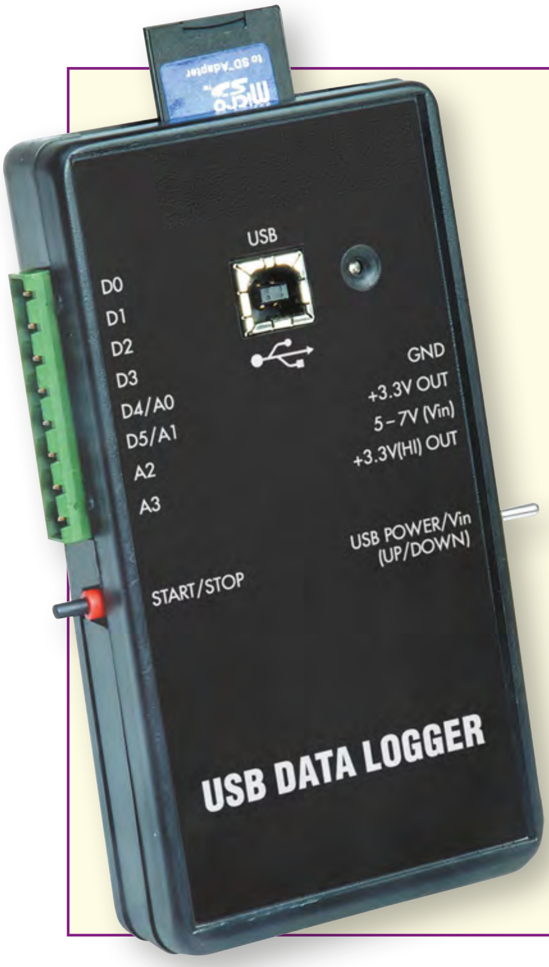
All in all, the part of the disk assembly that actually stored the data was about a cubic foot in size. How much memory did it hold? I'm glad you asked. It was just one megabyte, which was shared by everyone in the company. Furthermore, we all shared the same directory/folder (the file management system didn't support a hierarchy of folders) and all of the file names were in the old 8.3 format (eight alphanumeric characters for the name, a period, and a three-alphanumeric-character extension). So we used the first letter of the file to identify the owner ('M' for 'Max' in my case).

I was looking at my iPad a while ago contemplating the fact that it contains 64 gigabytes of Flash memory. Since I had a few free moments on my hands, I calculated that if we were to store the same amount of data on 8-inch diameter (1-inch wide) paper tapes, then they would occupy 24,000 cubic feet – that's 24 rooms each 10' × 10' × 10' in size.

Blowing a raspberry

I remember when I saw one of the first microprocessor-based home computers advertised in *Practical Electronics* (the illustrious ancestor of *EPE*) sometime in the mid-to-late 1970s. This was a single board computer with a hex keypad for input, a few seven-segment displays for output, one kilobyte of ROM, and one kilobyte of RAM … and this little beauty was so expensive that there was no way I could ever afford it. Now there are things like the credit card-sized Raspberry Pi, the B version costs only $35 (plus local taxes and shipping/handling fees), boasts 512Mb RAM, 2 USB port, and an Ethernet port; and can be plugged into your TV and connected to a keyboard to give you a very respectable computing system that can be used to do all sorts of fun stuff. If I'd had access to one of these little scamps when I was a young lad, I would have been walking around with a grin from ear-to-ear.

Now, I certainly don't want you to think that this is sour grapes, or imagine me blowing a raspberry, or any other fruit-related saying that pops into your mind ('Why so glum, sugar plum?' 'It's peachy keen, jelly bean.' Good grief, I think I'm 'going bananas!'), but the thought that 'Young folks have it so easy these days' does occasionally pop into my mind. What do you think? Please share your own experiences as to how electronics and computers have changed over the years by writing to the editor at: **enquiries@wimborne.co.uk** .



Universal USB Data Logger – Part 3

In this final article on the *USB Data Logger*, we describe how to use the accompanying Windows host software. This software allows you to edit and test scripts, upload them to the logger and change its settings.

By MAURO GRASSI

AS explained previously, 'scripts' are used tell the *USB Data Logger* which sensor(s) are attached, how to query them, what the readings mean, how often to log the data and the data format to use.

If you have not already prepared a memory card, you can format it with a FAT or FAT32 file system (a quick format is OK) before plugging it into the *Data Logger*, with the power off. Having installed the host software and driver (see Part 2, last month), plug the *Data Logger* into your PC and launch the software by double-clicking the **.exe file**.

What the software does

Essentially, the Windows host software is a 'development environment' that allows you to write scripts, upload them to the *Data Logger* and test them. It also allows you to monitor scripts as they run and download logged data over the USB interface. In addition, you can change the *Logger's* settings from the host software.

Since complex scripts can be difficult to debug when running on the *Logger* itself, the software allows you to 'simulate' the scripts, running them on the host PC to see what they do. Scripts can be simulated at an accelerated rate, which is useful for those which involve long delays. Note that because simulated scripts are run on the host PC, they cannot access the sensors as they can on the *Data Logger*. For example, if a simulated script reads from an analogue input, the result is always zero.

User interface

The interface for the Windows-based host software is shown in Fig.11. When plugged into a USB port, the *USB Data Logger* is detected automatically. Its firmware version and the connection status are shown in the window title bar, at top.

The main window has a number of sub-windows. The script editor sub-window is at upper left, and this is where scripts can be created or modified. The log sub-window below it allows you to keep track of program actions as they take place. There are some buttons between the two which clear the log window and perform other common actions.

At lower right is the console sub-window, which has a grey background. It allows you to see what a script is logging as it runs or is simulated, which is useful for testing complex scripts (see later). Above the console are several buttons, used to control the simulation.

At far upper right are the *Logger* settings and below them the Host Settings, which apply to the PC host software.

To the left of the settings are four additional sub-windows (two red, two green), which allow you to see the files and scripts stored on the *USB Data Logger* and on your host computer (respectively). They also allow you to manage scripts, including transferring them to and from the *Logger*.

Settings

The device settings (at upper right of Fig.11) are stored on the *Logger*, both in a file on the memory card and in its internal Flash memory. If the file on the memory card becomes corrupted or the card is removed, the *Data Logger* relies on its internally stored settings. Otherwise, the settings on the memory card are used.

You can copy the settings between the *Logger* and the host PC via the Host and Device menus. It is also possible to restore the settings to the defaults using

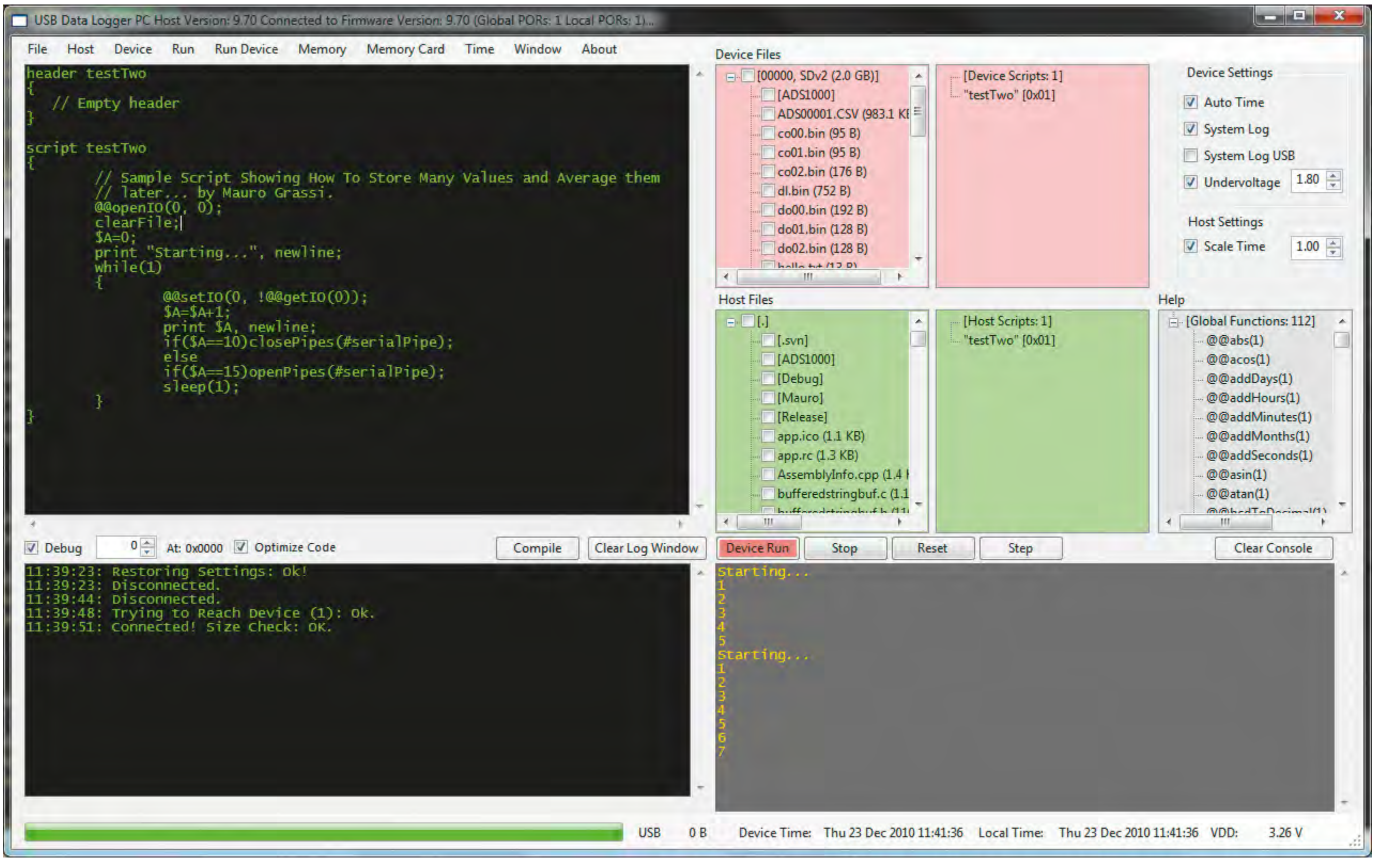


Fig.11: this is the user interface for the PC host software. This lets you edit, compile and upload scripts to the *USB Data Logger* via the USB interface. It also allows you to change settings and to download log files.

these menus, which work as follows:

Auto Time: when enabled, the PC host automatically sets the real-time clock in the *Logger* whenever they are connected. Without this option you can synchronise the time manually via the 'Time' menu.

System Log: when enabled, the *Logger* will note special events in a log file on the memory card (**syslog.txt**). This is useful for troubleshooting, but slows the *Logger* down and increases its power consumption. The contents of this file can be read or cleared through the host software via the Device menu when the *Logger* is plugged in.

System Log USB: when enabled, as well as logging to the '**syslog.txt**' file on the memory card, the *Logger* also sends system log messages over the USB serial interface and the host software diplays them in the console sub-window.

Undervoltage: when this is enabled and the battery voltage drops below the specified level, the *Logger* goes into sleep mode, minimising power consumption. This is recommended to avoid over-discharging the battery. Remember that this voltage does not take into account the voltage drop across the Schottky diode from the battery (the default setting is 1.8V, as shown).

Editor window

You can use any text editor you like to write scripts, but for convenience, the host software has a built-in editor, allowing small script changes to be made and then immediately simulated or uploaded to the *Logger* for testing. The script is shown in the upper left window, and most of the associated commands are located in the 'File' menu above it. The editor font size can be set via the 'Window' menu to provide the best legibility with your display.

If you are using a third-party text editor, the easiest way to upload the script is to paste it into the text editor window and then proceed from there.

File browser

As mentioned, the two red and two green sub-windows towards the upper right are the file and script browsers. The red windows show directories, log files and scripts on the *Data Logger,* while the green windows show the same information for the host computer. Using these windows, you can browse the contents of both devices and transfer files between the two.

In each case, the left-most window shows the file system directory structure and files (including log files), while the right-most window shows the loaded scripts (more on that later). Up to eight script files at a time can be loaded on the *Logger;* each is assigned a unique number, which is also shown.

Local files are stored in the same directory as the host software. In both cases, the file lists are sorted alphabetically. Directories are shown in square brackets, and directories and files can be opened by double-clicking them. Scripts are opened in the editor window. Right-clicking on a file gives a context menu with additional options. This includes options to initiate file transfers between the *Data Logger* and host PC.

Note that while this is a very convenient way to access log files on the *Logger*, for large log files (15MB or more) it can be faster to remove the

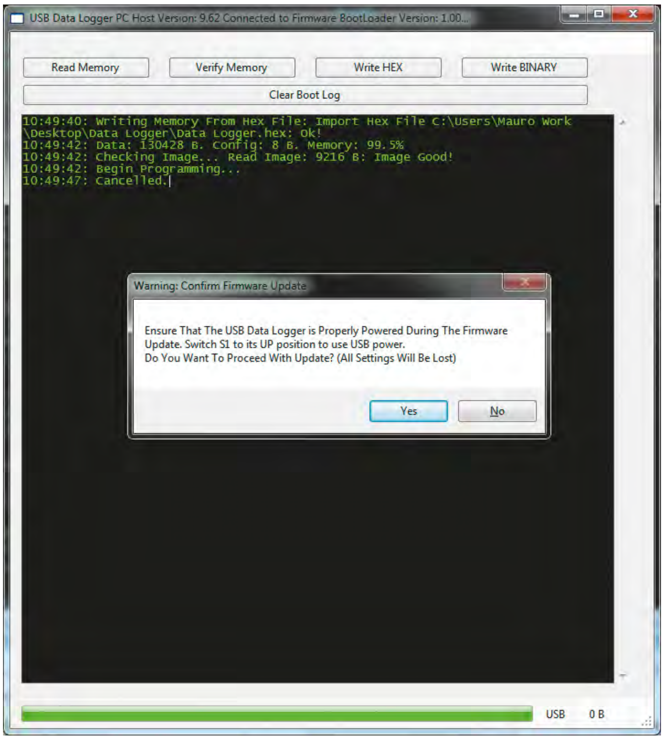


Fig.12: this interface appears if the PC host software is launched with the bootloader running. This then allows you to update the firmware in the *USB Data Logger*.

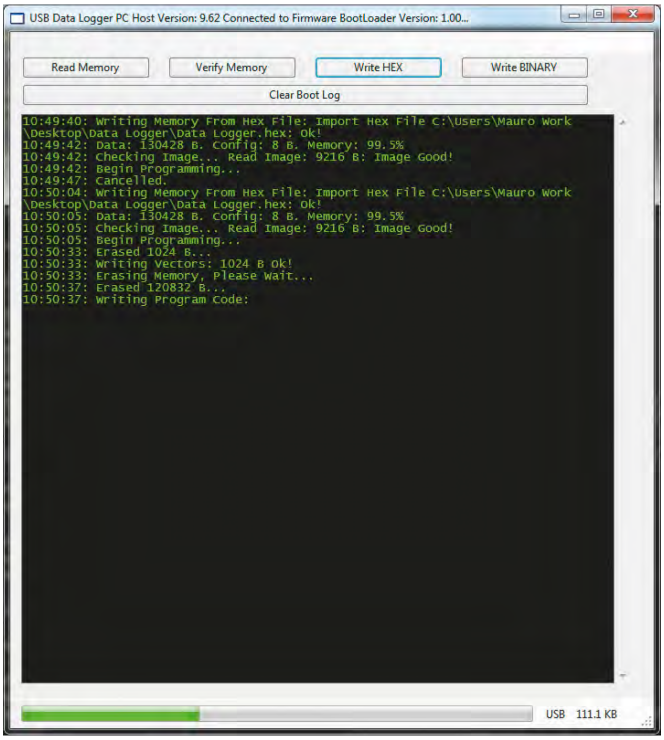


Fig.13: after selecting a hex file and clicking 'Yes' (see Fig.12), the new firmware is uploaded to the logger and a progress bar is displayed at the bottom of the window.

memory card and use a USB card reader to transfer them instead. This is because the *Logger's* USB transfer speed is limited by the PIC18F2753's small modest RAM and clock speed.

Compiling scripts

Before a script can be tested or used, it must be loaded into the editor window and then compiled. When it is compiled, the software checks that the script is valid. If there is anything wrong with it, the Compile button turns red, one or more error entries appear in the log window and compilation is aborted.

If errors are reported, the first invalid line in the script code is highlighted. The location of the error is also shown in the log sub-window, as a line and column reference. Once the problem has been fixed, you can attempt to compile the script again.

The compiler can also generate 'warnings'. As with errors, these are noted in the log sub-window, but they do not prevent successful compilation. Such warnings indicate possible errors in the script, but they can sometimes appear when the script is correct.

If the script is correct (ie, there are no errors), the Compile button turns green and the script is added to the list of available local scripts.

Rather than pressing the 'Compile' button, you can also press the F10 key on your keyboard. The compiled script can be transferred to the *USB Data Logger* by right-clicking on it in the green 'Host Scripts' window and selecting 'Send PC Script'. For convenience, you can press F11 instead, which compiles the script and then automatically sends it to the *Logger*, assuming the compilation was successful. You can also send all local scripts to the *Logger* by pressing Shift+F11.

There is a handy 'help' window at the right of the user interface (with a grey background) which lists all defined constants, global functions and global variables in the script. Each global function is listed with a number in parentheses indicating the number of arguments that the global function takes. Global define constants are shown with their values, while global variables are shown with their size.

The 'Optimize Code' option, above the log window, is enabled by default. This allows the compiler to remove any redundant portions of the script or simplify it where possible. This reduces the memory and processing required to run a script on the *USB Data Logger*.

Simulating scripts

Once a script is compiled, it can be simulated in the console sub-window (lower right of Fig.11) using the Run, Stop, Reset and Step buttons. Pressing Run, begins the simulation and the script output is shown in the console window (this would normally be stored in the log file on the memory card). If you click Stop, the script pauses and the next line about to be executed is highlighted in the editor window.

You can then use the Step button to proceed through the script, one line at a time. This is good for debugging – you can observe the program flow and see the log output from each individual line in the script. The Reset button can be used to start the script from scratch and the Clear Console button blanks the console sub-window.

During simulation, the Scale Time option can be adjusted (upper right) to change the speed at which the simulation runs. For example, if Scale Time is enabled and set to 10, a scripted delay of 25 seconds actually takes

2.5 seconds. This makes debugging scripts with long logging periods far less tedious.

You can also use the console sub-window to observe data being logged to the memory card in the *Logger* as it occurs. This is useful for the final test of a script, with real sensors attached.

Status bar

The status bar, at the bottom of the window, indicates what the host software is doing at any given time. This shows USB data transfers, the time from the *Data Logger* and so on. At the right of the status bar are two flexible displays which can show various statistics. They are selected by clicking on that portion of the status bar.

The first (left-most) flexible display shows information about time synchronisation. The second shows various voltages from the *Logger*, including the supply and battery voltages.

Updating the firmware

The *Logger's* firmware (the software running on the microcontroller) can be updated from the host computer over USB. To do this, first you must activate the bootloader by holding down pushbutton switch S2 on the *USB Data Logger*, while applying power (normally from USB). To do this, the battery *must* be removed, as there is no way to switch it off.

With the bootloader activated and the *Logger* plugged into the host PC via the USB port, launching the host software will display the bootloader interface instead of the usual development environment (see Fig.12).

In bootloader mode, the blue LED (LED3) flashes at around 1Hz. Once the USB interface has been recognised, the flash rate increases slightly and is faster again when the firmware is being read or written.

Typically, firmware updates are supplied as a hex file ('**.hex**' file extension). You can then use the 'Write HEX' option to transfer this file's contents into the microcontroller's Flash memory (Fig.13). It will check that the file is valid, then ask you to confirm that you want to overwrite the existing firmware. After rewriting the program memory, a verify operation is automatically performed to ensure that it was successful.

Tips for installing the USB driver

Here's a tip for installing the USB driver. The *USB Data Logger* will go into standby (and detach from the host PC's USB interface) when there are no custom scripts loaded. This is done to save power and since initially there are no scripts loaded, this will be the state of the *Logger* after it is first switched on.

This can affect the installation of the driver (since the USB connection may be lost during the driver installation), so it is advisable to install the driver with no memory card inserted in the socket. When switched on, if no memory card is present, the *USB Data Logger* does not enter standby as quickly as it does when a card is present.

This gives you around two minutes to plug it in and install the driver, which should be long enough in most cases. If not, you can always press S2 to keep it out of standby for another five seconds. This feature is provided as a fail-safe feature in case the *Logger* is used with a very old system.

Note that if later you use the *USB Data Logger* and then attempt to verify the firmware manually, using the Verify Memory button, the verification will fail, because the *Logger* also uses the Flash memory to store its settings. This also means updating the firmware resets the *Logger's* settings to its defaults.

Using the logger

When operating, pushbutton S2 and blue LED3 are used to control logging and provide feedback. A short press of S2 tells you the logging status: LED3 will flash once if at least one script is running, or three times if there are no scripts running (and therefore no logging is taking place).

A longer press of S2 pauses all scripts, in which case the logger flashes its LED three times to confirm that logging is paused. A second long press results in a single flash and logging resumes.

The blue LED also flashes to indicate USB activity when the USB interface is in use by the host software.

Standby mode

The logger automatically goes into standby mode when:

1) There are no custom scripts loaded

2) All the custom scripts that are loaded are paused or not running

3) There is a time delay of at least five seconds, during which no custom scripts need to run

4) The under-voltage protection is enabled, and the battery voltage is below the set threshold.

In standby mode, the *Logger's* USB interface shuts down (the PC host will show it as being 'disconnected') and the LED glows dimly, but does not flash.

