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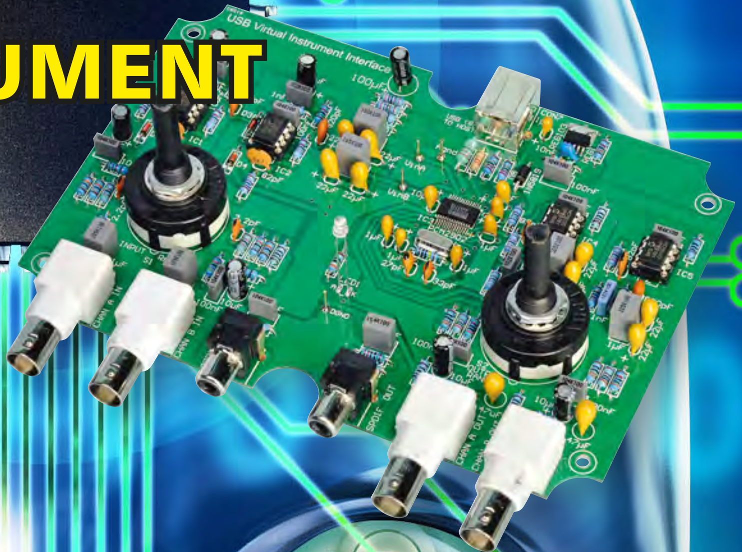

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VOL. 42. No 12 December 2013

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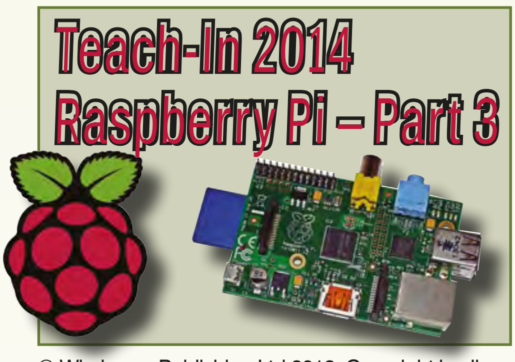

Our January 2014 issue will be published on Thursday 5 December 2013, see page 72 for details.

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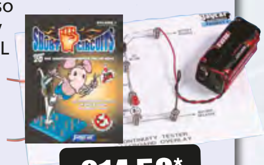

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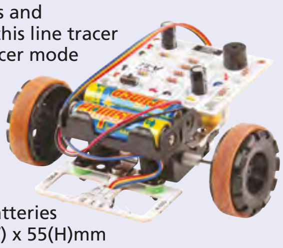

- Suitable for ages 12+
- Requires 2 x AA batteries
- Size: 120(L) x 64(W) x 55(H)mm

KJ-8906

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- Requires 6 x AAA batteries in total
- Size: 125(H)mm approx.

KJ-8952

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- PCB: 65 x 36mm

KC-5516

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KG-9068

Note: Not suitable for colour CMOS cameras

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Back to the workshop

Well, it wasn't such a bad summer after all, but the shorter days, drizzle and distinct chill in the air heralds a new season. So, if the tan is fading and you're feeling at a bit of a loose end it must surely be time to put away the garden furniture, dust off your oscilloscope and indulge yourselves in a new electronics project.

If that appeals then you really should have a look at this month's USB interface test instrument constructional project. A great combination of hardware and software that lets you build a Windows-based suite of test instruments: a two-channel digital scope, spectrum analyser, AC DMM and frequency counter, plus a two-channel audio signal/function/arbitrary waveform generator. It really is a very clever box of tricks that you'll use again and again… and again! When I was doing my degree back in the 80s a decent spectrum analyser was the kind of thing you bought from Hewlett Packard for the price of a not-so-small car – but now you can build your own, and I certainly encourage you to do so.

PIC n' Mix returns

This issue brings the very welcome return of Mike Hibbett and his *PIC n' Mix* column. We've all missed his writing and I'm delighted to see his clear and elegant explanations of all things PIC back in *EPE*.

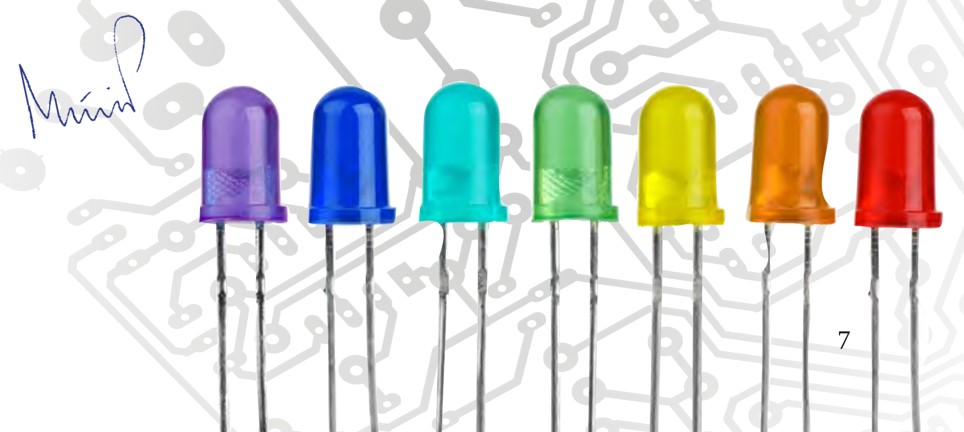
Reading his piece, my eye was caught by his comments on MakeShop, a Dubin-based shop/workshop where anyone can go and get involved with electronics – buying and making projects, as well as having access to some rather nice equipment. It sounds like a fantastic idea and I can't help wondering if our educationalists couldn't put a little more effort into that kind of enterprise and a little less time into constantly rearranging the syllabus or endlessly setting up new kinds of schools. Nothing beats 'hands on' fun and real experience-based learning for the next generation of scientists, technologists, designers and engineers. The Raspberry Pi has been a magnificent success and shows British engineers can still innovate and succeed at an international level, but we need policy makers to understand that kids being able to update a Facebook page is not an adequate substitute for real programming ability.

I hope you enjoy this issue of *EPE*, and as ever, we welcome your feedback via the postman, email or of course our very own popular forum – *Chat Zone* at: **www.chatzones.co.uk**

Binders & Strips

I am afraid to say that we will no longer be supplying binders for *EPE* magazines. We have now run down our stock, and due to the cost of packing and postage they are becoming very expensive to you, the customer.

We are advising customers that a far more cost effective way to buy binders would be to source a supplier near to you. If you would still like the *EPE* logo/year labels and plastic holders that we supply, then just call us on 01202 880299 to order. The plastic holders will be supplied in bundles of 12 at a price of £5.50 (inc P&P) to the UK, and £6.00 (inc P&P) Airmail.



NEWS

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

Remembering Ray Dolby – by Barry Fox

Ray Dolby died as the HDMI Licensing Authority upgraded its standard to carry not only Ultra HD or 4k TV, but also 32 channels of audio – which is just what's needed to bring Dolby's new Atmos surround system into the home. Whether we want 32-channel surround is of course another matter, and we shall never know whether Ray thought it was a good idea. He had been ill for a while and not taken any active role in Dolby Laboratories for several years. The company he founded in the UK in 1965, to market tape hiss noise reduction, has changed a lot recently and did not even send out a press alert on his death and legacy.

Ray Dolby (1933-2013)

Dolby hiss reduction

I met with Ray Dolby quite often in the early years when Decca's studios were pioneering use of the professional 'A' system and the consumer 'B' version was launched. Then came the format wars between rival types of consumer system; Dolby B, C, dbx, DNR, ANRS and Telefunken's High Com. During this time I always found him patient and gentlemanly, never wanting to be too critical of the rival systems. He just presented the facts.

I remember his strong sense of decency and fair play. One year at CES in Chicago he just couldn't understand why a US journalist had gleefully revealed details of what Dolby Labs was announcing, a few hours ahead of the official press briefing.

Ray Dolby had a quiet sense of humour. When he launched Dolby S analogue noise reduction, he lectured the UK Institute of Broadcast Sound. An engineer in the audience asked him if there were any more, even better, systems in the pipeline.