As mentioned in Part 1 (Dec 2012), the full power savings will not be made unless the minimum logging period of all executing scripts is above the threshold for going into standby – 5s. Below this threshold, the microcontroller does not switch off power to certain components, including the memory card, because otherwise the initialisation sequence would take too long. You will, therefore, get the best battery life if your logging scripts execute sleep periods of greater than or equal to this time.

In standby mode, the current drain from the battery is around 560µA to 850µA. If the battery voltage is very low, the PIC enters sleep mode, which is at the lower end of this range (560µA) and it stays in sleep mode until the device is power cycled.

This does not include the current consumed by any sensors powered from the *USB Data Logger*. Typically, sensors will not consume much power when they are idle, but for long-term logging, even a small amount of additional power can reduce battery life.

If the *Logger* goes into standby mode while plugged into USB, it will disconnect from the host PC (unless the host program is running). Pressing push-button S2 or inserting a memory card exits the *Logger* from standby mode.

While writing to the SD card, instantaneous power consumption from the battery can be 25mA or more, but if the scripts have long sleep periods, this averages out to a much lower value in the long term.

Sample excerpt from syslog.txt

Time unavailable: USB Data Logger version: 9.60. Global PORs: 4. Local PORs: 1.
Time unavailable: Memory card detected, Total size: 2.0GB free size: 2.0GB.
Time unavailable: VM(s) running: 1 of 2.
Time unavailable: The following VM(s) are loaded: { oneScript, csvScript }

System log

As mentioned earlier, the *USB Data Logger* can store events in a system log for troubleshooting purposes. A sample excerpt from the **syslog.txt file**, as created when the *Logger* is switched on, is shown in the accompanying panel.

The first line shows the *USB Data Logger* firmware version and the number of power cycles (power on resets or PORs) that the *Logger* has undergone. The Global reading indicates full resets, while the local reading shows the number of times the scripts have been reset by the software. This can happen if the memory card is removed.

The second line shows information on the memory card, and the third shows how many virtual machines (VMs) are actively running scripts (there are up to eight). The fourth line shows the names of the scripts that are loaded. Here are some more example system log entries:

Thu 23 Dec 2010 05:42:01: Destroy 2 VM(s).
Thu 23 Dec 2010 05:42:11: Holding.

The first line indicates that two scripts were reset, resulting in their virtual machines being 'destroyed'. The second indicates that script execution has been paused by a long press on pushbutton S2.

Digital sensor requirements

When using an input for frequency or event counting, you must make sure the signal is within 0V to 5V (for D0 to D3) or 0V to 3.6V (for D4 and D5).

For I^2C sensors, their SCL (clock) line must be connected to D0 and the SDA (data) line to D1. While the pin connections for the I^2C bus are fixed, multiple scripts can access sensors on the one bus.

One Wire sensors can connect to any of the six digital pins D0 to D5. You must configure the correct pin number in the script. The same applies to the serial port; you specify the Transmit and Receive pin numbers, the baud rate and the mode. The serial port supports baud rates up to 0.5Mbps.

Multiplexed peripherals

While the PIC18F27J53 microcontroller has just two serial peripherals, each of the eight possible scripts can configure its own serial port with whatever configuration it requires (pin connections, baud rate, and so on). The PIC's peripheral pin select (PPS) feature allows the software to re-map the UARTs as appropriate for each script as it runs. This is the same feature which allows One Wire sensors to be connected to any of the I/O pins.

For example, you can have one custom script sending data to a serial port on pin D0 at 9600bps, while having another script sending data to an independent serial port on pin D1 at 115,200bps. The hardware state is saved and changed as required by the firmware for the currently executing custom script.

As well as selecting the pin connections and baud rate for the serial port, scripts can choose to invert the receive or transmit logic, or to have an open drain output.

Writing scripts

Finally, for those who build the *USB Data Logger*, we have prepared some detailed information on writing logging scripts, including a complete description of the language's syntax and global functions and variables.

This information is available as a PDF file from the February 2012 section of the *EPE* website. It is named 'USB Data Logger User Manual.pdf'. ***EPE***

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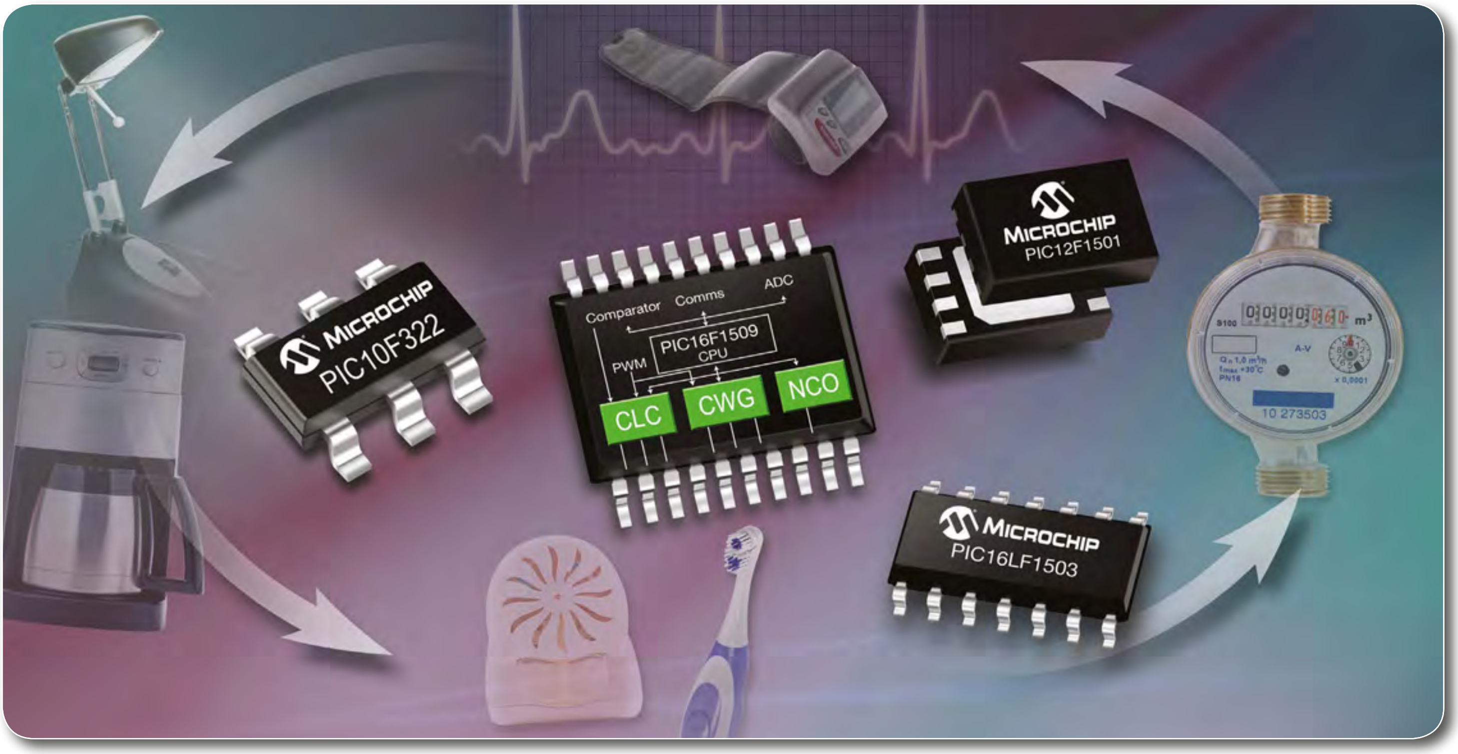

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By Mike and Richard Tooley

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

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

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

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

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

Coming attractions

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

This month, we shall be moving into the world of digital electronics with a useful item of test equipment that you will find invaluable for troubleshooting and general fault-finding. Our Logic Probe *will help you to diagnose faults on a wide range of digital circuits.*

The Logic Probe *combines both analogue and digital circuit techniques. The analogue part of the circuit is based on two comparators, while the digital part involves the use of a circuit that is able to detect a sudden change in voltage level (ie, a pulse) and stretch it so that its presence can be detected.*

We start our design notes with an explanation of the way in which 'logic levels' are represented by voltages in digital circuits.

Under the hood

The simplified block schematic of our *Logic Probe* is shown in Fig.1. The circuit is able to detect, and provide indications of, voltage levels that correspond to the logic 1 (*high*) and logic 0 (*low*) states for both CMOS and TTL logic. It is also able to detect and provide an indication of the presence of one or more narrow pulses, which might otherwise go undetected when using a more simple logic probe design. To aid portability, our *Logic Probe* is built into a small hand-held case and makes use of the power supply available from the circuit on test (more of this later).

Design notes – *Logic levels*

The voltage levels that we need to be able to detect are simply the range of voltages associated with the logic levels that represent the logic 0 (*low*) and logic 1 (*high*) states. It's important to note that the logic levels for CMOS logic gates differ markedly from those associated with their TTL counterparts.

In particular, CMOS logic levels are relative to the supply voltage used, while the logic levels associated with TTL devices tend to be absolute, as shown in Fig.2. Note that V_{DD} is the positive supply voltage associated with CMOS devices.

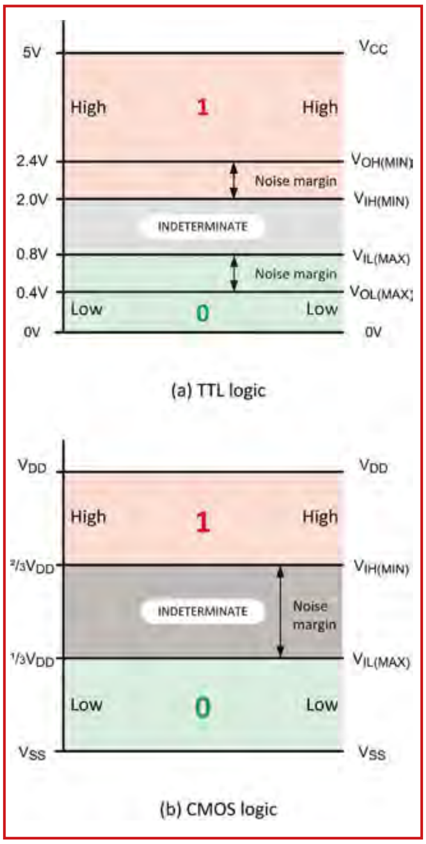


Fig.2. Logic levels for typical CMOS and TTL devices

It is well worth explaining Fig.2 in a little more detail, as this has a direct impact on the design of a logic probe that can be used with *both* of the major logic families. A standard TTL logic circuit will operate from a +5V power rail. Thus any voltage level greater than +2V is equivalent to a *high* or logic 1 state, whereas any voltage level less than +0.8V is used to represent a *low* or logic 0 state, as shown in Fig.2(a).

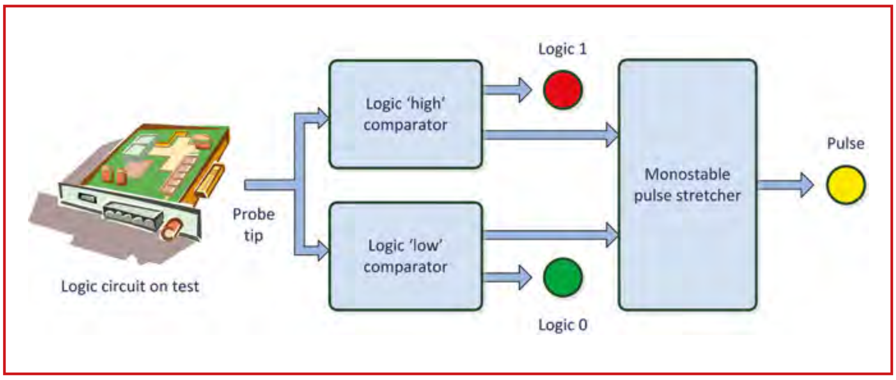


Fig.1. Simplified block schematic of our ***Logic Probe***

By contrast, CMOS logic is designed to operate over a wide range of supply voltages (typically between +5V and +15V). Consider the case of a CMOS logic device operating from a +9V supply. In such a circuit, any voltage level greater than +6V is equivalent to a high or logic 1 state whereas any voltage level less than +3V will be equivalent to a low or logic 0 state, as shown in Fig.2(b).

The high and low state comparators used in our *Logic Probe* will need to be designed so they are able to correctly distinguish between the high and low states used for both TTL and CMOS logic. This has to be something of a compromise but, in general, a low state range extending from zero to one-third of the supply voltage and a high state range extending from two thirds of the supply voltage to the supply voltage will work for both types of logic.

Noise margin

Finally, it's worth mentioning the *noise margin* (shown shaded in Fig.2). This is a measure of the ability of the device to reject noise; the larger the noise margin the better is its ability to perform in an environment in which noise is present. Noise margin is defined as the difference between the minimum values of high-state output and high-state input voltage and the maximum values of low-state output and low-state input voltage.

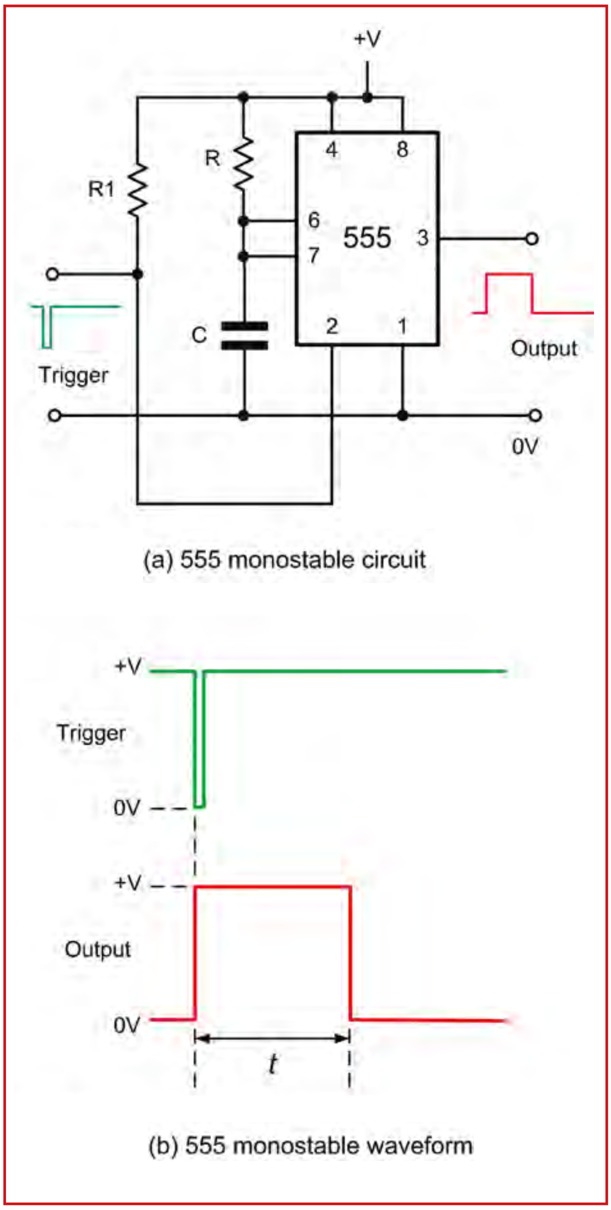


Fig.3. 555 monostable circuit and waveforms

Hence:

$$\text{noise margin} = V_{OH(MIN)} - V_{IH(MIN)}$$

or

$$\text{noise margin} = V_{OL(MAX)} - V_{IL(MAX)}$$

where $V_{OH(MIN)}$ is the minimum value of high-state (logic 1) output voltage, $V_{IH(MIN)}$ is the minimum value of high-state (logic 1) input voltage, $V_{OL(MAX)}$ is the maximum value of low-state (logic 0) output voltage, and $V_{IL(MIN)}$ is the minimum value of low-state (logic 0) input voltage. The noise margin for standard 7400 series TTL is typically 400mV, while that for CMOS is $\frac{1}{3}V_{DD}$, as shown in Fig.2.

Monostables

In many logic circuits, the logical conditions do not remain static but change all the time. Thus, as well as having to detect steady voltages (which can be either low, high or indeterminate) we also need to be able to recognise the presence of very rapid changes in logic state (pulses), which might otherwise go undetected.

This can be achieved by incorporating a circuit that can stretch a narrow pulse so that it is 'remembered' for a period of time that's long enough for it to produce a visible display. The circuit that we use is known as a *monostable pulse stretcher*.

Monostables (or *one-shots*) provide us with a means of generating precise time delays. Delays become important in a variety of logic applications and particularly where logic states are constantly changing.

The action of a monostable is quite simple – its output is initially logic 0 until a change of state occurs at its *trigger* input. The level change can be from 0 to 1 (positive-edge trigger) or 1 to 0 (negative-edge trigger). Immediately the trigger pulse arrives, the output of the monostable changes state to logic 1. It then remains at logic 1 for a pre-determined period before reverting back to logic 0.

A standard 555 timer, operating as a monostable, is shown in Fig.3. The monostable timing period (ie, the time for which the output is high) is initiated by a falling-edge trigger pulse applied to the trigger input (pin 2). When this falling-edge trigger pulse is received and falls below one third of the supply voltage, the 555 output (pin 3) goes high. The capacitor, C, then charges through the series resistor, R, until the voltage at the threshold input (pin 6) reaches two thirds of the supply voltage (V_{cc}) and the output (pin 3) then goes low, remaining in the low state until another trigger pulse arrives. The time for which the output remains high following the arrival of a trigger pulse is given by the relationship, $t = 1.1\ C\ R$.

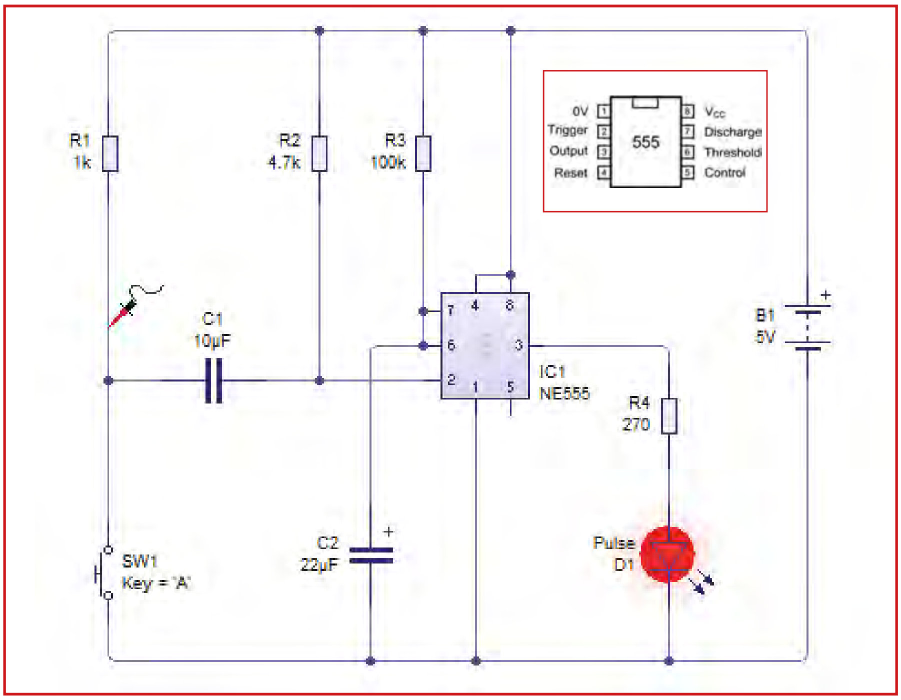


Fig.4. Using Circuit Wizard to check the 555 monostable circuit

Comparators

We've already seen how an operational amplifier (op amp) can be used to compare two voltages (see July *EPE* page 49 and November *EPE* page 49), and in this month's instalment we will be exploiting this principle again. If you need to know how a comparator works, just take a quick look back at these two previous issues of *EPE*.

Get real

You might now be ready to check the operation of a monostable circuit for yourself. Fig.4 shows a simple 555 monostable circuit displayed as a virtual circuit using *Circuit Wizard* (you might like to compare this arrangement with the circuit shown in Fig.3).

The problem of being able to generate a trigger input pulse can be easily resolved by using a pushbutton switch

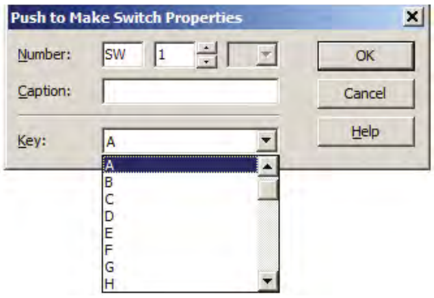


Fig.5. Assigning a key ('A' in this case) to the trigger input switch, SW1

and assigning a key to it, as shown in Fig. 5. The trigger-pulse waveform can be displayed using Circuit Wizard's virtual oscilloscope, as shown in Fig.6. When the assigned key ('A' in this case) is depressed (even if only momentarily) the LED (D1) will become illuminated for a time determined by the product of R3 and C2. You might like to check that the circuit and the formula quoted earlier really does work!

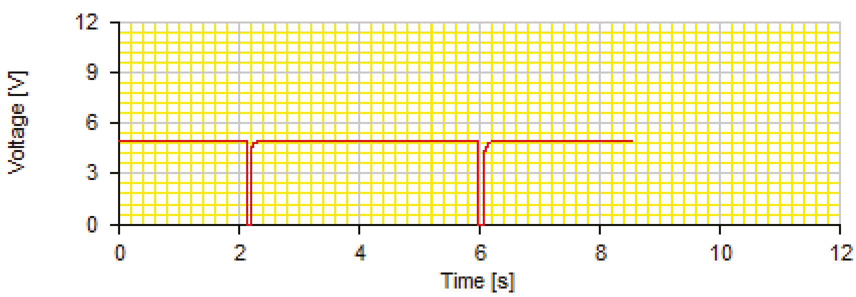


Fig.6. Momentary trigger pulses generated by switch SW1

Logic Probe – using Circuit Wizard

NOW we're ready to put our circuit into action. Our complete *Logic Probe* circuit diagram is shown in Fig.7. Note that, when converting to a printed circuit board (PCB), the variable voltage source is converted to a single pin for external connection), while the battery is replaced with a two-way PCB mounting terminal block.

Probe case

We want our logic probe PCB to fit into a small handheld probe case. These are readily available from electronic component suppliers like Rapid and RS, and are supplied with the metal probe 'pin'. The enclosure that we selected also includes a removable face plate, making marking out and drilling easier. Do be warned that some probe cases are very narrow and only allow enough space to fit a small, slim PCB; this may make designing a layout difficult or impossible using through hole components and depending on your skill.

If you'd prefer not to spend out on a pre-manufactured probe case, a simple and effective home-made probe case can be made from a short length of box section electrical conduit. A further alternative is to mount the PCB into a standard table top case and include a wired probe. Similarly, the battery is converted as a two-pin terminal block for connection to the power supply of the test circuit (see also later).

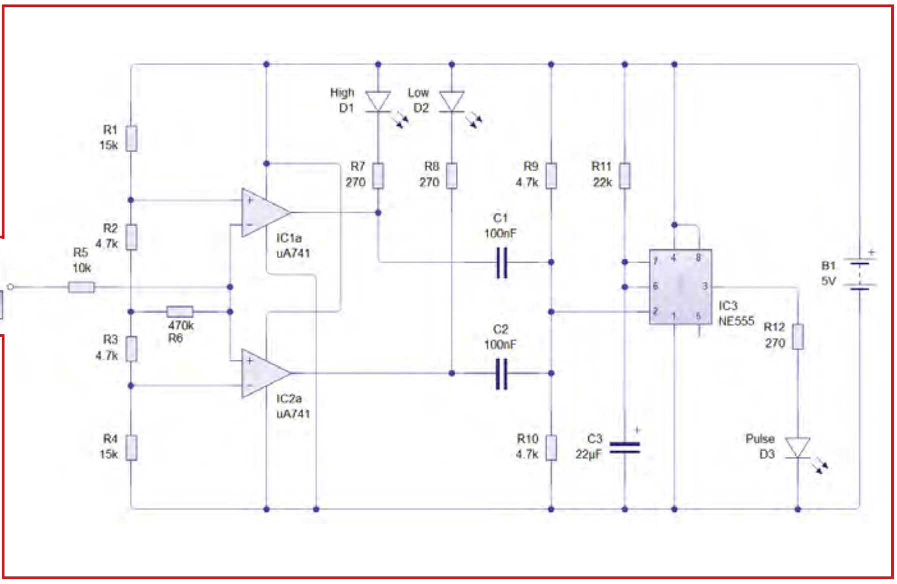


Fig.7. The complete circuit of our *Logic Probe*

Circuit board

In order to fit all of the components and connections onto a PCB small enough to mount into a small hand-held enclosure you will need to employ some of the design skills that you learned earlier in the series.

Producing a compact design requires a high component density (components mounted closer together to get more in to a given space) and thinner copper track widths. It's also more important than ever to use the space efficiently, taking extra care to place

You will need...

Logic Probe

1 PCB, code 887, available from the *EPE PCB Service*, size 70mm × 36mm
1 Two-way PCB mounting terminal blocks
1 PCB solder terminal pin
2 insulated crocodile clips (one black and one red)
3 8-pin low-profile DIL sockets
1 probe case, size 104mm × 44mm × 20mm (Rapid 31-0330)

Semiconductors
2 741 operational amplifiers (IC1, IC2)
1 NE555 timer IC (IC3)
1 Red LED (D1)
1 Green LED (D2)
1 Yellow LED (D3)

Resistors

2 15kΩ (R1, R4)	4 4.7kΩ (R2, R3, R9, R10)
1 10kΩ (R5)	1 470kΩ (R6)
3 270Ω (R7, R8, R12)	1 22kΩ (R11)

Capacitors
2 100nF 50V mini polyester or ceramic (C1, C2)
1 22µF 25V radial electrolytic (C3)

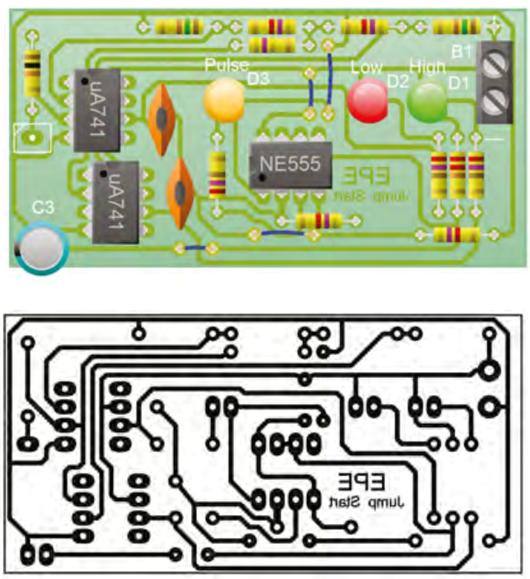


Fig.8. Printed circuit board (PCB) component layout and track layout viewed 'through' the board for the *Logic Probe*. Final size is 70mm × 36mm

the components appropriately prior to routing.

You will probably want to reduce the grid divisions in Circuit Wizard to permit more intricate routes and allow smaller track gaps. Of course, you always need to keep in mind that as you design more elaborate circuit boards with smaller gaps and tracks, this must be matched with more care and precision when you physically manufacture the board itself and this may impose limits depending on the quality of your processes. Our final PCB design in shown in Fig. 8.

In our prototype, the PCB was mounted modestly by using a short strip of double-sided foam pad. There is just enough height in the case to fit the taller components and therefore traditional feet/stand-offs would not be possible. When designing the circuit, we also allowed space for the tall capacitor C1 to be bent over at 90° towards the probe connection, so as to reduce the height.

A short piece of insulated wire was soldered to the probe pin, via a solder tag, as shown in our 'Photo Gallery'. You may need to pre-heat and/or tin the probe to make connection easier. Make this connection *before* attaching the probe to the case; do not attempt to solder the pin when 'in position' in the case as the metal probe will get hot enough to melt the plastic.

Power supply

We cannibalised a pair of crocodile clip leads to use for the power supply connections (black for negative, red for positive). This makes it really easy to clip it to a convenient point to pick up the supply on the test circuit.

Note that you must use the power supply from the circuit on test, as the probe does not have its own power source. It is also worth using a small plastic insert to provide strain relief for the two power leads at the point at which they exit the probe case.

Lowering the cover plate (drilled to accept the three LEDs) and then clicking it into place in the upper section of the probe case will ensure that everything is a snug fit when the two case halves are brought together. Finally, when connecting the *Logic Probe* to a circuit under test, it is essential to make sure that you observe the correct polarity!

Using the Logic Probe

We bring this instalment of *Jump Start* to a close with a brief introduction to using the *Logic Probe*. Fig.9 shows how a simple logic arrangement (in this example, a two-to-four line decoder) can be quickly and easily tested using the *Probe*. The expected truth table for our example logic circuit is shown in Table 1.

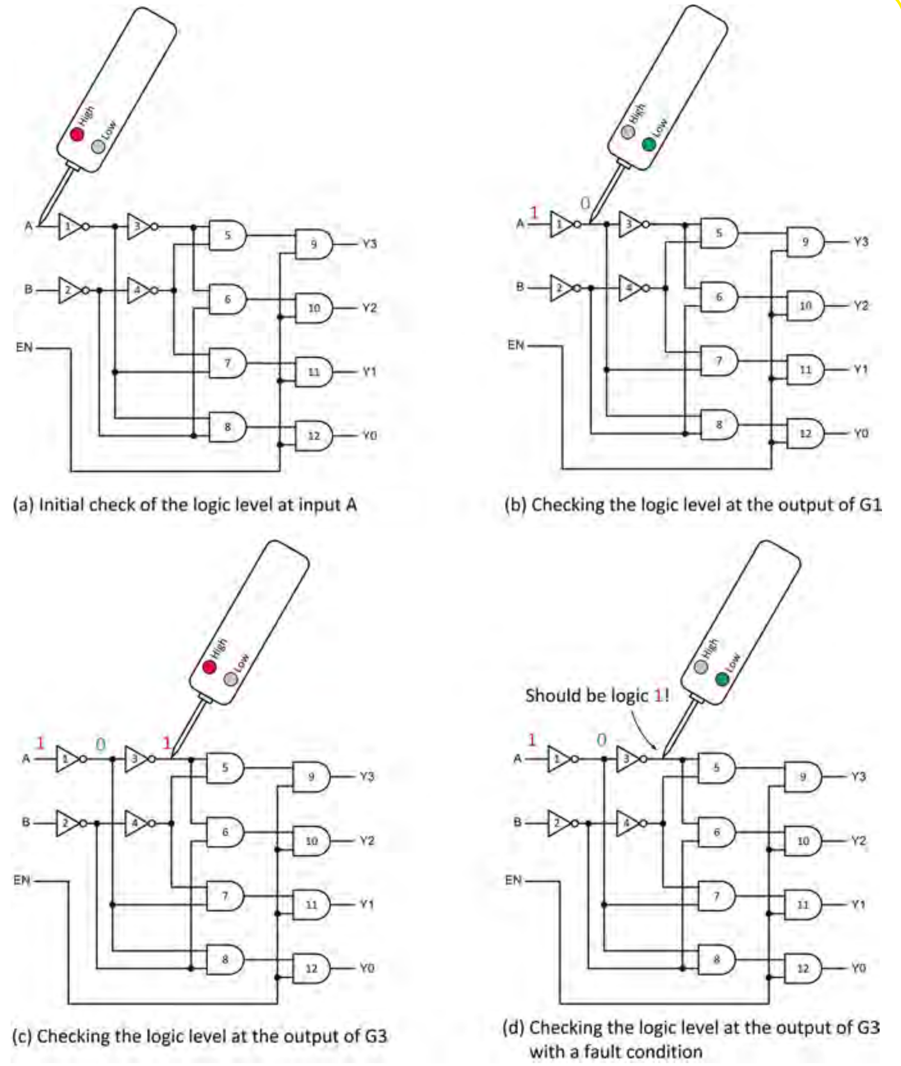


Fig.9. A two-to-four line decoder on test

Before any measurements can be carried out, the two power leads (red and black) will need to be connected to appropriate points on the circuit under investigation. The voltages supplied to the *Logic Probe* (0V and +V) must be the same as those used to power the logic circuit on test, and they MUST be connected with the correct polarity! Fig.10 shows a typical connection to a circuit, with the probe tip being connected to the particular point under investigation.

Point-to-point testing

In the example shown in Fig.9, the probe tip is moved systematically from point-to-point, starting at the input and moving towards the output. The logic level at each point is noted and compared with that which should be expected (see Fig.11).

In Fig.9(a) the probe tip is connected to one of the inputs which is found to be in the high (logic 1) state. In Fig.9(b) the probe tip is transferred to the output of the first logic gate (G1), which is found to be in the low (logic 0) state. Since G1 is an inverter this is what would be expected and it confirms that G1 is operating correctly.

In Fig.9(c) the probe tip is moved to the output of the next logic gate, G2. If this gate is operating as expected, the logic level at this point should once again be high (logic 1). However, if it is low (logic 0) as shown in Fig.9(d) this will indicate a fault condition in which either G3, G5 or G6 has developed a problem.

Table 1: expected truth table for the two-to-four line decoder

A	B	EN	Y3	Y2	Y1	Y0
X	X	0	0	0	0	0
0	0	1	0	0	0	1
0	1	1	0	0	1	0
1	0	1	0	1	0	0
1	1	1	1	0	0	0

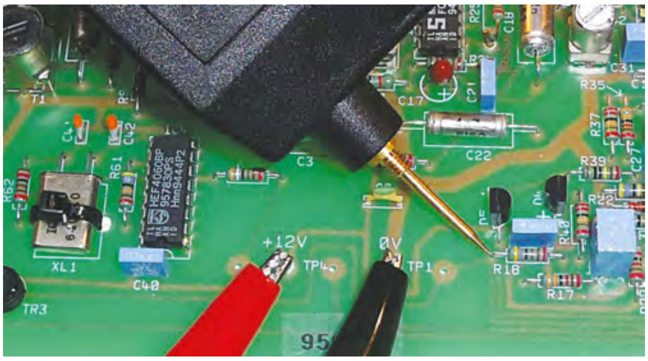
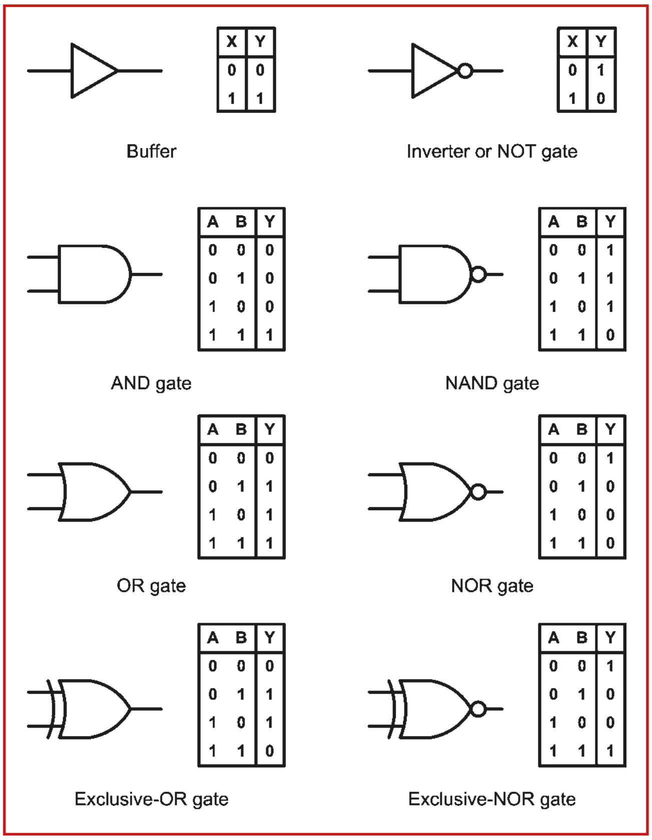


Fig.10. A typical connection to a logic circuit on test



Buffer

X	Y
0	0
1	1

Inverter or NOT gate

X	Y
0	1
1	0

AND gate

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

NAND gate

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

OR gate

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

NOR gate

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Exclusive-OR gate

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive-NOR gate

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

Fig.11. Truth table for some common types of logic gate

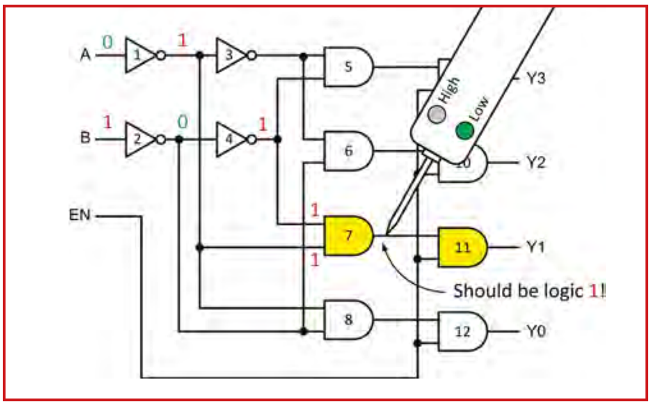


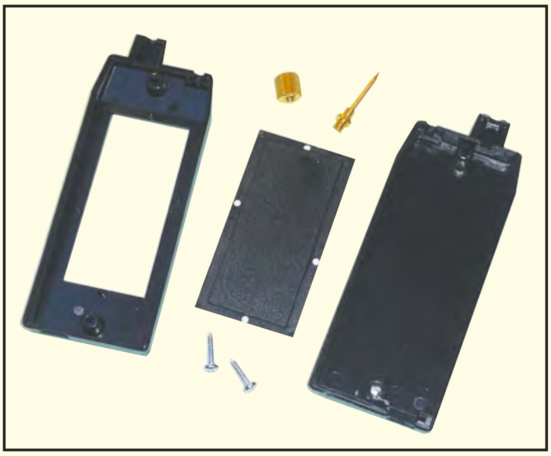
Fig.12. A further example of a logic circuit fault

A different fault is illustrated in Fig. 12. In this case, both of the inputs to the AND gate, G7, are in the high (logic 1) state, but the *Logic Probe* indicates that the output is low (logic 0). In this case, either G7 or G11 must be considered suspect.

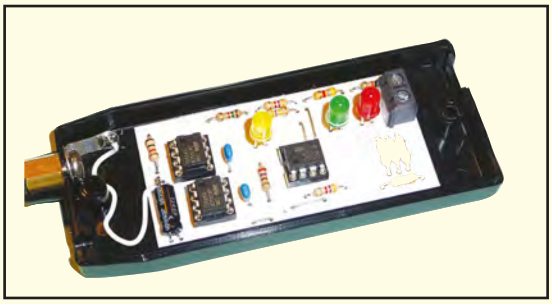
Photo gallery...

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

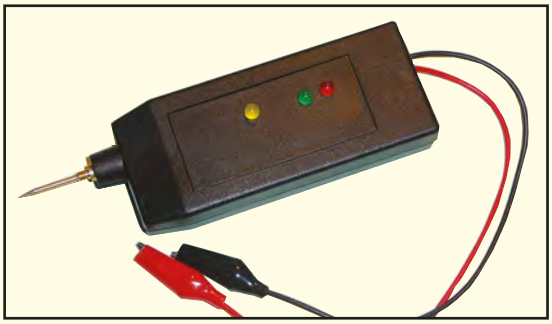
The techniques that we have used are available in nearly every secondary school and college in the country, and we believe that our series will provide teachers with a tremendously useful resource!



Case parts for the *Logic Probe*



PCB assembled in the lower case half. Note the probe solder tag and white lead to the circuit board

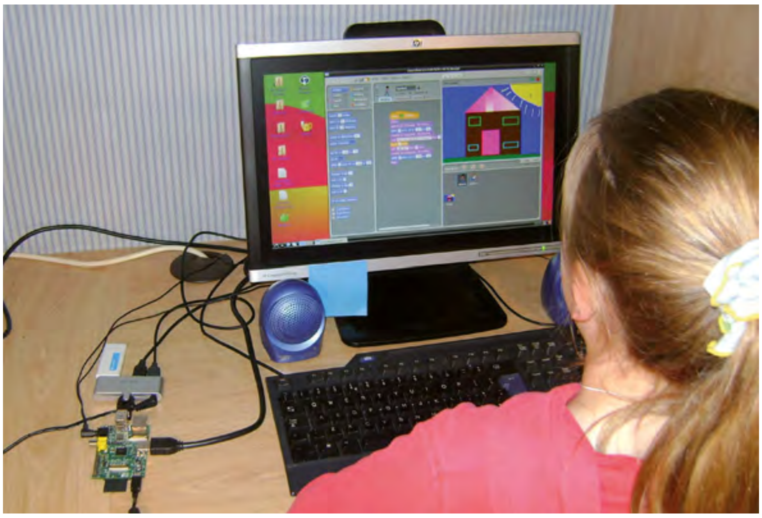


Assembled Probe ready for labelling

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

Next month

Next month we shall be describing a *Simple DC Motor Controller* that is ideal for use with a wide range of models and other motorised projects.



Raspberry Pi

Software investigation

Time for some Pi

Mike Hibbett

WE put the soldering iron away this month and investigate different software approaches for developing software on the Pi. We also take a look at recent developments in the Pi operating system and the hardware itself, explaining the issues found and improvements made.

PCB header

As you may have noticed over the last few articles, we are fans of the 'Slice of Pi' prototyping board. While it is very useful for putting together robust prototypes, you will at some point want to build your own boards. A key ingredient for doing that will be the 26-way header, shown in Fig.1.

It's been a difficult part to track down, but we have finally found a cheap supply. Available from Tandy (**www.tandyonline.co.uk**) part number 276-0000. At 69 pence each, and with a delivery charge of less than a pound, it's excellent value. Expect some more advanced hardware projects soon!

Hardware problems

One of the main complaints raised about the Pi has been with devices connected to the USB ports either not working or locking up after a short time. This has been tracked down to a pair of polyfuses in the USB supply rails. Polyfuses are self-resetting fuses, but have the unfortunate side effect of having a significant internal resistance. With USB devices, such as Wi-Fi dongles that draw large amounts of current, this caused the 5V supply to drop below the minimum level required by the attached device.

The fuses have been seen as 'overkill' by the designers, and the latest revision of the board has these fuses replaced by zero-ohm links. If you are comfortable with de-soldering SMD components, then this is a modification that you can do yourself – or simply solder-bridge across the parts. It's a little challenging and not something we are prepared to do until our second Pi arrives!