'I like to think we are nearing the end of the line and can stop designing for a while', replied Ray Dolby. 'It must have been like this several hundred years ago in the Scotch whisky industry. There came a time when the blenders said to themselves, "hey, let's stop developing, and start just enjoying the product." And since then, everyone else has been doing just that'.

More recently, Ray Dolby talked to the Audio Engineering Society in New York. Since Dolby Labs was floated he had retired from research, but still needed a challenge.

So he said he learned to fly. He'd flown himself and his wife to New York from San Francisco in his eight-seater jet, alone and without a crew because 'that way there's always something to think about'.

For local trips, back home in California, he flew a helicopter. 'Aren't they tricky things to learn to fly', he was asked? 'When I was a child I had no one to teach me how to ride a bike', he recalled. 'So I just figured it out by falling off, getting back on and trying something different. I don't want to offend any flight instructors, but I found learning to fly a helicopter much the same'.

Quadrulplex video

Before starting Dolby Labs, Ray Dolby was part of the team at Ampex that developed the Quadruplex video recorder. It was unveiled at the Conrad Hilton Hotel in Chicago during the National Association of Radio and Television Broadcasters convention in April 1956. Ray Dolby had been responsible for the FM system which Ampex adopted, instead of AM as previously used, and which made clear pictures possible.

Industry rumours had it that Ray's contribution to Quad video had been undervalued in historical writings. Years ago I asked him if it was true that the essential pieces of the jigsaw had occurred to him 'like a flash of light'. Could he explain more? But he flatly refused to discuss his part in the team effort, saying 'that can wait until after I'm dead.' So I sincerely hope he wrote it down for us now to read.

Yo!Bot – the mobile robot

Gadget developers BBTradesales and Zeon Tech have launched Yo!Bot a miniature robot with a mobile brain. The mini 'bot uses a free App and a smartphone as its intelligence. Using a PC, Mac, tablet, the Internet, an iPhone or Android smart device, users can navigate their Yo!Bot forwards, backwards and spinning both clockwise and anti-clockwise. Set the mobile device and Yo!Bot into camera mode and 'botmasters' can stream live videos from the Yo!bot's field of vision back into the computer or tablet.

Yo!Bot is available from **www.geniegadgets.com** for around £20.95. It is compatible with Apple iPhone models 3GS, 4, 4S and 5, and also Android phones that run Adobe AIR (for example, the Galaxy s3). It runs off four AA Batteries.

The Yo!Bot an inexpensive and fun basis for intelligent projects on the go

IET guidelines following increase in solar panel popularity

Sunlight is the world's largest energy source, and the amount available via existing technology greatly exceeds the world's primary energy consumption. Today, solar photovoltaic (PV) technology is becoming widely accepted as an important form of power generation with over 2GW of installations contributing to the UK energy supply and projections for growth to over 20GW installed by 2020.

The Institution of Engineering and Technology's (IET) new *Code of Practice for the Design, Installation and Operation of Solar Photovoltaic Systems* is set to support existing users and potential consumers of the technology.

The new *Code of Practice*, due for publication mid-2014, will address the requirements for the design, installation and operation for all scales of solar PV deployment in the UK. It will provide engineers and technicians with guidance on the safe, effective and competent application of grid-connected solar PV systems, including building-mounted, building-integrated and ground-mounted installations.

Solar panels can be used for a variety of applications, including domestic, large roof, building facade and solar field. The IET has done extensive work on solar power, and a *Solar Power Factfile* produced by experts at the Institution can be found on the IET website: **www.theiet.org/factfiles/energy/solar-power-page.cfm**

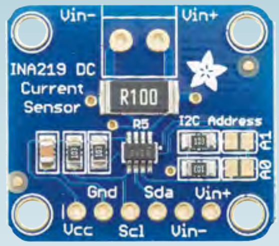
One million British-made Raspberry Pi boards

The first Raspberry Pi modules were manufactured in China. However, from September 2012, Raspberry Pi production was moved to a plant owned by Sony in Pencoed, South Wales. So, the chances are very good that any Pi bought this year will have been made here in the UK. A small, but nevertheless very welcome positive contribution to Britain's electronics balance of trade.