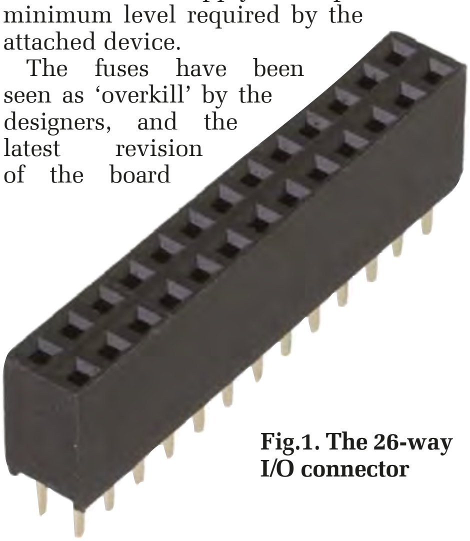


Fig.1. The 26-way I/O connector

Memory upgrade

The latest version of the Pi is now fitted with 512MB SDRAM rather than 256MB, and this will be the most significant change that people will notice. We will report on the impact of this additional memory next month (assuming our device arrives in time. Delivery times are still unpredictable.)

The new board also comes with an additional, smaller I/O header (P5) and a two-pin socket for a reset switch (P6), as shown in Fig.2. For our hardware designs we will stick with the original 26-way header, so as to support all Pi owners. Expect the older 256MB versions of the Pi to become available on eBay as people rush to swap their 'older' models for the new revision. Hopefully, the price of these lower memory Pis will reduce as they are seen as inferior for use as a PC. For embedded projects, where a GUI is not required, they will, of course, be perfectly adequate.

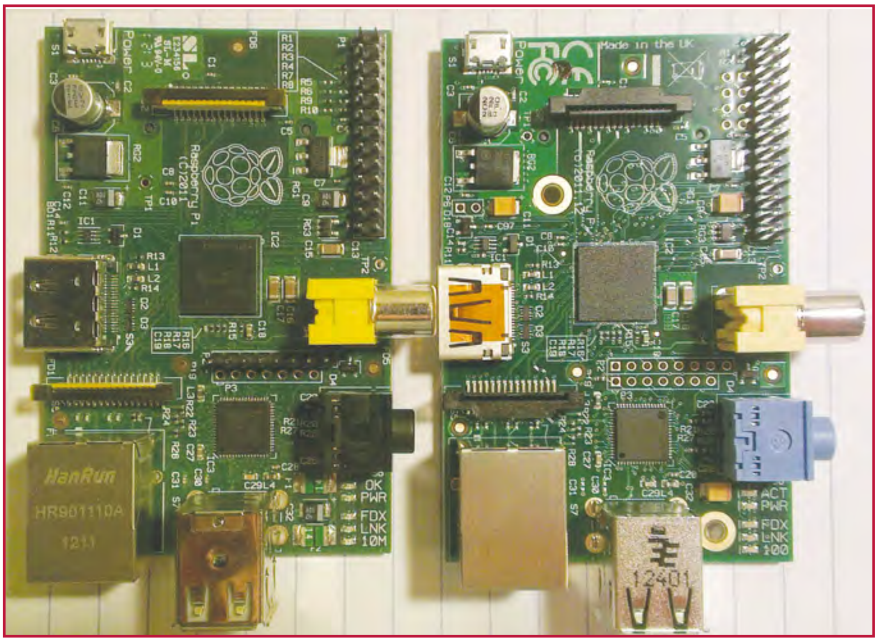


Fig.2. The new Pi – new on the right, old on the left

The new version of the Pi is referred to as 'Raspberry Pi Model B Rev 2.0'. It's available now from Farnell and RS. Delivery dates are still variable however, and you are advised to check before placing an order. The cheaper Model A (which comes without the Ethernet interface and a single USB port) is scheduled for release in 2013.

As a final point on hardware this month, we can expect a camera module to become available soon. This promises to be a very interesting peripheral because it connects directly to the processor rather than through USB – so it should be fast, and low power. This will be of particular interest to us because we are looking to create a battery-powered night-time wildlife video recorder. Watch this space!

New OS image

October 2012 saw the release of an updated Linux distribution for the Pi, called 'Raspbian Wheezy'. This release makes use of the hardware floating point co-processor within the Pi's ARM SOC (system on chip). Previous releases used software instructions to emulate the co-processor, reducing the speed at which floating point calculations can be made. This has a noticeable effect on the speed of graphical applications.

Using software to perform floating point calculations is a common approach for ARM software development, since not all ARM processors contain a hardware floating point co-processor. As the Pi does, the Raspbian Wheezy image is a welcome upgrade.

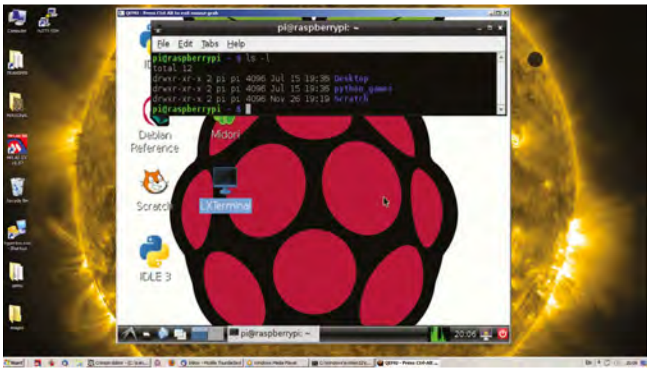


Fig.3. The processor simulator QEMU running on a PC

Development environment

While it's quite a novelty developing software directly on the Pi, it does have several drawbacks. First and foremost, it's very slow. Unless you have a high quality LCD monitor the text quality is poor and strains the eyes after just a few minutes. Another concern is that compiling programs results in a high level of writes to the SDMedia card, which can wear it out – potentially in a few months of intense use. And as your code is stored on the SDMedia card, that's a risk if you cherish your work and don't back it up frequently.

There are several reasons why it's slow; the processor is running at only 700MHz, there is relatively limited SDRAM (for a desktop computer) and, more significantly, the 'harddisk' is a slow Flash memory device connected over a serial interface. It's amazing that it works as well as it does.

For the development of very simple programs, this is not a significant issue, but as your designs become more challenging, a faster and more enjoyable method is required. Fortunately, there are several alternative techniques available, and some of them are easy to set up.

Processor simulation

It's not necessary to possess a Pi to run the operating system and develop software for it. 'Processor Simulator' programs exist that can run ARM programs, translating them into the native PC processor instructions. They also provide a simulation of a video interface, keyboard, mouse and network interface to a level of accuracy that means the Raspbian Wheezy Linux image will boot up without modification.

This has been done for the Pi using the processor simulator QEMU, which is freely available. There are a number of projects on the Internet that have packaged QEMU with the Pi's boot image; one of them can be found at: **http://sourceforge.net/projects/rpiqemuwindows/**

You can see an example of QEMU running the Pi image in Fig.3.

There are drawbacks to using a processor simulator. First, it's very slow – slower even than the Pi itself. Second, it does not support the peripherals on the Pi's I/O header.

Processor simulation is a poor alternative to developing on the Pi itself, but if you would like to explore the software on the Pi before buying one, it's better than nothing.

Cross compilation

Cross compiling refers to the technique of writing and building software for a processor that is different to the processor used on your development machine. It's how we develop software for microcontrollers – the code you create can only run on the target processor.

This is the fastest and most convenient way to build software for the Pi, but it does require you to download the software to the Pi once it is built (just as you do with a PIC microcontroller.) Fortunately, as the Pi is such a powerful system this is quite easy to do with a network connection between the Pi and your PC.

The cross compiler is simply the gcc compiler tool set, built to run on the PC, but instructed to generate ARM output code. Configuring gcc to do this is a complex job best left to the experts, and at the time of writing this article there are a number of projects on the Internet attempting to achieve this. A cross-compiler has already been made available for people using Linux-based PCs; for those of us who use Microsoft Windows, it's still a work in progress. We will report on progress later in the year.

Remote terminal session

The easiest approach (and the approach we are using at the moment) is to store and edit the code on a PC, transfer the source files to the Pi and then run the compiler on the Pi itself. Although this does not solve the 'wear' concern for the SDMedia card, it does mean that you can back up your source code on your PC, and use your favorite editor.

To set up a remote terminal development environment, we start by installing the latest version of the Pi operating system, Wheezy. There are a few other tools that we need too, so we will install those at the same time. All of these are free, and available on the Internet.

Several of these installation steps will require administrator privileges on your PC, so make sure you are running in an admin account before starting. Once the software has been installed you may return to a standard user account if you wish.

The latest Pi OS image can be downloaded from the Pi Foundation website at: **www.raspberrypi.org/downloads**. Although a zip file, it's large at 500MB, but on a broadband link it takes just a minute or two to download. Once downloaded, extract the single **.img** file inside it to the desktop.

The image must be copied to the SDMedia card using a special program; you cannot simply copy it to the card using normal Windows tools. We use the Win32DiskImager application to do this. The link to the program is on the Foundation download page too. Once downloaded, extract the contents to a sub-directory somewhere convenient. We will probably need this again in the future, so don't delete it once we have finished.

Connect your SDMedia card to your PC through any interface adaptor and run the Win32DiskImager.exe application. Select the correct drive letter for the SDMedia card and click the folder icon to navigate to the Pi **.img** file. Select the file, and click 'Save'. Now click the 'Write' button, followed by 'Yes'. The write will take up to a minute, so be patient. Click on 'Exit' when done, and then remove the SDMedia card.

To run and download programs remotely to the Pi, we need two applications – a remote terminal application and a file transfer utility. We are going to use two simple utilities Putty and WinSCP. There are many other programs available, we've chosen these for simplicity of use and familiarity.

Putty is a simple single executable file. It can be downloaded from: **www.chiark.greenend.org.uk/~sgt atham/putty/download.html**. Download it to a convenient location.

WinSCP is a GUI file transfer program, with a user interface that looks like a standard file explorer. It can be downloaded from: **http://winscp.net/eng/download.php**, selecting the 'Installation Package'. Once downloaded, run the program, which presents a standard installation dialog. (On the 'WinSCP recommends' dialog you may want to disable the two Chrome add-ons it recommends, unless you really want a new browser installed. We didn't.)

We now have all the tools we need. It's time to set them up.

Environment set up

We need to set the Pi up to enable remote access. On first starting the Pi with a new image – as we are about to do – the Pi will display a handy configuration screen. From here select the 'SSH' option, and select 'Yes'. You may also want to enable the 'Start desktop on boot?' option, to automatically run startx at power up, but it's not necessary. Cursor down to the bottom of the list, then press the right cursor key to select finish. The Pi will now reboot.

To connect to the Pi, we will, of course, need some kind of network connection. The simplest way is to connect the Ethernet interface of the Pi into a router, such as your broadband access router if you have one. By default, the Pi is configured to automatically request a network address from a router, and it is a simple case of rebooting the Pi once you have made the connections to have it join your home network.

To discover what network address has been assigned to your Pi once it has started up, open a terminal shell on the Pi and type the command:

ifconfig

The command will list details of your two network connections, 'eth0' (the Ethernet connection) and 'lo' (an internal local loopback connection.) Under eth0 look for the line starting with 'inet addr:'. The network address will follow this text. It should look something like **192.168.1.67**.

Logging in remotely

Now we have the Pi configured for remote access and we know it's address on our home network, it's time to get connected.

First, we will start a remote terminal shell. Start the Putty program, and in the dialog that is displayed (see Fig.4) click

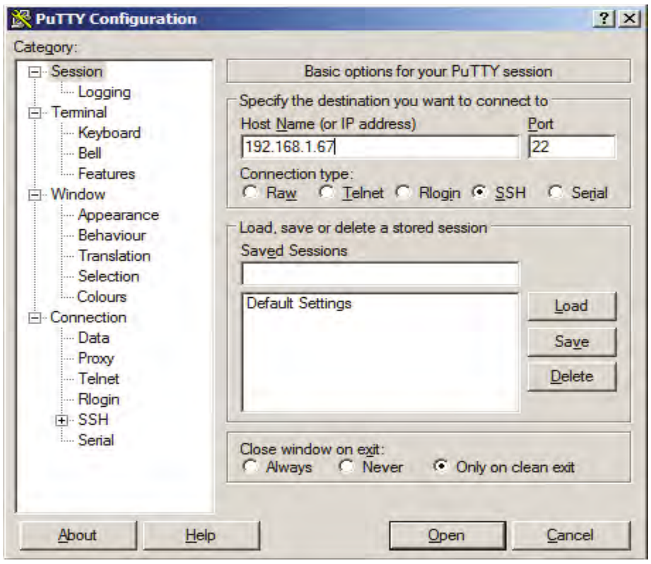


Fig.4. Configuring the Putty program

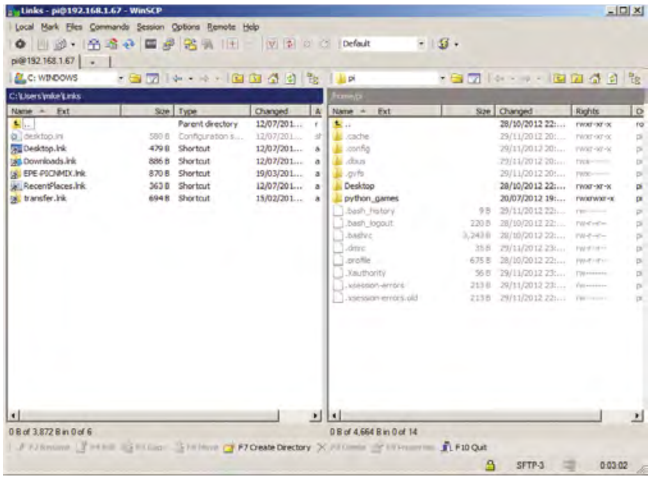


Fig.5. Running WinSCP

on the 'SSH' radio button and then type the Pi's network address into the 'Host Name' field. Then click 'Open'. You may be warned about a 'key' on first connection; you can ignore this warning for now, as we are connecting through a local home network.

You will be presented with a request for username and password; these are whatever you have set for your standard 'pi' account login (the password is 'raspberry' by default.) Once entered, you will see a terminal window identical to that displayed on the Pi itself. You can run programs from here and navigate through the file system as normal; the only restriction is that you cannot run the GUI – that only runs on the Pi's display.

So, we can now compile and run programs – but if we are editing our source files on the PC, how do we get them *to* the Pi? This is where WinSCP comes in.

If you start WinSCP you will be presented with a dialog very similar to Putty. Enter the Pi's network address in the 'Host name' field, and then the username and password in the fields below. After clicking 'Login', you will again be presented with a warning about keys; just click 'Yes' to continue. You will then be presented with a familiar file explorer dialog, as shown in Fig.5. Files may be dragged in either direction between the Pi and the PC.

Software development is now a breeze – store and edit your source files on the PC, drag them to the Pi using WinSCP, and then compile and run them through the Putty terminal window. We've found this a far more pleasant development environment, and results in less clutter on the table – no need for two screens, two keyboards and two mice. You are still developing the software on the target device – the Pi – but editing and backup of your source code is now much easier to do.

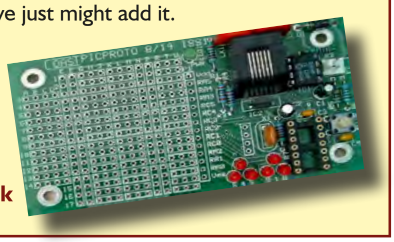
Advanced debugging

Developing software on the target device – either directly, or via a network connection – does allow for some advanced debugging techniques. Just as we have a debugger built into MPLAB for looking at the internals of our program when it's running on a board, Linux has a similar tool, called GDB. This program provides similar capabilities to MPLAB's debugger, allowing breakpoints to be added to the program under test. Variables can be viewed or changed, and information about the general state of the processor can be interrogated.

It's not as easy to use as MPLAB, but is well worth investigating. We will dedicate an article or two to GDB later in the year. GDB can run on the Pi itself, but a Windows PC version is also available that can debug a Linux program across a serial or network connection, and it makes an excellent companion to Putty and WinSCP.

Next month

Next month, we will look at how to get your program to start automatically on power-up, and take a closer look at the new 512MB Pi.



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PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Reducing power consumption

IN last month's article we looked at how interrupts, though difficult to set up, can make our programming tasks easier. We showed how they could consign unessential tasks to the background, de-cluttering the main application. In the real world, interrupts play a much more vital role in ensuring that a system is responsive and draws as little power as possible – conserving battery power on mobile phones, and minimising heatsinking requirements on desktop computers.

Microcontrollers (which by their nature are low-speed, low-power devices) perform relatively simple tasks, typically running a 'main loop' control program that continually spins round a loop looking for triggers, such as variables changing values, that cause it to temporarily branch off to some other subroutine. The processor is running continuously, spending most of it's time doing nothing worthwhile.

If a laptop or standard desktop were to run continuously like this it would quickly overheat and shut down. (It's a rather sad indictment of modern computer design – you may think you are buying a 1.8GHz quad core laptop, but it can only provide that power in very short bursts.)

Power play

Power management is one of the many facilities provided by an operating system, and a programmer should make use of it to ensure that the system as a whole remains responsive when their program is running. While this is of no concern for hobbyists with relatively small microcontroller projects, where our designs have total control of all CPU resources (ie, we do not have to worry about how well other programs run), using those resources appropriately does become important when low power consumption is an objective.

Using processor resources in a power efficient manner requires a mind-set change for the developer more used to running the processor continuously at full speed, reacting to changes in the 'state' of the system such as a key press or time intervals occurring. The guiding principle is to keep the processor effectively switched off, turning it on only to respond to changes in the state of the system and then immediately turning the CPU back off.

A common concern when this approach is discussed with beginners is 'but my system is constantly updating the display, I can never turn the CPU off!' This miss-understanding is born from our biologically limited perception – a system that updates the display once every 100ms may appear to be reacting continuously, but as it may take the CPU only a few milliseconds to write to the display, the processor is actually idle for more than 95% of the time. We forget just how quickly a microcontroller can accomplish the tasks we set it, and overlook how much time it spends idling in 'busy wait loops.'

To take advantage of this idle time and enable the processor to fall into a low power mode, CPU manufacturers provide a number of hardware features on-chip. Used in conjunction with a revised approach to software design, these can increase the battery life of a design from hours to days or even months.

The processor we are currently experimenting with comes from the 'nanoWatt XLP' family – clearly emphasising the low power nature of the device. But this low-power does not come enabled 'out of the box' – we have to incorporate the features into our design, right from the point of creating the circuit if we want to make the most of them.

Power consumption

Before we look at these features, let's take a look at the sources of power consumption in a processor, referred to as *static* and *dynamic*.

Static power consumption is due to the leakage current that flows through each and every transistor within a microprocessor IC when it is held in the 'off' state. Although this leakage current is tiny, there are tens of thousands of transistors in even the smallest processor, and these leakage currents add up.

Dynamic power consumption refers to the temporary surge in current flow as transistors switch modes (such as when a flip-flop changes it's output level from high to low). The size of this current is related to the transistor's gate capacitance and the rate at which it is switching.

In both cases, the higher the voltage, the higher the power consumption.

There is nothing we can do about the static power consumption or the transistor's gate capacitance, so the only variable we have to play with is the switching rate. In summary, when the processor is not required to perform any calculations, turn the clock off, and you will get minimum power consumption.

That's great in theory, but turning the clock off means that timers will not run, serial ports won't receive data, and so on – not very useful to a real world application! So, to solve this dilemma, processor manufacturers have added hardware features to let us have a range of partial shutdown options, so we can choose what is best for us – typically a compromise option, depending on your design requirements.

CPU features

The most significant contributor to power consumption is the system clock. When your code is running, tens of thousands of transistors are switching, millions of times per second. Turning this clock off will have a major impact. Unfortunately, it will also have a major impact on the ability to process any events, so there are a number of clock operation modes made available – RUN, IDLE and SLEEP.

RUN is the normal operating mode when the processor is executing instructions. IDLE is where the clock to the CPU is turned off, but the clock is still provided to the hardware peripherals of the device – which means the serial port will still receive data, timers will still run and analogue-to-digital conversions can still take place. In SLEEP mode, the clock is turned off completely, which means the only peripherals that function are the external interrupt pins, (and the on-board watchdog timer, if enabled.)

Entering the low-power mode is a simple case of calling the SLEEP instruction. To enter IDLE mode rather than SLEEP, set the bit IDLEN in the OSCCON register before calling the SLEEP instruction.

Waking from sleep

On waking from the SLEEP or IDLE mode, the CPU will start executing instructions immediately following the SLEEP instruction. So what causes the wake up? Interrupts. Any enabled and active interrupt source will cause the processor to wake up. If the GIE bit (global interrupt enable) is set then the corresponding interrupt routine will be called first. If the bit is cleared, execution will proceed with the instruction immediately following the SLEEP instruction.

What interrupt source you need to be the trigger to wake the processor up will determine what sleep mode you can use. If it will be an external interrupt (such as a button press) then you can place the processor in full SLEEP mode; if you want to wake periodically from a timer, then you must use IDLE.

```
main:
    movlw    0x00
    movwf    TRISB ; Set PORTB as an output
    movlw    0x70
    movwf    OSCCON    ; Set processor to run at 8MHZ

    movlw    TOGGLE_LED_TIME
    movwf    delay_1s

    bcf      INTCON, TMR0IF
    movlw    HIGH TMR0_COUNT_1S
    movwf    TMR0H
    movlw    LOW TMR0_COUNT_1S
    movwf    TMR0L
    movlw    TMR0_CONF
    movwf    T0CON    ; Start the timer
    bsf      INTCON, TMR0IE
    bsf      INTCON, GIE

loop:
    goto     loop

    end
```

```
main:
    movlw    0x00
    movwf    TRISB ; Set PORTB as an output
    movlw    0x70
    movwf    OSCCON    ; Set processor to run at 8MHZ

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    movwf    TMR0H
    movlw    LOW TMR0_COUNT_1S
    movwf    TMR0L
    movlw    TMR0_CONF
    movwf    T0CON    ; Start the timer
    bsf      INTCON, TMR0IE
    bsf      INTCON, GIE
    bsf      OSCCON, IDLEN

loop:
    sleep
    goto     loop

    end
```

Fig.1. Source code, before and after

Testing it out

Let's return to our example circuit and software design from last month – a simple LED flasher. To re-cap, this circuit is a basic processor with an LED attached, which is flashed once every 10s by an interrupt routine. The 'main loop' is a simple busy loop that does nothing. You can see the code in Fig.1, on the left.

For a design like this, the choice of low-power mode is simple – it uses a timer to wake periodically, so we must use IDLE. The corresponding code changes are very simple too in this case, and are shown on the right in Fig.1 – the addition of just two instructions.

We did a simple current measurement before and after by inserting a DVM in the supply to the board. In the original example it consumed 2.44mA when the LED was off. In the second example, taking advantage of the IDLE mode, it consumed 1.16mA. No change in operation of the system, but a significant power saving. Don't be fooled by a reduction of 'only' 1.28mA – this is a reduction *to* 1.28mA. If you were running the processor at a higher clock speed, the difference would be even greater.

Obviously, this is a contrived example, and with the addition of alternative clock sources, the time lag in starting different oscillator types and the multitude of interrupt sources this is a complicated subject, but the rewards can be considerable. It does require careful planning at the early design stages to address how you can keep the processor in a low-power mode for as long as possible.

It is possible, however, with examples like ours, to make significant differences in current consumption without major surgery on one's design.

Further improvements

Controlling the processor power consumption in the processor is not the end of the story. To achieve the lowest current consumption it's also necessary to look at the rest of the circuit.

If you have an LCD attached, consider controlling the supply to the LCD from a FET switch. Ditto for radio modules – it's not enough to hold a radio module in reset; stick a FET switch in series with the supply. It may take a few tens of milliseconds longer to power up, but if you are only sending data once a minute or so, the power saved can be significant.

Even flashing LEDs can have an impact – consider using higher value series resistors, and experiment with the width of the pulse that you apply to the LED to illuminate it. The less power your circuit consumes, the more important current sources like these can be.

If your circuit is drawing an average current of, say, 100mA then an LED drawing 10mA for half a second every ten seconds is not significant. However, if your average current consumption is 100μA (quite possible with a PIC microcontroller design) then the average current consumption of that LED does have an impact – it's average current consumption is $10000 \times (0.5/10)$ μA, which is 500μA – five time more than the rest of your circuit!

Designing circuits and software for minimal current consumption can become a fun intellectual challenge in it's own right, and Microchip provide a vast range of tools for you to play with.

We've only touched on the options available for reducing current consumption; the more advanced technique involves making use of the multitude of oscillator options available. Even on our device, you can run the CPU from an internal RC oscillator, external crystal oscillator *and* an external watch crystal oscillator, and you can make use of all three in your design if required.

The watch crystal oscillator is the more interesting option, as it runs at a very low frequency (32kHz) and the drive circuit has been optimised for very low power – specifically to enable battery-powered devices that require an accurate time source. We will pick up on this in a future article, when we add a real-time clock circuit to our board.

Sleep time

As a final point, an obvious question about designing for low power circuits is: 'is it better to run off a slow clock, or run off a fast clock?' This is asked in connection with a design that may wake up periodically to perform some operation and then return to sleep.

Should you run fast, at high power, and then quickly return to sleep, or run at a slower clock rate and take longer before returning to sleep? We did some research on this in the 1990s and found that running at high speed resulted in the lower average power consumption. Possibly due to the increased quiescent power consumption that is constant while running the CPU.

If you are looking for ways to improve an already well-designed low-power system, reducing the supply voltage is the simple answer – even if it means putting a diode in series with the supply rail.

May you enjoy fewer battery purchases!

Circuit Surgery

Regular Clinic

by Ian Bell

Rectifier circuits

THIS month we have a question about rectifier circuits posted on *Chat Zone* by ***quornhog***

Some circuits for mains adaptors use a pair of diodes for rectification, others use a bridge rectifier. How do I decide which method to use?

In response, we look at various arrangements of transformer and diodes which can be used for obtaining unregulated DC voltages from the mains. To produce illustrative waveforms for the circuits discussed in *Circuit Surgery*, use is often made of circuit simulations.

Typically we employ LTSpice, a tool which is also used by a number of regular *Chat Zone* contributors. In this case, we encounter the issue of using transformers in the simulation – you will not find a transformer in the list of LTSpice components. Therefore, this article will discuss creating transformers in LTSpice, as well as looking at some rectifier and related circuits.

A step-down

Mains supplies in most countries are AC, with voltages of either around 110V to 120V, or around 220V to 240V, and with frequencies of either 50Hz or 60Hz. For many applications, we need much lower DC voltages, so we need to step down the mains voltage and convert it to DC. As indicated in the question, the conversion of AC to DC is called *rectification* and is typically achieved using one or more diodes.

Traditionally, voltage step-down is provided by a transformer connected to the mains; however, this is not the only approach. It is possible to make transformerless step-down supplies using resistive or capacitive voltage dividers, particularly for applications with low current demands. Diodes are still used for rectification.

Transformerless circuits are lighter, smaller and lower cost than transformer-based designs and are, therefore, popular in commercial products. Lower voltage supplies can also be made using switch-mode techniques, but this is not really relevant to quornhog's question.

The downside, however, is that transformerless supplies provide much less isolation from the mains than trans-former-based circuits and therefore, present a potentially higher risk to the user. There is also greater risk of component damage from voltage spikes on the mains. Touching any part of a transformless circuit may result in shock.

This should not be an issue when used in suitable commercial designs, which are fully encapsulated, and where appropriate safety measures are included in the circuit. However, for home-brew designs the reduced safety MUST be seriously thought through. For these reasons we will only consider transformer-based circuits in this article.

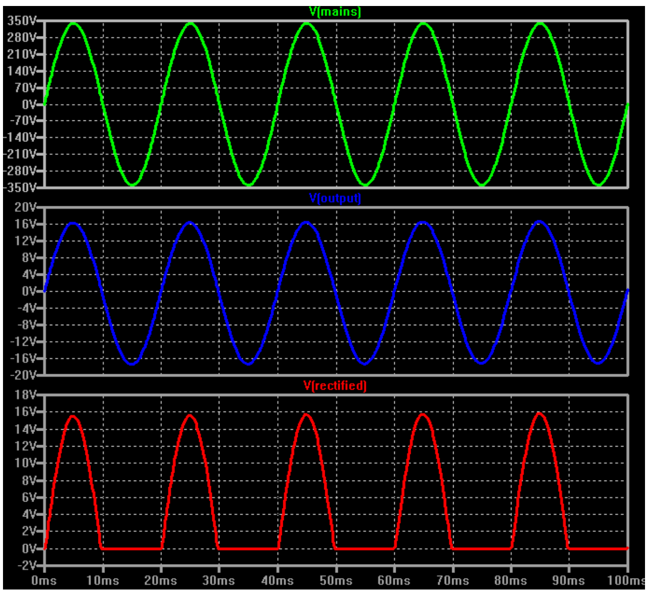

Fig.2. Half-wave rectifier simulation waveforms

Basic rectifier circuit

The most basic transformer and rectifier circuit is shown in Fig.1. This only uses one diode and is known as a *half-wave rectifier*, because only half of the AC waveform is involved in producing the DC output.

The diode, D1, only conducts in one direction, so current only flows into the load when output A of the transformer is positive with respect to output B. This occurs during one half of the AC cycle, so the load receives a series of half-sine-shaped pulses.

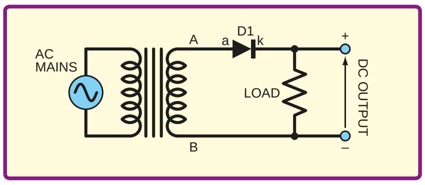

Fig.1. Half-wave rectifier circuit

The simulated waveforms are shown in Fig.2. The upper (green) trace is the mains. The middle (blue) trace is the transformer secondary output, and the lower (red trace) is the rectified output.

As indicated, simulating the circuit in Fig.1 is perhaps not as straightforward as with many other basic circuits. This is because you will not find a transformer listed in the components and circuit elements available in LTSpice. You have to build the transformer from individual inductors. We will explain this in a moment. The LTSpice circuit used to obtain the waveforms is shown in Fig.3.

LTSpice simulation

For the benefit of readers not already familiar with it, the LTSpice analogue circuit simulator can be downloaded free in its full form from the Linear Technology website at: **www.linear.com/designtools/software/**.

The 'Spice' part of the name refers to the acronym Simulation Program with Integrated Circuit Emphasis – a *de-facto* industrial standard for computer-aided electronic circuit analysis,

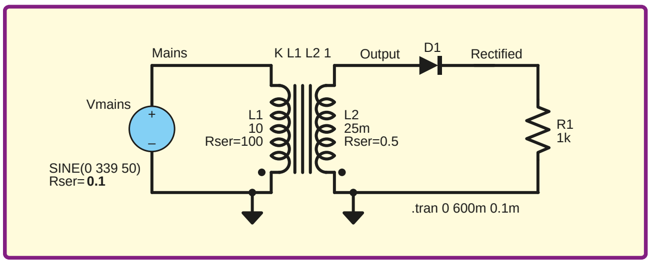

Fig.3. LTSpice simulation schematic for Fig.1.

with many commercial versions. It was originally developed in the early 1970s at the University of California, Berkeley. There is plenty of LTSpice tutorial material available online to get you started if you have not used it before.

To create a transformer for simulation in LTSpice, put an inductor on the schematic for each winding (L1 and L2 in Fig.3). You will probably need to rotate the symbols and move the labels around to get everything in the right place for a conventional transformer symbol (but the relative position of the inductors on the schematic does not change the simulation).

When placing the inductors, it is useful to be able to see the phase dot, which is not shown by default. You can opt to show it by right clicking on the inductor symbol. The ends of the windings with the dot will be in phase when the inductors are coupled to form a transformer. This is particularly important when dealing with a transformer with multiple or centre-tapped secondary windings.

As LTSpice does not have any transformer symbols, you will have to draw lines for the core lines manually if you want them on the schematic (use draw from the edit menu and select line). You may need to set the line type to solid. By default, the lines may snap to the drawing grid, which may be too far apart; holding down the Control key while moving the lines will override the snap-to-grid, allowing the core lines to be more closely spaced.

As we are using individual inductors to create the transformer, there is no way of directly specifying turns ratio (there is no 'turns' parameter in LTSpice). The inductance of the windings must be set in proportion to the square of the turns ratio.

So, for example, a mains transformer with a 240V primary and a 12V secondary, which has a turns ratio of 20 (=240/12), will require two inductors with an inductance ratio of 400 (=20^2). If the primary inductance is 10H the secondary needs to be 25mH. These are the values used in Fig.3 – they are not meant to represent the actual values of a particular real transformer, as we are aiming for a close to ideal model here.

Mutual inductor

We couple the inductors together using a mutual inductor Spice directive (command statement) – this creates a transformer from what would otherwise be completely independent inductors. To do this, click the **.op** button in the schematic editor tool bar. This will open a window in which you can type the text of the command. When you click OK, you can place the Spice directive on the schematic.

The mutual inductor directive starts with the keyword 'K' followed by a list of all the inductors involved (separated by spaces). You can couple several inductors in one statement, not just two. If you have multiple individual transformers in a circuit, use K1, K2, K3, etc for each separate transformer. The final item of the statement is the coupling coefficient, which indicates how well coupled the inductors are. This is a value ranging from 0 (uncoupled) to 1 (perfectly coupled).

Linear Technology advise starting all simulations with the coupling coefficient equal to 1, adjusting it later if needed. In our case, we can stick with 1, particularly as real iron-cored mains transformers have very good coupling.

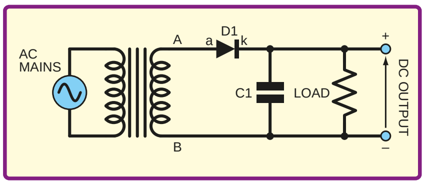

Fig.4. Half-wave rectifier with smoothing

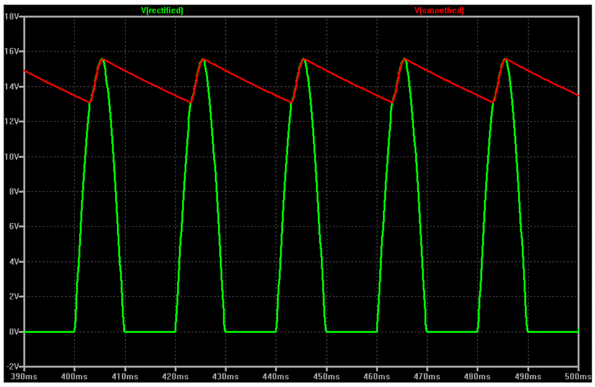

Fig.5. Smoothed waveform from circuit in Fig.4 (red trace) together with unsmoothed output from circuit in Fig.1 (green trace)

To couple two inductors, L1 and L1, to form a transformer the Spice directive is:

K L1 L2 1

Adding the mutual inductor statement causes the phase dot to be shown automatically, if this was not already done manually.

Mains modelling

The mains can be modelled as a voltage source configured to produce a sinewave of 50Hz or 60Hz as appropriate. The voltage specified for the mains is RMS (root mean square), whereas LTSpice requires the peak value. You need to multiply the RMS mains voltage by √2 (square root of two = 1.4142) to get the peak voltage (amplitude). For example, for 240V RMS mains use 339V amplitude in LTSpice. For a 12V RMS secondary output we would expect about 17V peak.

We want to look at waveforms, so we need a transient simulation – this is set up by 'edit Simulation Command' from the Simulate menu. One cycle of a 50Hz wave takes 20ms, so a simulation time of 100ms should be sufficient to see a few cycles. However, it is better to run it for longer in case the circuit takes a few cycles to settle. Unexpected long-term changes may also indicate problems with the simulation set-up, so it is useful to be able to see this.

If you simply connect an LTSpice voltage source to an inductor and run a transient simulation, you will get an error: 'Voltage source Vxxx and inductor Lxxx are paralleled making an over-defined circuit matrix.' There has to be some resistance in the circuit for it to be solvable by LTSpice.

This is easily achieved by right clicking both the voltage source and primary winding inductor, and setting the series resistance via the pop-up window. The example in Fig.3 uses the following series resistances: 0.1Ω for the voltage source, 100Ω for the transformer primary (L1) and 0.5Ω for the secondary (L2). These are noted on the schematic using comment text.

These values are not an attempt to accurately model the mains or a real transformer. These values just help LTSpice simulate a near-ideal transformer, to which we can connect our rectifier circuits.

If the secondary circuitry is left isolated (floating) then again you will get an error message when you try to simulate: 'Singular matrix: check node xxx. This circuit has floating nodes.'

There is a fundamental rule in Spice simulations that every point in the circuit must have a DC path to ground. This can be achieved by placing a ground in both the primary and secondary circuits (as shown in Fig.3) or by connecting the secondary to ground by a very large resistor. However, the latter approach can create unwanted long time constants.

Rectifier circuit

Having sorted out the simulation, we can return to discussing our rectifier circuit. The circuit in Fig.1 produces a series of pulses – certainly not what we would think of as continuous DC supply. To overcome this we need to store some of the energy from the pulse and release it to the load during the gaps, hopefully keeping the DC voltage constant.

This is referred to as *smoothing*, and is easily achieved using a capacitor connected across the rectified output, as shown in Fig.4. Fig.5 shows simulated waveforms for Fig.4, with C1=1000µF, superimposed on the original unsmoothed waveform.

The smoothed waveform shown in Fig.5 is much more like a DC voltage than the output from the circuit in

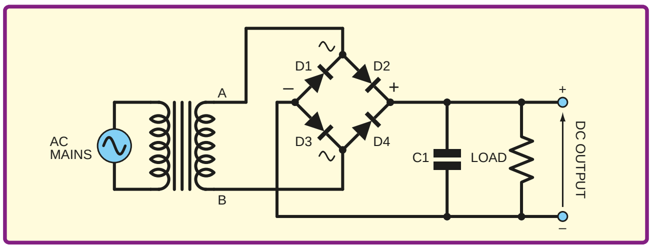

Fig.6. Full-wave bridge rectifier with smoothing

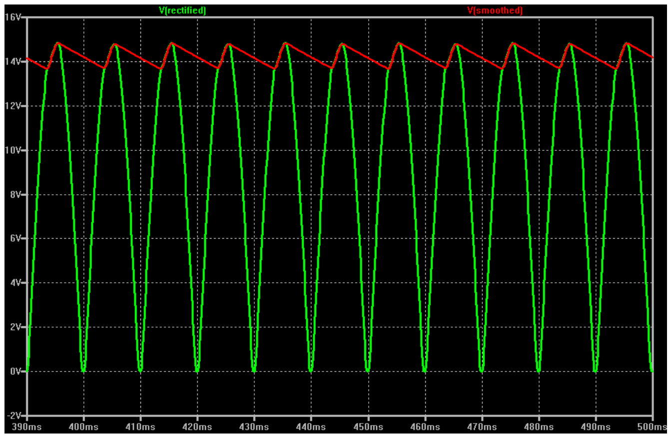

Fig.7. Smoothed (red trace) and unsmoothed (C1 removed, green trace) waveforms for full-wave rectifier circuit in Fig.6

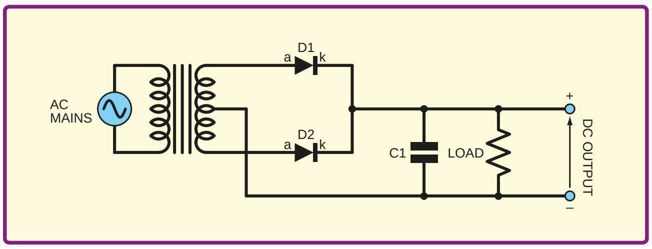

Fig.8. Bi-phase full-wave rectifier with smoothing

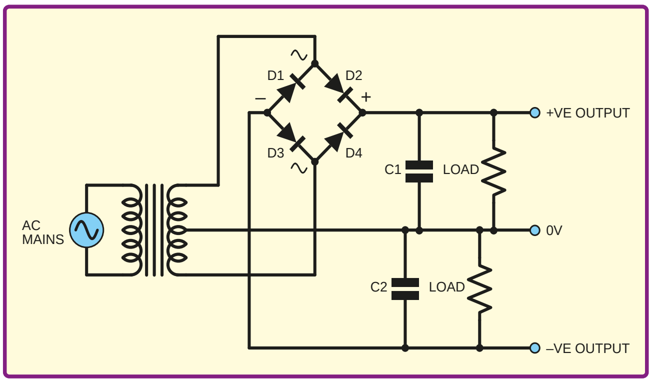

Fig.9. Centre-tapped bridge rectifier providing dual (+/-) DC supplies

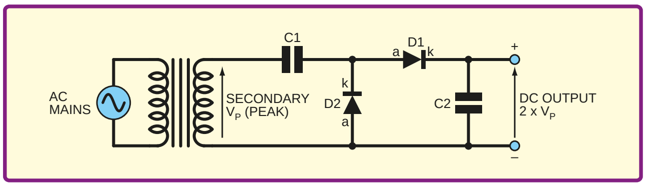

Fig.10. Voltage doubler circuit

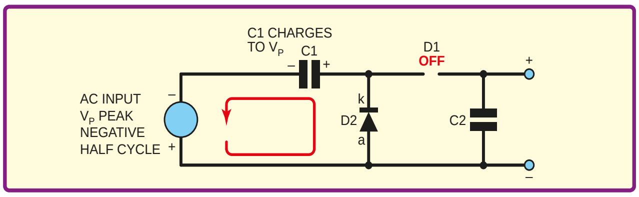

Fig.11. Voltage doubler during negative half cycle

Fig.1, but it still does not look very smooth. This variation in DC voltage is called *ripple*. The ripple voltage – which is defined as the difference between the maximum and minimum DC output – will increase if the load current increases, or if the capacitor value is reduced. We can estimate the ripple for the half-wave circuit using the formula:

$$V_{ripple(HW)} = \frac{I}{fC}$$

Where *I* is the average load current (A), *f* is the mains frequency (Hz) and *C* is the smoothing capacitor value (F). For example, for the circuit in Fig.4, with a 12V RMS secondary, C1=1000µF, *f*=50Hz, and an average current of around 140mA (14V across 100Ω), the formula gives the ripple as 2.8V.

Measurement of the waveform using LTSpice's cursors gives 2.4V (right click the waveform name to activate the cursors). The discrepancy is because the formula ignores the time the smoothing capacitor spends changing and assumes the discharge is linear (actually it is exponential).

Full-wave rectifier

The ripple can be reduced using a full-wave rectifier. This can be achieved by using four diodes in bridge rectifier configuration, as shown in Fig.6. On positive half cycles of the mains, when point A is positive with respect to point B, diodes D2 and D3 conduct. On negative half cycles diodes D1 and D4 conduct. Thus, a DC pulse is occurs on every half cycle (there are no gaps between pulses, as in Fig.5). After smoothing, the ripple output has twice the frequency of a half-wave circuit.

Fig.7 shows the simulated output waveforms for the circuit in Fig.6. It should be clear by comparison with Fig.5 that the ripple is about half that of the half-wave circuit because the capacitor discharges for half the time before charging again. The approximate formula for full-wave ripple is:

$$V_{ripple(FW)} = \frac{I}{2\,fC}.$$

It is possible to make a full-wave rectifier with just two diodes if you have a centre-tapped transformer. The circuit is shown in Fig.8. This is known a centre-tapped full-wave, or bi-phase full-wave circuit. This is effectively two half-wave circuits on opposite phases (hence the bi-phase name) and, therefore, only uses half of the transformer secondary at any one time (the full-wave rectifier uses the whole secondary all the time). To simulate this circuit in LTSpice you would need three mutual inductors as each half of the centre-tapped secondary would require a separate inductor.