Now, the Raspberry Pi Foundation has reached an impressive landmark. The big news is that the factory in Pencoed has made its millionth British Raspberry Pi. Add to that million the existing Chinese ones, and that makes around one and three quarter million Raspberry Pi boards in use worldwide.

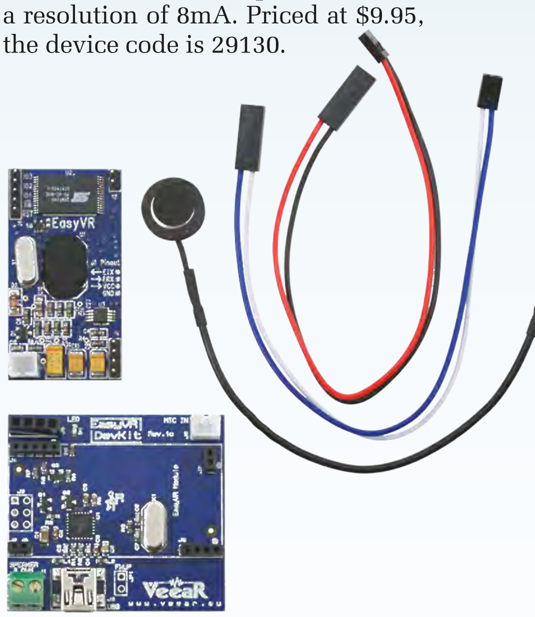
To celebrate this achievement, Sony presented the millionth British Raspberry Pi to the Foundation in a gold-plated case.

New from Parallax



DC Current Sensor

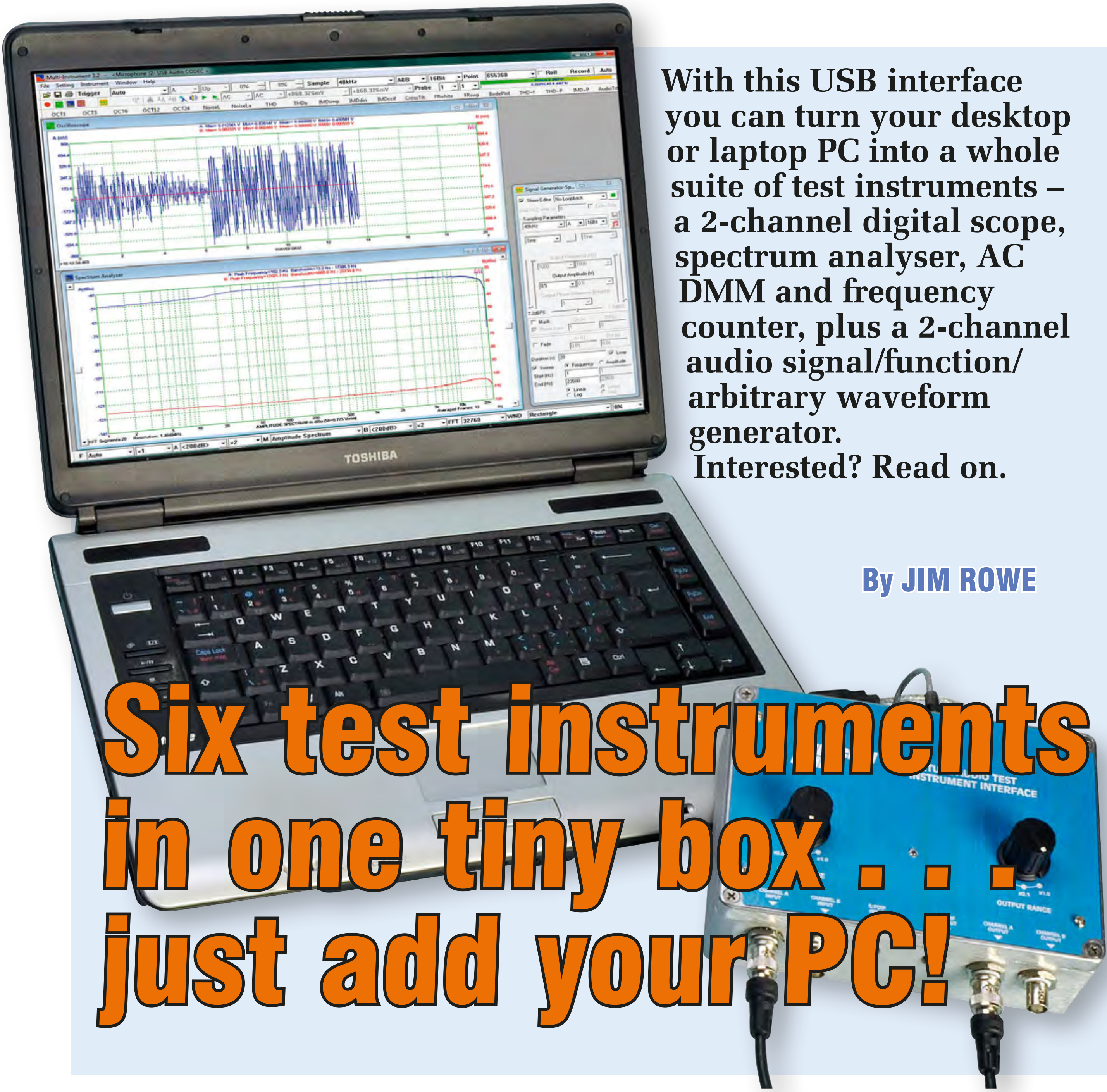
From Parallax, comes a precision amplifier for DC current measurement. The device measures the voltage across a 0.1Ω, 1% sense resistor. Since the amplifier maximum input difference is ±320mV, this represents up to ±3.2A. The internal 12-bit ADC means the resolution at ±3.2A is 0.8mA. Advanced users can customise the unit with their own choice of sense resistor. Just remove the 0.1Ω current sense resistor and replace it with, for example a 0.01Ω resistor, to measure up to 32A with a resolution of 8mA. Priced at $9.95, the device code is 29130.