The circuits in Fig.6 and Fig.8 may account for quornhog's observations of circuits using either two or four diodes. The single diode half-wave circuit is rarely used due to its inefficiency.

Fig.9 shows another basic rectifier circuit. This uses a centre-tapped transformer and bridge rectifier (four diodes) to provide both positive and negative DC outputs.

Voltage doubler

Using diodes and capacitors we can do more than just rectify the AC voltage to DC voltage near the peak AC value. It is possible to make voltage multiplying networks which produce a DC output at a multiple of the peak AC voltage (doublers, triplers and quadrupler can be made). Fig.10 shows one example of a voltage doubler circuit.

To understand voltage multipliers it helps to consider a couple of basic facts. First, an AC voltage connected to a capacitor via a diode will charge the capacitor to the AC peak voltage during one half cycle of the AC. The diode will be reverse biased in the other cycle and so the capacitor will store the charge, retaining the voltage across it. Second, if we already have a capacitor which has been charged in one half-cycle, then (if we arrange the circuit right) the voltage stored on the capacitor will be added to the AC input voltage during the other half cycle. Thus we obtain a maximum voltage in the circuit of two times the AC peak voltage

Fig.11 shows the currents in the voltage doubler during the negative half cycles of the AC input. Capacitor C1 is already charged to the peak voltage via Diode D2 during this half cycle. Diode D1 is off, so C2 is unaffected, but can supply current to any load. Fig.12 shows what happens in the positive half cycle. Here C2 (which carries the output voltage) is charged via Diode D1 by both the AC input and the voltage on C1 (which together sum to two-times the peak voltage, Vp).

The voltage doubler output will not reach 2 × Vp on the first positive half cycle, it will take several cycles to reach the final output voltage, recovery from a loading peak will also take a while. This can be seen in the simulation of the circuit in Fig.10, shown in Fig.13. This uses the same transformer set up as Fig.3. The diodes are ideal, the capacitors are 100µF and there is a 10kΩ load across R2.

The voltage doubler can be cascaded to give further multiples of voltage, a circuit which is known as the 'Cockroft-Walton' multiplier. Care *must* be taken when using voltage multipliers to make sure that the diodes and capacitors have sufficient voltage ratings to withstand the multiplied voltages.

Voltage multiplier circuits do not give very good regulation and perform poorly with high loads. They are typically used for applications where high voltages are required at reasonably low currents, or where some ripple can be tolerated.

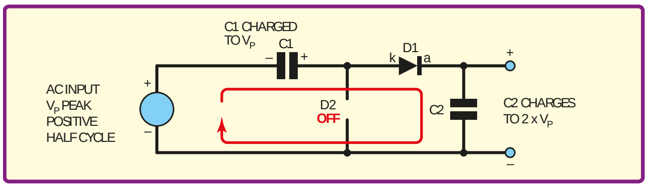

Fig.12. Voltage doubler during positive half cycle

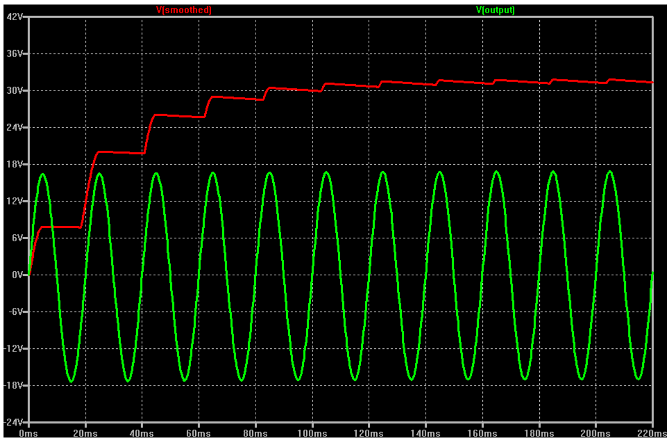

Fig.13. Voltage doubler simulation

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By Robert Penfold

INTERFACE

Computers and the real world – sensing water and people

THE world of computing seems to be increasingly dominated by the virtual world, with virtual this, that, and the other being released to the market all the time. However, many of the most useful computer applications require computers to deal with reality, and this month we continue with the theme of sensors that enable computers to deal with the real world.

Impure thoughts

One of the simplest types of sensor is one that enables water to be detected. Detecting pure water is relatively difficult, since it is a poor conductor of electricity, but water in the real world tends to be more accommodating. It usually contains small amounts of impurities that increase the conductivity to a level that makes detection very easy. Rain and tap water both contain sufficient impurities to make them easy to detect.

The most basic form of water detector is a simple DC circuit that relies on a sensing element consisting of two electrodes separated by a small air gap. The resistance between the two electrodes is normally very high due to the high resistance of air at low voltages. Any water bridging the two electrodes, other than the distilled variety, will produce a much lower resistance between the electrodes.

The exact resistance depends on factors such as the size of the electrodes, the gap between them, and the amount of impurity in the water. It could be anything from a few ohms to a few megohms, and would typically be a few kilohms. The exact resistance is not important, since it can easily be distinguished from the massively higher resistance produced with air between the electrodes.

A circuit as simple as the common emitter switch of Fig.1 is sufficient for a simple DC water detector. With air between the electrodes there will be no significant base current flowing into TR1, and only minute leakage currents will flow between its collector and emitter terminals. The output of the circuit is therefore high (logic 1) in this standby state. With water between the two electrodes, and even if there is still a resistance of a megohm or so between them, the base current flowing into TR1 will be sufficient to switch it on and take the output low (logic 0). Resistor R1 protects TR1 from an excessive base current if a very low resistance or short-circuit is placed across the electrodes.

This type of circuit works well enough in the short term, but it has the drawback of poor long term reliability, due to corrosion of the electrodes. The impurities in the water that make it slightly conductive can also produce corrosion, and the current passing through the system can also increase the problem due to electro-migration.

There can also be problems with bubbles caused by electrolysis tending to insulate the electrodes. I suspect that these are problems that occur mainly if the electrodes will be wet for much of the time, and are less troublesome if they will only become wet infrequently and for short periods.

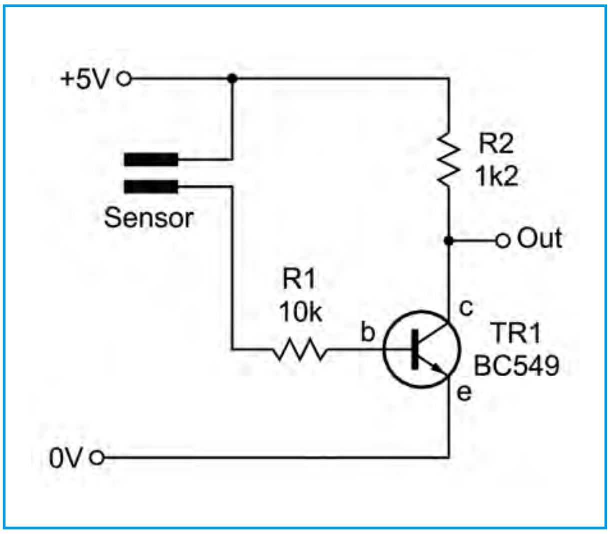


Fig.1. A water detector can be as simple as two metal electrodes and a common emitter switch. However, a DC circuit such as this might not work well in the long term

Alternating alternative

Anyway, for greater long-term reliability it is generally deemed better to use an AC system. I cannot see how this would help with the electrolysis problem, so it would still be advisable to clean the electrodes from time to time in order to ensure that the sensor continues to work well. Presumably, the main point of using an AC system is to reduce the problem of electro-migration eating away the electrodes. Although an AC water sensor cannot be quite as ultra-simple as a DC type, it only requires some uncomplicated and inexpensive electronics.

In the past, there was at least one water detector chip in the form of the National Semiconductor LM1830N, but this seems to have been discontinued. I used the alternative single chip approach of Fig.2, and this circuit is based on an inexpensive CMOS 4001BE quad 2-input NOR gate.

In this circuit, each of the four gates has its two inputs connected together so that a simple inverter function is obtained. Gates IC1a and IC1b form a simple astable (oscillator) circuit that operates at somewhere in the region of 200Hz, but the exact operating frequency is unimportant. The output signal at pin 4 of IC1b is a squarewave signal.

This signal is fed via C2 to the sensor electrodes, and the output signal from the sensor, if there is any, is fed by way of C3 to a rectifier and smoothing circuit based on D1 and D2. Of course, with no water present between the electrodes the only coupling through the sensor will be due to its tiny amount of capacitance. This is too low to be of any significance at the operating frequency used here, and there will be no output from the rectifier and smoothing circuit.

With water between the electrodes there will be some coupling through to the rectifier circuit, and due to the high value of R2 in the smoothing circuit, a strong coupling will be obtained even if the resistance through the water is many kilohms. In fact, the coupling will be sufficient to produce a strong positive output voltage from the smoothing circuit, even if the water resistance is around a megohm or so. This voltage is fed to a simple non-inverting buffer stage based on IC1c and IC1d. The output from the circuit is therefore *high* if water is detected, or *low* if no water is present on the sensor.

Bear in mind that the 4001BE used for IC1 is a CMOS device and it therefore requires the normal anti-static handling precautions. The prototype circuit worked well using ordinary silicon diodes for D1 and D2, and any general-purpose silicon diodes should suffice. However, there is possibly some advantage in using a type that has a low forward voltage drop, such as Schottky or good quality germanium diodes.

Sensor

It is important that a suitable material is chosen for the electrodes in the sensor. Using an AC circuit avoids increased

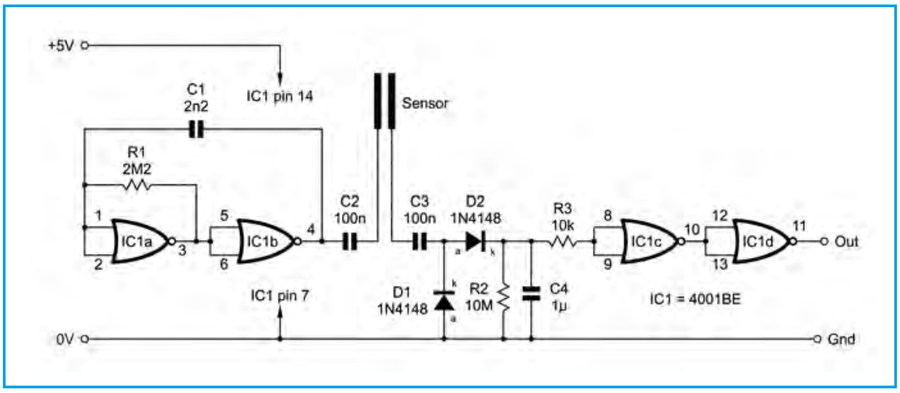


Fig.2. The circuit for a simple AC water sensor. The four NOR gates in IC1 are all used here as inverters

corrosion of the electrodes, but it does not protect them from it. For reliable long-term operation the material used still needs to be resistant to corrosion.

Printed circuit boards and stripboard are sometimes used as the basis of water sensors, but the copper tracks are very vulnerable to corrosion. Something like rods or strips of stainless steel, or galvanised nails represent better choices. Having relatively large electrodes placed close together increases the chances of detecting water that has low levels of impurity.

Hot stuff

Optical sensors for detecting objects, including people, have been covered previously. These days, the most popular choice for people detection is the passive infrared variety, which is almost, but not quite, a form of optical sensor. The infrared used by these systems is at the lower frequency end of the infrared range, and well away from the visible light spectrum. It is body heat that they are designed to detect, and the maximum heat output from a human is at wavelengths from around 8µm to 14µm.

A couple of points should be borne in mind when dealing with this type of sensor, and the most obvious one is that they will only detect people, or something else that is producing significant amounts of heat at suitable wavelengths. Unlike optical sensors, they are unsuitable for most types of general object detection. The second point is that they are motion sensors, and will not detect suitable sources of infrared that are stationary or moving very slowly.

Some passive infrared sensors can have a single sensing element, but in most cases they have two in a balanced arrangement that reduces problems with background infrared. In use, the dual variety must be mounted so that the sensing elements are side-by-side, and not one above the other. The detected infrared signal is then swept across the sensor in a way that activates one element and then the other, and not both together, which would give little output signal.

With the aid of a suitable lens, it is possible for a high degree of sensitivity to be obtained, and for a large area to be covered. This type of thing can be something of a mixed blessing though, leaving the system open to numerous 'false alarms'. A fox or badger walking by on the opposite side of the road seems to be sufficient to set off the security light of one of my neighbours! This is technically very impressive, but means that the light is switched on for much of the time.

Hot and cold

For many applications, and particularly for indoor use in normal size rooms, a more basic approach will often suffice. Something as simple as a piece of tubing to narrow the sensor's angle of view might be sufficient, or a sort of miniature Venetian blind made from cardboard and used vertically should give good results.

For the system to work, it is essential that someone moving across the sensor's field of view produces at least one well defined change from cold to hot and back to cold again. The sensors usually have a fairly wide field of view and will be largely ineffective without some outside assistance. A little experimentation will probably be needed in order to get the desired result.

The circuit of Fig.3 should work with any normal three-terminal passive infrared sensing device, such as one from the Chartland Electronics range (RE200B). These devices normally have some form of field effect transistor (FET) buffer stage at the output. Resistor R1 is the load resistor for this stage, and is not essential if the sensor is a type that has a built-in load resistor.

The output signal from the sensor will not be very large, and is unlikely to be more than a few millivolts peak-to-peak. A large amount of amplification is, therefore, needed to bring the signal to a more useful level. This is provided by a two-stage common-emitter amplifier based on TR1 and TR2, which gives a voltage amplification of around 1000. If necessary, the gain of the circuit can be increased by reducing the value of R8.

In this application, it is only very low frequencies at around 0.5Hz to 3Hz that are of interest. Capacitors C3 and C5 are therefore used to reduce the gain of the circuit at higher frequencies. This gives a lower noise level and reduces problems with instability due to stray feedback.

IC2 is an operational amplifier (op amp), but in this circuit it is used as a voltage comparator. Its non-inverting (+) input is fed with a preset reference voltage from VR1, and its inverting (–) input is fed from the output of TR2. Preset VR1 is adjusted to give a reference voltage which is a little higher than the voltage at the output of the amplifier. This results in the output of IC2 going high under standby conditions, which in turn switches on common-emitter switch TR3 and sends the output of the circuit low. TR3 is used as a level converter that gives the circuit an output at normal 5V logic levels.

The voltage at the output of the amplifier varies either side of its quiescent level when the unit is activated, and on positive output half cycles this results in the inverting (–) input of IC2 being taken to a higher potential than the reference level at the non-inverting (+) input. This sends the output of IC2 low, and the output of the circuit high.

The circuit will still work if the reference voltage is set a little below the voltage at the output of the amplifier. However, the output of the circuit will then be high under standby conditions and will produce low pulses when the unit is activated.

Avoid setting the reference voltage too close to the amplifier's output voltage, since doing so will give problems with spurious triggering. Both integrated circuits are MOS devices and require the standard anti-static handling precautions.

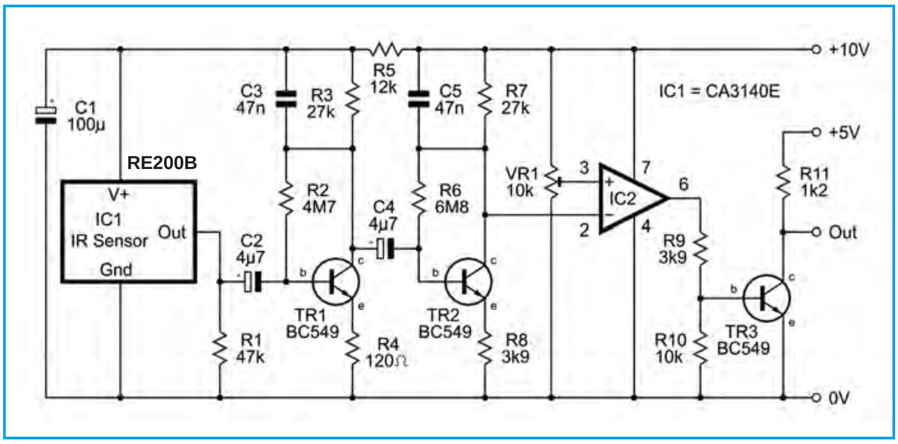


Fig.3. The circuit for a person detector based on a passive infrared sensor. It actually detects changes in long wavelength infrared radiation (heat) and is a form of motion detector

NET WORK

by Alan Winstanley

Fair trade!

ENGLAND is a nation of shopkeepers, so said Napolean Bonaparte, but what about the shoppers themselves? In last month's *Net Work* I questioned the behaviour of shoppers who use a bricks-and-mortar retailer to check over some goods, or maybe waste retailers' time on in-store demonstrations and advice, before making their excuses to leave and buying the exact same merchandise online instead. This poor behaviour is called 'showrooming' and it hurts small independent traders the most.

The savage pricing of online vendors, coupled with the recession, have made the lure of the Internet more irresistible than ever. As I reckoned last month, probably no one under 35 will understand why 'showrooming' is an unethical and ultimately self-defeating way of carrying on. At that rate, independent retailers will be disincentivised from staying in business at all, as it will become unviable to offer shoppers the luxury of browsing around a store, treating it like a public attraction, before they go and source merchandise on the web instead.

Shopping habits are changing drastically and online trading has had an irreversible effect on our society. As a UK business owner, I have bought US graphics software downloaded from a German server, but the invoice originated from the Netherlands and it had an Irish VAT number. Where is the transaction actually 'done', and what are the tax implications for global Internet-based companies? Thanks to the web, the world has become a whole lot smaller, but the tax regime has failed to keep up, although EU sales tax changes buried traders under even more bureaucracy. European VAT regulations and statistics are very onerous to deal with, and the penalties for non-compliance harsh.

Political showboating

In Britain, a Parliamentary Select Committee has been investigating the levels of business tax paid into the UK economy by multi-national companies (MNCs). Some soft juicy targets include Starbucks, Google and notably Amazon. This has been an ideal opportunity for British politicians to grandstand: there is much talk of MNCs not 'playing fair', being 'unethical' and 'immoral' and – worst of all – not paying what they loosely call 'the right amount of tax'. A business owner will reply that business is business, and each MNC retorted that they have obeyed the law and paid everything that has been asked of them anyway.

In the 1990s, well before Amazon arrived in the UK and Germany, I would import parcels direct from Amazon USA. Amazon invested epic amounts of cash during their start-up phase, when the press carried doleful reports of how it had burnt through yet more cash. Predicting the likely demise of Amazon became a sport, but the company persevered and has become the success that it is today.

Much more than a bookstore, it has enriched most people's lives in our Internet age, offering myriad products delivered to our door, MP3 music downloads, cloud storage, industrial data processing services, and also enabling small businesses to operate their own storefronts on Amazon Marketplace. One small trader I know is doing a roaring trade thanks entirely to Amazon.

The naïve accusations of 'tax evasion' being stoked up against Amazon and other MNCs are making enormous profits coupled with wilful tax avoidance by offshoring their business. The popular cry is that, in doing trade in Britain, the British deserve some tax revenue. What, then, would taxpayers like to see? More tax, obviously. Perhaps they had a large donation in mind then, because until tax 'fairness' is quantified in law, who can say how much is fair? MNCs including Google and Amazon are highly gifted in creating tax-efficient practices and none of them has been accused of breaking any law. Until the politicians change their own tax regime, it is no use them, nor 'showrooming' consumers, complaining about loopholes in their own tax system and boycotting Amazon or Google in the meantime.

W7 Mobile Device Centre settings: showing as 'Not Connected', which will allow Internet sharing

Phoned home

Always-on Internet access that many of us enjoy today is, like most utilities, something that is taken for granted until it goes wrong. The ADSL broadband service operated by BT was founded on good old copper wires, the cost of which have probably been bought many times over by BT subscribers over the years. The cables are often decades old and data rates depend on the quality of the copper cables, the integrity of the connections and the distance from the exchange. Distances and throughput have gradually edged up in line with technological updates as well as BT's confidence in being able to deliver a consistent service. The industry has also cleaned up its act a little, and users now understand that the promise of data rates 'up to 8 Mbps' or whatever, usually means far less than that in practice.

Access to high-speed fibre-based broadband seems to be a prize in a postcode lottery. Some users may enjoy a cable service or full-on fibre to the home/premises (FTTH/FTTP), but 'fibre' for many users will, mean fibre-to-the-cabinet (FTTC) or curb/kerb (US), a reference (UK) to roadside cabinets with copper wire forming the last leg of the journey.

The reason for my interest in copper wires, readers, is that once again my overhead phone cable has developed a fault at the pole's junction box, and this has left me with neither a phone landline nor an ADSL service. For BT users in the UK, faults can be reported on 0800 800 151 and progress reports can be received on another contact number. Residential users face up to a five-working-day lead time on repairs. In my case it looks like BT will run to the 11th hour, and, including the weekend, I'll endure seven days without broadband.

I suggested in previous *Net Work* columns that now is a good time to consider moving on from Windows XP in favour of Windows 7. It runs decently enough on a moderate-spec Pentium PC and is a mature and extremely well-sorted operating system, with fast boot-up and power-down times. Brand new systems may offer Windows 8, but a W7-based package is still easy enough to find. Feeling a bit desolate without my Internet connection, I pondered how to check email on an XP netbook or my Windows 7 PC and keep things moving, when I spotted my Windows mobile phone.

UK readers have doubtless heard of the arrival of 4G service, which offers high-speed mobile access, typically 8Mbps to 12 Mbps or so, but for users not within the catchment area of major cities this pipedream is irrelevant. My 3G mobile phone soldiers on with Windows Mobile 6.1 and I spent some of my ADSL downtime hooking it to my PC, using the phone as a wireless modem. Data simply passes through the phone using the mobile phone's GPRS data service.

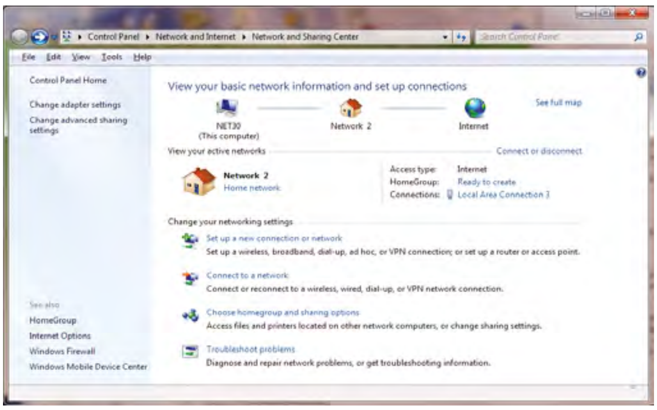
Getting hooked

Although I cannot cover every step in detail, some general pointers may help with the job of configuring a typical Windows mobile phone for Internet access and readers are encouraged to explore the options available to them. On the phone itself, I opened Communications Manager (in my case) and turned on Internet Sharing, ensuring that the connection settings and data service pointed to the mobile operator's data service.

After hooking them together with a mini USB cable, various drivers installed in Windows 7 automatically. Mobile Device Centre will open in Windows 7, where mobile device settings can be viewed. If the phone shows as 'Connected', then this refers to the sync mode between the Windows phone and PC to exchange email, files etc with each other, as opposed to sharing the phone's Internet connection with the PC, which is what we need, so close the sync session if needed (eg, close Activesync): the phone will then show as 'Not Connected' (see screenshot).

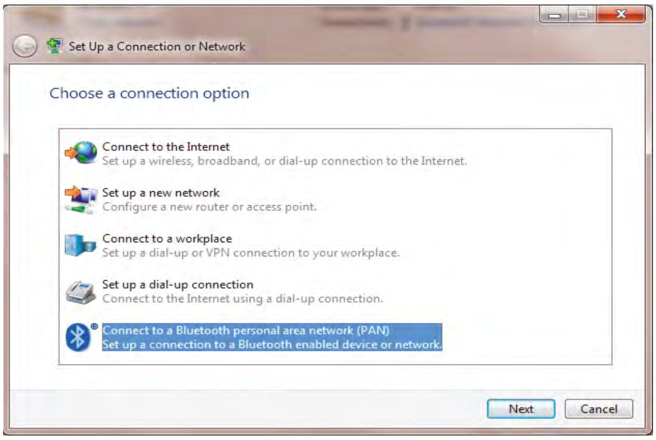
By viewing Connection settings in Mobile Device Centre, I could enable the key option 'Allow USB connections'.

By opening Control Panel/Network and Internet/Network and Sharing Centre, the new connection to the Internet could be seen. The process was commendably smooth and trouble-free, and email soon started to trickle onto my PC while I worked. Thanks to authsmtp (**www.authsmtp.com**) I could also send email as normal without making any changes to my email SMTP settings. It is undoubtedly very slow, but better than nothing, and helps with checking email, or emergency online banking.



Network and Sharing Centre in Windows 7 displays the new network name, Network 2

You can also use the phone's Bluetooth connection to achieve the same thing wirelessly. A Bluetooth dongle for a PC costs as little as £1 from a Poundstore and Windows 7 makes it easier than ever to install one. In Networking and Sharing Centre, simply set up a new connection or network by clicking 'Connect to a Bluetooth personal area network (PAN)' and follow the prompts.



In Windows 7, you can connect to a Bluetooth personal area network (PAN) and follow the prompts

Ensure that both Internet Sharing and Bluetooth are enabled on the phone, and that the phone's Internet Sharing is configured to connect through a Bluetooth PAN instead of USB. To connect to a PC for the first time, the device must be made 'visible' in Bluetooth settings and the phone may offer to do that automatically. Back at the Windows PC, right-click on the Bluetooth icon in the system tray, and select 'Join a Personal Area Network'; choose the mobile device in Devices and Printers and right-click on it, Connect Using [Access Point] and the PC should connect to the phone straight away.

In my case, my multithreading Eudora email program soon started fetching mail from a number of mailservers, but of course, the process is very much slower than normal. I found that incoming telephone calls knocked off the Bluetooth connection, which has to be re-established at the phone and the PC (join a PAN) again.

It's a dongle

If you don't have access to a phone, then another option is to try a USB GPRS dongle, which plugs directly into a USB port and connects to a designated mobile network. I borrowed such a USB dongle and Windows XP netbook, which offered a GPRS mobile data quota on the O_2 network. The dongle is free with some BT broadband packages, and mine had a 3GB monthly usage quota. The Huawei dongle carries its own Connection Manager software on the built-in memory stick, and it installed completely fuss-free on several test machines. They can also be used on Wi-Fi.

After 30 seconds or so it registered on the O_2 network, ready for use, with a popup proclaiming a snail-paced speed of 80kbps, a bit faster than a fax machine. The program displays usage on that machine (total them up manually, if spread across multiple devices), and I found that after an intense day of surfing, about 1% of the monthly allowance had been spent. Most mobile operators offer USB dongles on a 'Pay As You Go' or monthly contract basis. Watch out for time-outs and lock-ins, with a typical PAYG dongle requiring topping up after three months otherwise any pre-paid quota will be lost.

For non-city dwellers, high-speed mobile Internet access and 4G are tantalisingly out of reach, and local coverage should be checked before investing in a new 4G phone. There is no disputing that GPRS is excruciatingly slow, but it manages to keep online banking moving along and basic online transactions can be carried out as well. Trying to download complex pages full of graphics will be an extremely unrewarding experience and is barely worth the effort.

That's all for this month's *Net Work*. You can contact the writer by email to **alan@epemag.demon.co.uk** or share your views with the editor at **editorial@wimborne.co.uk** for possible inclusion in *Readout*, and you could earn a valuable prize!

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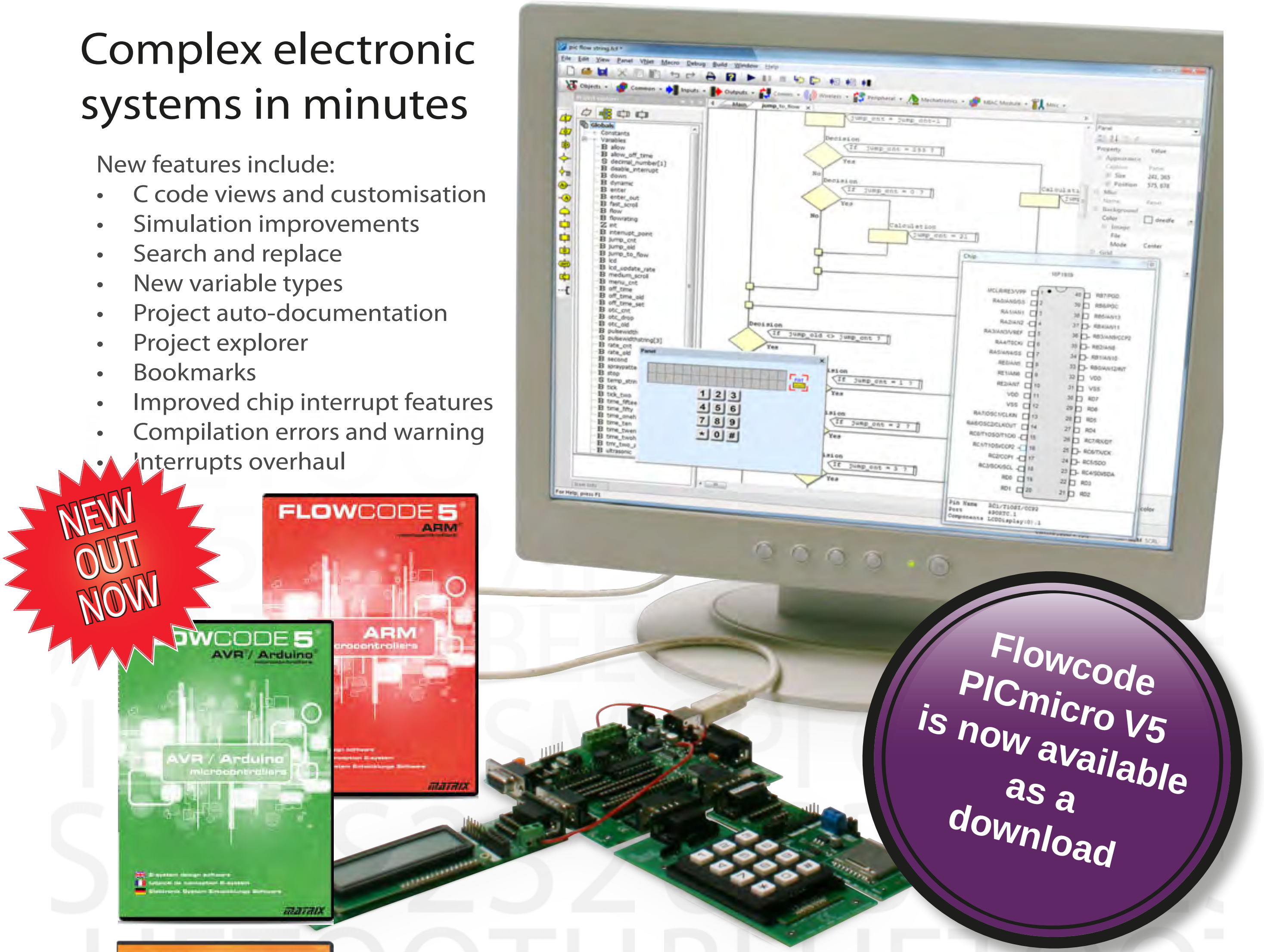

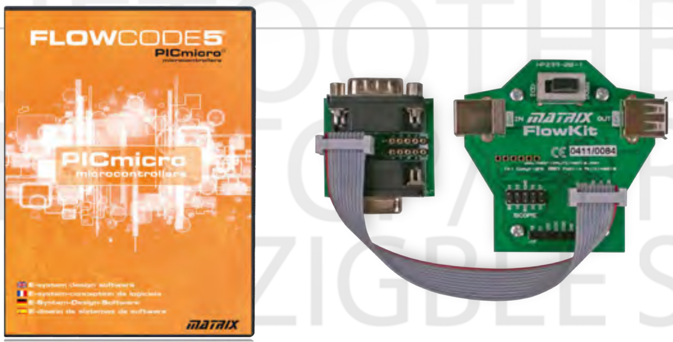

The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your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

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Please note: Due to popular demand, Flowcode PICmicro, AVR & ARM V5 are now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you. If you require the CDROM as a back-up (available June 2012) then please add an extra £14 to the above price.

PICmicro TUTORIALS AND PROGRAMMING

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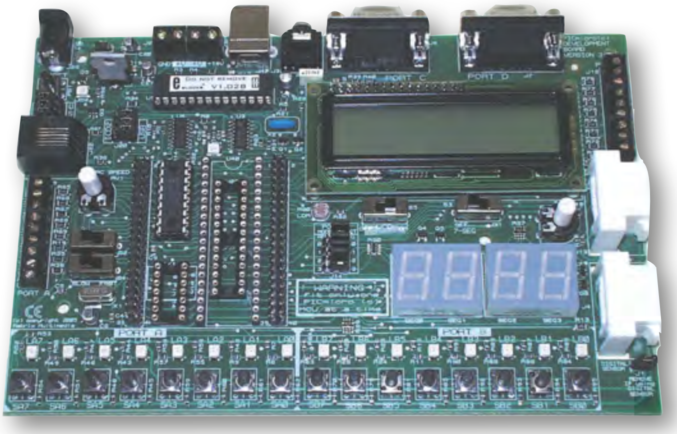


This board is being upgraded, therefore, it is currently unavailable.

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

SOFTWARE

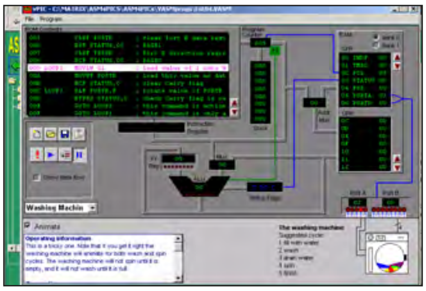
ASSEMBLY FOR PICmicro V4

(Formerly PICtutor)

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

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

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



'C' FOR 16 Series PICmicro Version 4

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

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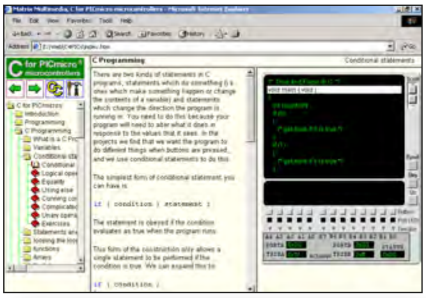

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro 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.

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- Full on-screen simulation allows debugging and speeds up the development process.
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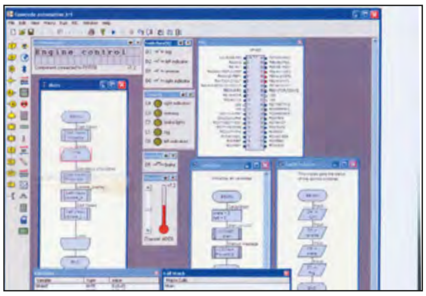
Features include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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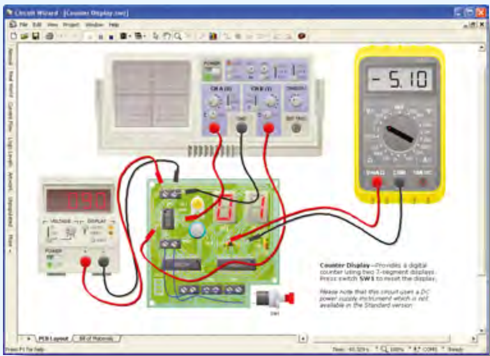
- *Multiple document support*



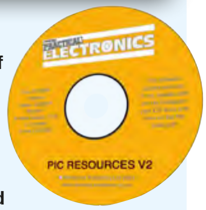
This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

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

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.

EPE PIC RESOURCES V2

Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)



The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
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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 ★

Rugged systems

Dear editor
I was interested to see the news item in the December 2012 issue of *EPE* concerning the retro technology used in the latest Mars rover. At the risk of sounding pedantic, I must take issue with the assertion that the on-board computer has an old PowerPC chip as its core.

The concept of using old, fully-debugged and proven designs is, of course, not new: I was involved in the design of the RAF *Nimrod* anti-submarine gear in the 1970s, and despite semiconductor RAM being available, MoD requirements meant that magnetic core memory technology had to be used. In that case, it was also because ferrite core memory was resistant to nuclear radiation.

Space probes have the same problem with radiation, which is why the computer at the heart of *Curiosity* uses a microprocessor chip, the core of which has its origins with the PowerPC 750, but which use completely different hardware technology. The device, a RAD 750, is made by BAe Systems and is fitted in a gold-plated module that sells for $200,000. The design of the silicon has been optimised for radiation resistance, but in theory the RAD 750 could run programs written for the old Apple Mac!

Another example of proven designs being used, is the computer system for the *Bloodhound* SSC supersonic car project. This uses ruggedised computer modules with a processor chip based on Pentium III technology.

There are new microcontroller families aimed at applications with high safety requirements, such as the Texas Instruments Hercules and the Freescale PXS range. These are based on redundant-core techniques, which takes me right back to my PhD research on automatic train control. Scope here for an article on safety/high-reliability systems I would of thought!

Bill Marshall, by email

Matt Pulzer replies:

Thank you very much for a most interesting letter. Not at all pedantic, but a fascinating window into the world of rugged systems. I like your suggestion for an article on 'safety/high-reliability systems', and we will definitely consider it.

Throwing down the gauntlet!

Dear editor
I am a long-time subscriber with a little suggestion and a wish. Wouldn't it be nice to publish a valve (tube) pre-amplifier and amplifier – not everything has to be small and transistorised! Plus, the sound they say is better – but that is another discussion.

On the web, I see so many very expensive valve designs. The challenge for *EPE* is can you can design something that is really good and not too expensive; with components that aren't to hard to source.

Will you take up the gauntlet?

Steven de Kat, The Netherlands, via email

Matt Pulzer replies:
Thank you for your suggestion, or should I say challenge?

We do not have any plans for a valve amplifier at the moment, but a clever design may be just around the corner. Any readers out there who would like to help Steven or make a submission to Ingenuity Unlimited?

Cat's eyes and processors

Dear editor
The final lines in Mark Nelson's motoring article (*Techno Talk*, November 2012) set me wondering. I appreciate that the eye-brain combination is complex and that 'persistence' of vision is used for all manner of circuits and system: brightness control, multiplex displays and television. In most of these, the image maker and viewer remain relatively static.

When does the eye/brain begin to perceive a 250Hz refresh cycle as a 'new' image to be processed, especially as I presume our brains recognise the road scene should be changing because we are driving along? I'm guessing there is a car velocity *vs* cat's eye displacement *vs* refresh frequency which begins to get the eye/brain combination 'annoyed or distracted'. Could this trigger photo-induced seizure?

I have seen figures of 5Hz to 25Hz for triggering photosensitive sufferers. However, I suspect I may be looking at a theoretical issue with far too many unknowns to solve on the back of a cigarette pack. I know someone who suffered photo-induced migraines – driving along the old A4, with a line of trees alternately blocking and unblocking a low sun, instantly triggered a migraine.

My thoughts are far less to do with looking at or tracking 'a particular' LED cat's eye, but between 'this one' and the 'next one'. I doubt that the LEDs are either exactly 250.00Hz or synchronised. So, with a moving vehicle at a suitable speed to make the 'next cats eye' appear to 'replace' the previous cat's eye, could there be a sort of a 'beat' effect that the eye brain perceives as a 5Hz to 25Hz signal.

If I were thinking of this in a DSP area, then I would be looking at a 250Hz signal sampled at 30Hz (seems to be a figure for the eye's 'exposure time' in camera terms). Well below the Nyquist sampling frequency and, therefore, prone to a frequency alias.

I'm not certain my explanation is clear, but I found the following link (BBC no less) **http://news.bbc.co.uk/1/hi/england/essex/6226285.stm**, though I note the quoted 100Hz.

I'm in favour of solar-powered active cat's eyes because they open up the possibility of turning off motorway and dual carriageway streetlights, while still providing a medium/long-distance view of lanes. This in turn might help vehicles halted on hard shoulders to be seen to be 'not in my lane'.

So, I do wonder if a shift to 1kHz would still give the desired illumination *vs* energy saving and completely avoid 'beats'. The whole topic seems like a 3D bat detector heterodyne, but with light instead of sound!

Youth in electronics

On a completely different track, I am one of the leaders of the teenagers' Saturday Science Club at the Catalyst Science Discovery Centre (**www.catalyst.org**) in Widnes. I take along my Arduino and .NET Gadgeteer projects as a sideline to see if I can interest any of the youth in electronics. It's interesting to see how .NET Gadgeteer is making electronic systems a 'plug and play plus a bit of software' world. I can't say I'm totally in favour of this approach, as these processors are far too over-specified for many of the simple tasks they are used for. I understand that the interrupts aren't true, but a 20ms poll – almost an eternity in PIC code.

So, I discern at least three tiers of such electronics: PIC/AVR with interface chips and assembler/Basic/C; then comes the Arduino, with plug and play shields and a C development system (but abstracted away from port registers to 'pin x'); and finally the .NET heavyweights, where the user is hardly aware of what a chip is! But each seems to have its place.

Mike Halliday, via email

Matt Pulzer responds:
Thank you for a fascinating and thought-provoking letter. I must confess I do not know very much about persistence of vision, but the following Wikipedia piece does provide some interesting facts and figures when it comes to film and TV refresh rates:

http://en.wikipedia.org/wiki/Refresh_rate

I did a little more digging – and, of course, Wikipedia produced another interesting page:

http://en.wikipedia.org/wiki/Photosensitive_epilepsy

My impression is that 250Hz is sufficiently fast to avoid most problems and perhaps that is why it was chosen, but as you point out, the LED frequency is not the only one of interest.

Implementing safety is often not the simple and straightforward process that we would like it to be. It is often a balance of sensible and practical funding versus conflicting requirements. These active cat's eyes might help prevent 100 accidents but contribute to one or two. Of course, we'll never know who avoids an accident, but the 'one or two' who suffer from a seizure might feel they have been jeopardised unnecessarily.

I should end with the caveat that Wikipedia is usually very reliable (in my experience) especially in 'non-controversial' areas such as engineering, but that references and citations should always be followed up if you wish to really check facts and claims.

Circuit Wizard limitations

Dear editor
Perhaps you should warn your readers that while Circuit Wizard is excellent as far as it goes, especially useful in drawing layouts from circuit diagrams, it seems to be aimed primarily at digital circuits only.

I have found two drawbacks so far. First, plotting a frequency response seems to be impossible, as the function generator does not allow varying frequencies or wave shapes, and even if it did, plotting would have to be done with pencil and paper because there is no instrument to display a frequency/voltage curve (ie, a Bode plotter). Second, there seems to be no way of adding random text to a circuit drawing; eg, labelling switch terminals or annotating any point of interest.

If you were to alert CW designers to these points, and maybe others, it would vastly improve its usefulness. They might take more notice of a magazine than an individual, because they told me they had no plans to include these suggestions in the future.

Lloyd Stickells, via email

Mike Tooley responds:
I'm not sure that there's a lot that Richard and I can do to make the improvements that are suggested to the Circuit Wizard package, but I will at least pass on your comments to the company.

In our defence, we have never envisaged readers of Teach-In *and* Jump Start *doing any frequency/phase response plots for the projects that we have described. We are attempting to produce a series for beginners and not for those at a more advanced level (for whom Tina Pro would be a much more effective tool). Maybe we'll consider a future series based on Tina Pro for readers with a little more experience and/or students studying at a higher level.*

Richard and I have used a large number of different electronic design packages over the last 20 years, and we remain convinced that Circuit Wizard is a first-rate tool for teaching the basics of electronic circuit design and construction to younger learners. Yes, it has shortcomings compared with more expensive packages, but that's not really surprising because these are designed primarily for professional users and not for the education market

Hearing Loop

Dear editor
I have very much enjoyed reading and learning from John Clarke's series of articles about the construction of a *Hearing Loop* and the associated *Level Meter*.

However, I do have a technical question about a small detail of the *Hearing Loop Level Meter* that was featured in the November 2012 Issue of *EPE*. My question is about the capacitor placed in the feedback path of IC1b. I understand that this capacitor, in conjunction with the parallel 100kΩ resistor, rolls off the high frequency response of the amplifier, thereby acting as a low pass filter.

My question is this – how did John come to arrive at a value of 33nF for this capacitor? The way I usually calculate the value of a capacitor placed in this position is to use the equation:

$f_{cutoff} = 1/(2\pi RC)$

Rearranging for C yields:

$C = 1/(2\pi R f_{cutoff})$

R is the feedback resistor (equal to 100kΩ), connected in parallel with the 33nF capacitor.

f_{cutoff} is the high frequency cut-off point, otherwise known as the –3dB point.
π is the familiar constant, equal to approximately 3.14.

By use of this equation, I calculate that the 33nF capacitor gives an upper cut-off frequency (–3dB point) of about 48Hz, which seems far too low for this application, whereas a smaller capacitor (of say 33pF) would have given an upper cut-off frequency of about 48kHz, leaving IC1a's feedback components to give the required 10kHz upper cut-off frequency of the overall circuit, as is shown in the graph of Fig.4 on page 14.

Is my theory correct, or am I missing some practical reason for John specifying the higher value 33nF capacitor? I do understand that John must be a very busy man, but I would be very grateful if he could find the time to answer my query and put my mind at rest.

Chris Hinchcliffe, Dorset, via email

John Clarke responds:
The amplifier roll-off is to compensate for the rising response of the pickup coil. As the pickup coil has an increase in level with frequency, the 33nF capacitor rolls off at the same rate, so there is an overall flat frequency response. The roll-off is at 48Hz, the lower end of the audio bandwidth for the hearing aid loop receiver

TK3 Tookit problems

Dear editor
I see there is a letter about the *TK3 Toolkit* software in the November 2012 issue. I have a different problem with the system from that quoted, so there may be a need for an update or warning.

I built the kit from Magenta at the time it appeared, after I had already been using the earlier TK2 board, and used both successfully for a time. Other matters then took over and the kit was put aside for some years. I recently took it out again following a requirement for motor control in the work I do with REMAP, a charity whose members use their engineering and other skills to improve the lives of adults and children with disabilities.

However, I now find that the 16F84 is unobtainable and have had to use the 16F628 – not with total success though. What happens is that an attempt to download is suddenly blocked halfway though the development of a program by a message that implies that the code is protected, and I cannot see how to get out of the impasse. I certainly have not consciously instigated this. Any suggestions? I see there is an option for low-voltage programming on the 16F628, but the board does not offer this.

Best wishes for your articles encouraging young beginners.

LM Newall, via email

Matt Pulzer responds:
Thank you for the warning about TK3 – have any readers met and solved this issue?

DIRECT BOOK SERVICE

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

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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A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

Available NOW – see page 24 in this issue for details

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 last book page.

FOR A FURTHER SELECTION OF BOOKS AND CDROMS SEE THE UK SHOP ON OUR WEBSITE

www.epemag.com

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COMPUTING AND ROBOTICS

WINDOWS XP EXPLAINED
N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and home editions.

The book was written with the non-expert, busy person in mind. It explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, notepad and paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; how to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows set-up, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

264 pages **Order code BP514** **£7.99**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages + Large Format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision command system

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages **Order code BP902** **£14.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages **Order code NE36** **£25.00**

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION
John Crisp

If you are, or soon will be, involved in the use of microprocessors and microcontrollers, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors and micrcontrollers. Assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern micros.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** **£29.99**

EASY PC CASE MODDING
R.A Penfold

Why not turn that anonymous grey tower, that is the heart of your computer system, into a source of visual wonderment and fascination. To start, you need to change the case or some case panels for ones that are transparent. This will then allow the inside of your computer and it's working parts to be clearly visible.

There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including:- Electro luminescent (EL) 'go-faster' stripes: Internal lighting units: Fancy EL panels: Data cables with built-in lighting: Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube: Digital display panels: LED case and heatsink fans: Coloured power supply covers.

192 pages + CD-ROM **Order code BP542** **£8.99**

ROBOT BUILDERS COOKBOOK
Owen Bishop

This is a project book and guide for anyone who wants to build and design robots that work first time.

With this book you can get up and running quickly, building fun and intriguing robots from step-by-step instructions. Through hands-on project work, Owen introduces the programming, electronics and mechanics involved in practical robot design-and-build. The use of the PIC microcontroller throughout provides a painless introduction to programming – harnessing the power of a highly popular microcontroller used by students, hobbyists and design engineers worldwide.

Ideal for first-time robot builders, advanced builders wanting to know more about programming robots, and students tackling microcontroller-based practical work and labs.

The book's companion website at http://books.elsevier.com/companions/9780750665568 contains: downloadable files of all the programs and subroutines; program listings for the Quester and the Gantry robots that are too long to be included in the book.

366 pages **Order code NE46** **£26.00**

THEORY AND REFERENCE

GETTING THE MOST FROM YOUR MULTIMETER
R. A. PenfoldM
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£5.49**

OSCILLOSCOPES – FIFTH EDITION
Ian Hickman
Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.

This handy guide to oscilloscopes is essential reading for anyone who has to use a 'scope for their work or hobby; electronics designers, technicians, anyone in industry involved in test and measurement, electronics enthusiasts . . . Ian Hickman's review of all the latest types of 'scope currently available will prove especially useful for anyone planning to buy – or even build – an oscilloscope.

The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscilloscopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.

288 pages **Order code NE37** **£36.99**

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop
Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.

Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.

228 pages **Order code NE35** **£36.99**

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold
This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** **£5.45**

MICROCONTROLLER COOKBOOK
Mike James
The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages **Order code NE26** **£36.99**

FULL COLOUR COMPUTING BOOKS

HOW TO FIX YOUR PC PROBLEMS **R.A. Penfold**
What do you do when your laptop or desktop stops working properly. Do you panic, try to find the answer on the page of fault finding tips you may find at the back of the manufacturers manual. Or do you spend hours trying to get through to a telephone helpline or waste even more time waiting for an email reply from a helpdesk.

Well help is now at hand! This book will assist you in identifying the type of problem, whether it's hardware, software or a peripheral that is playing up? Once the fault has been identified, the book will then show you how to go about fixing it. This book uses plain English and avoids technical jargon wherever possible. It is also written in a practical and friendly manner and is logically arranged for easy reference.

The book is divided into four main sections and among the many topics covered are: Common problems with Windows Vista operating system not covered in other chapters. Also covers to a lesser extent Windows XP problems. Sorting out problems with ports, peripherals and leads. Also covers device drivers software and using monitoring software. Common problems with hard disc drives including partitioning and formatting a new drive. Using system restore and recovering files. Also covers CD-ROM and Flash drives. Common problems with sound and video, including getting a multi-speaker system set up correctly.

An extremely useful addition to the library of all computer users, as you never know when a fault may occur!

Printed in full colour on high quality non-refective paper

128 pages **Order code BP705** **£8.49**

AN INTRODUCTION TO WINDOWS VISTA **P.R.M. Oliver and N. Kantarris**
If you have recently bought a new desktop or laptop it will almost certainly have Windows as its operating system. Windows Vista manages the available resource of a computer and also 'controls' the programs that run on it.

To get the most from your computer, it is important that you have a good understanding of Vista. This book will help you acheive just that. It is written in a friendly and practical way and is suitable for all age groups from youngsters to the older generation. It has been assumed that Vista is installed and running on your computer.

Among the numerous topics explained are: The Vista environment with its many windows. How to organise your files, folders and photos. How to use Internet Explorer for your web browsing. How to use Microsoft Mail for your emails. How to control your PC and keep it healthy. How to use Vista's Accessibility features if you have poor eye sight or difficulty in using the keyboard or mouse. And much more besides....

With the help of this book you will easily and enjoyably gain a better understanding of Microsoft's amazing Windows Vista operating system.

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COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION **R.A. Penfold**
Laptop computers have rapidly fallen in price, increased in specification and performance and become much lighter in weight. They can be used practically anywhere, then stored away out of sight. It is therefore, not surprising that laptop sales now far exceed those of desktop machines and that they are increasingly becoming the machine of choice for the older generation.

You may want to use your laptop as your main computer or as an extra machine. You may want to use your laptop on the move, at home, at work or on holiday. Whatever your specific requirements are, the friendly and practical approach of this book will help you to understand and get the most from your laptop PC in an easy and enjoyable way. It is written in plain English and wherever possible avoids technical jargon.

Among the many topics covered are: Choosing a laptop that suits your particular needs. Getting your new computer set up properly. Customising your computer so that it is optimised for your particular needs. Setting up and dealing with user accounts. Using the Windows 'Ease of Access Center'. Optimising the life and condition of your battery. Keeping the operating system and other software fully up-to-date. Troubleshooting common problems. Keeping your computer and data safe and secure. And much more besides...

Even though this book is written for the older generation, it is also suitable for anyone of any age who has a laptop or is thinking of buying one. It is written for computers that use Windows Vista as their operating system but much will still apply to Windows XP machines. Printed in full colour on high quality non-refective paper

120 pages **Order code BP702** **£8.49**

AN INTRODUCTION TO EXCEL SPREADSHEETS **Jim Gatenby**
The practical and friendly approach of this book will help newcomers to easily learn and understand the basics of spreadsheets. This book is based on Microsoft's Excel 2007 spreadsheet, but much of the book will still apply to earlier versions of Excel. The book is written in plain English, avoiding technical and mathematical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Install the software. Use the exciting new features of Excel 2007. Create and use a spreadsheet. Enter, edit and format text, numbers and formulae. Insert and delete columns and rows. Save and print a spreadsheet. Present the information on a spreadsheet as a graph or chart. Manage and safeguard Excel files on disc. Use Excel as a simple database for names and addresses.

This book will help you to quickly gain confidence and get to grips with using spreadsheets. In fact, you will wonder how you ever managed without them.

Printed in full colour on high quality non-reflective paper.

118 pages **Order code BP701** **£8.49**

AN INTRODUCTION TO DIGITAL PHOTOGRAPHY WITH VISTA **R.A. Penfold**
The friendly and practical approach of this book will help newcomers to digital photography and computing to easily learn the basics they will need when using a digital camera with a laptop or desktop PC. It is assumed that your PC uses Windows Vista, however, if it is a Windows XP machine the vast majority of this book will still apply. The book is written in plain English, avoiding technical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Understand the basic features of a digital camera. Transfer photographs from your digital camera to your computer. View your photographs. Save, sort and file your photographs. Manipulate, crop and carry out simple corrections to your photographs. Copy your photographs on to CD or DVD. Print your photographs. Share images with family and friends anywhere in the world by email or with an online album.

This book will help you quickly get to grips with, gain confidence and expand your horizons in the fascinating hobby of digital photography.

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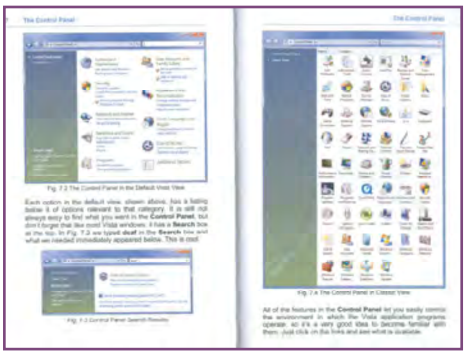

COMPUTING & PROJECT BUILDING

eBAY – TWEAKS, TIPS AND TRICKS

NEW

R. A. Penfold

Online auction sites are one of the most popular types of site on the internet, and the most popular of these is the eBay site. On eBay you can buy and sell practically anything at surprisingly low cost, and all from the comfort of your armchair!

This book contains numerous tweaks, tips and tricks covering various aspects of buying and selling on eBay. These tweaks, tips and tricks will help both new and more experienced users of the site to make the most of eBay's facilities while remaining safe and secure.

Among the many topics covered are: Finding the items you require using the eBay search facility: Getting the best prices when buying and selling on eBay: Avoiding both buying and selling scams: Determining the market value for items you intend buying or selling: How to avoid problems that may arise when buying and selling on eBay: Making the most of the various facilities that are built into the eBay site: How to take good photos of items you wish to sell using basic equipment: Using the My eBay page to stay in control of your buying and selling activities: And more besides.

128 pages **Order code BP716** **£7.50**

THE INTERNET – TWEAKS, TIPS AND TRICKS

NEW

R. A. Penfold

Robert uses his vast knowledge and experience in computing to provide you with useful hints, tips and warnings about possible difficulties and pitfalls when using the Internet. This book should enable you to get more from the Internet and to discover ways and means of using it that you may not have previously realised.

Among the many topics covered are: Choosing a suitable browser: Getting awkward pages to display properly: Using Java, spell checkers and other add-ons: Using proxy servers to surf anonymously and privacy facilities so you do not leave a trail of sites visited. Ways of finding recently visited sites you can no longer find: Using download managers to speed up downloads from slow servers. Plus, effective ways and tricks of using search engines to locate relevant info: Tricks and tips on finding the best price for goods and services: Not getting "conned" when buying or selling on eBay: Finding free software: Finding and using the increasing range of Cloud computing services: Tips on selecting the best security settings: Etc,etc,etc.

128 pages **Order code BP721** **£7.50**

FREE DOWNLOADS TO PEP-UP AND PROTECT YOUR PCS

NEW

R. A. Penfold

Robert uses his vast knowledge and experience in computing to guide the reader simply through the process of finding reliable sites and sources of free software that will help optimise the performance and protect their computer against most types of malicious attack.

Among the many topics covered are: Using Windows 7 optimisation wizard: Using Pitstop for advice on improving performance, reducing start up times, etc: Free optimisation scans and the possibility of these being used as a ploy to attack your PC.

Plus, free programs such as Ccleaner, Registry checker and PCPal optimisation software: Internet speed testing sites and download managers: Overclocking sites together with warnings about using this technique: Sites and software for diagnosis of hardware faults, including scanning for out of date drivers and finding suitable replacements: Free Antivirus software and programs that combat specific types of malware: Firewalls: Search engines to identify mystery processes listed in Windows Task Manager.

128 pages **Order code BP722** **£7.50**

HOW TO BUILD A COMPUTER

R.A. Penfold

To build your own computer is, actually, quite easy and does not require any special tools or skills. In fact, all that it requires is a screwdriver, pliers and some small spanners rather than a soldering iron! The parts required to build a computer are freely available and relatively inexpensive.

Obviously, a little technical knowledge is needed in order to buy the most suitable components, to connect everything together correctly and to set up the finished PC ready for use. This book will take you step-by-step through all the necessary procedures and is written in an easy to understand way. The latest hardware components are covered as is installing the Windows Vista operating system and troubleshooting.

320 pages **Order code BP591** **£8.99**

BUILDING VALVE AMPLIFIERS

Morgan Jones

The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

PRACTICAL FIBRE-OPTIC PROJECTS

R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

BOOK ORDERING DETAILS

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COMPUTING AND ROBOTICS

NEWNES INTERFACING COMPANION

Tony Fischer-Cripps

A uniquely concise and practical guide to the hardware, applications and design issues involved in computer interfacing and the use of transducers and instrumentation.

Newnes Interfacing Companion presents the essential information needed to design a PC-based interfacing system from the selection of suitable transducers, to collection of data, and the appropriate signal processing and conditioning.

Contents: Part 1 – Transducers; Measurement systems; Temperature; Light; Position and motion; Force, pressure and flow. Part 2 – Interfacing; Number systems; Computer architecture; Assembly language; Interfacing; A to D and D to A conversions; Data communications; Programmable logic controllers; Data acquisition project. Part 3 – Signal processing; Transfer function; Active filters; Instrumentation amplifier; Noise; Digital signal processing.

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PCB SERVICE

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Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

PROJECT TITLE	ORDER CODE	COST
DECEMBER '11		
★ Wideband Oxygen Sensor Controller	829	£11.47
★ WIB (Web Server In A Box)	830	£9.72
★ Ginormous 7-segment LED Panel Meter		
– Master (KTA-255v2)	831	£12.67
– Slave (KTA-256v2)	832	£5.05
– Programmed Atmega328		£10.13
JANUARY '12		
Balanced Output Board For The Stereo DAC	833	£9.72
FEBRUARY '12		
★ Air Quality Monitor (CO$_2$/CO)	834	£8.75
WIB Connector Daughter PCB	835	£6.80
MARCH '12		
★ Internet Time Display Module	836	£8.16
Solar-Powered Intruder Alarm	837	£9.33
★ Very, Very Accurate Thermometer/Thermostat	840	£9.33
APRIL '12		
★ Digital Audio Signal Generator		
– Main Board (Jay ***or*** Alt)	838 } pair	£18.86
– Control/Display Board	839 } pair	
EHT Stick	841	£9.15
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MAY '12		
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★ Solar-Powered Lighting Controller	845	£9.91
Jump Start – Plant Pot Moisture Sensor	846	£7.97
– Rain Alarm (Main)	847 } pair	£15.36
– Rain Alarm (Sensor)	848 } pair	
JUNE '12		
★ Digital Insulation Meter		
– Main/Display	849 } pair	£16.33
– DC-DC Converter	850 } pair	
Dual Tracking ±0V to 19V PSU		
– Main PCB	851	£9.33
– Front Panel	852	£8.16
– LCD Meter	853	£7.19
Jump Start Quiz Machine		
– Master	854	£7.39
– Contestant	855	£7.39
JULY '12		
★ 16-Bit Digital Potentiometer	856	£13.99
★ Intelligent 12V Fan Controller	857	£10.10
Jump Start – Battery Voltage Checker	858	£9.14
AUGUST '12		
High Performance Microphone Pre-amplifier	859	£7.58
Jump Start – Solar Powered Charger	860	£7.20
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High-power DC Motor Speed Controller		
– Non-Reversible	863	£6.50
– Reversible	864	£6.75
(Both boards double-sided)		
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Hearing Loop Receiver	865	£8.55
★ Ultrasonic Anti-Fouling For Boats	866	£9.14
Jump Start – Versatile Theft Alarm	867	£9.33

PROJECT TITLE	ORDER CODE	COST
OCTOBER '12		
S/PDIF To TOSLINK Converter	868	£8.16
TOSLINK to S/PDIF Converter	869	£8.16
★ Digital Lighting Controller		
– Master Board	870	£12.05
– Slave Board	871	£16.72
Jump Start – Crazy Eyes	872	£7.78
– Ghostly Sounds	873	£8.16
NOVEMBER '12		
Hearing Loop Level Meter	874	£9.53
RFID Security System	875	£7.75
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DECEMBER '12		
Hot Wire Cutter – Controller	877	£8.55
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Jump Start – Mini Christmas Lights	879	£10.69
JANUARY '13		
Low-Capacitance Adaptor for DMMs	880	£8.55
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– Main Board	881 } pair	£20.00
– Switch Board	882 } pair	
Stereo Compressor – Main Board	883	£12.63
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10W LED Floodlight	885	£6.75
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Jump Start – Logic Probe	887	£6.42

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

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PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

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For editorial address and phone numbers see page 7

Next Month

Content may be subject to change

Digital Spirit Level

Build an electronic version of a spirit level – except that this one gives a digital readout of the angle of any flat surface in 0.1° increments from 0 to 360°. At the heart of the project is a precision MEMS accelerometer chip, as found in the latest tablets and smartphones.

Lightning Detector

You don't want to be caught in a thunderstorm, especially if you are on a sports field, out boating, hillwalking or working in the open. If there is even a risk of an electric storm, take this *Lightning Detector* with you before venturing outdoors.

Interplanetary Voice – may the voice be with you!

Impersonate a robot, a droid or one of the many infamous interplanetary aliens such as Daleks, Cybermen, Klingons, Cylons or even Darth Vader!

SemTest – Part 2

We present the full circuit of this versatile unit, which can test all those semiconductors in your collection. Under-the-hood, a PIC16F877A microcontroller runs all the different tests and displays the results on a 2-line LCD panel.

Jump Start – DC Motor Controller

An ideal project for model makers and electric train enthusiasts. Learn how to control the ubiquitous DC motor with this simple, but effective project.

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