EasyVR Development Kit

The EasyVR is a multi-purpose speech recognition module designed to add a versatile and robust speech and voice recognition capability to virtually any application. The module can be used with any host that has a UART powered at 3.3 to 5V, such as Propeller and BASIC Stamp microcontrollers. With a number of built-in speaker-independent commands, users will be able to run basic controls in six different languages (English, Italian, German, French, Spanish and Japanese). The kit includes a PWM audio output terminal that drives 8Ω speakers.

Suggested application areas include robot voice control, home automation and access control. Priced at $53.99, the device code is 30019 on the Parallax website: **www.parallax.com**



With this USB interface you can turn your desktop or laptop PC into a whole suite of test instruments – a 2-channel digital scope, spectrum analyser, AC DMM and frequency counter, plus a 2-channel audio signal/function/arbitrary waveform generator. Interested? Read on.

By JIM ROWE

Six test instruments in one tiny box . . . just add your PC!

In this article, we present an advanced multi-instrument project with a USB interface and a Windows-based audio testing package called *Multi-Instrument 3.2*, developed by Singapore-based firm Virtins Technology. This is a very professional software package and is reviewed elsewhere in this issue.

The interface described here is a development of the *USB Recording and Replay Interface* described in September 2013 and uses the same USB CODEC. For those familiar with that design, the input channel circuitry has been changed to be more similar to that of an oscilloscope/analyser and the output channel circuitry changed to be more like that of an AF signal/function/arbitrary waveform generator. Both the input and output channels have also been improved in terms of bandwidth, noise floor and crosstalk.

How it works

Since the heart of this project is the same Texas Instruments/Burr-Brown PCM2902 IC, as in the September 2013 interface, we won't give the detail of its operation. If you want to know more, refer to the September 2013 article, which gives an internal block diagram and discusses its operation in detail.

For our present purposes, it's enough to know that the PCM2902 is a single-chip stereo audio CODEC with an inbuilt full-speed USB protocol controller, a serial interface engine (SIE) and a USB transceiver. It provides a pair of 16-bit ADCs (analogue-to-digital converters) capable of working at seven sample rates between 8ks/s and 48ks/s and also a pair of 16-bit DACs (digital-to-analogue converters) capable of working at three sample rates: 32, 44.1 and 48ks/s.

The PCM2902 contains internal firmware that makes it fully compliant with the USB 1.1 standard and it installs automatically on Windows XP

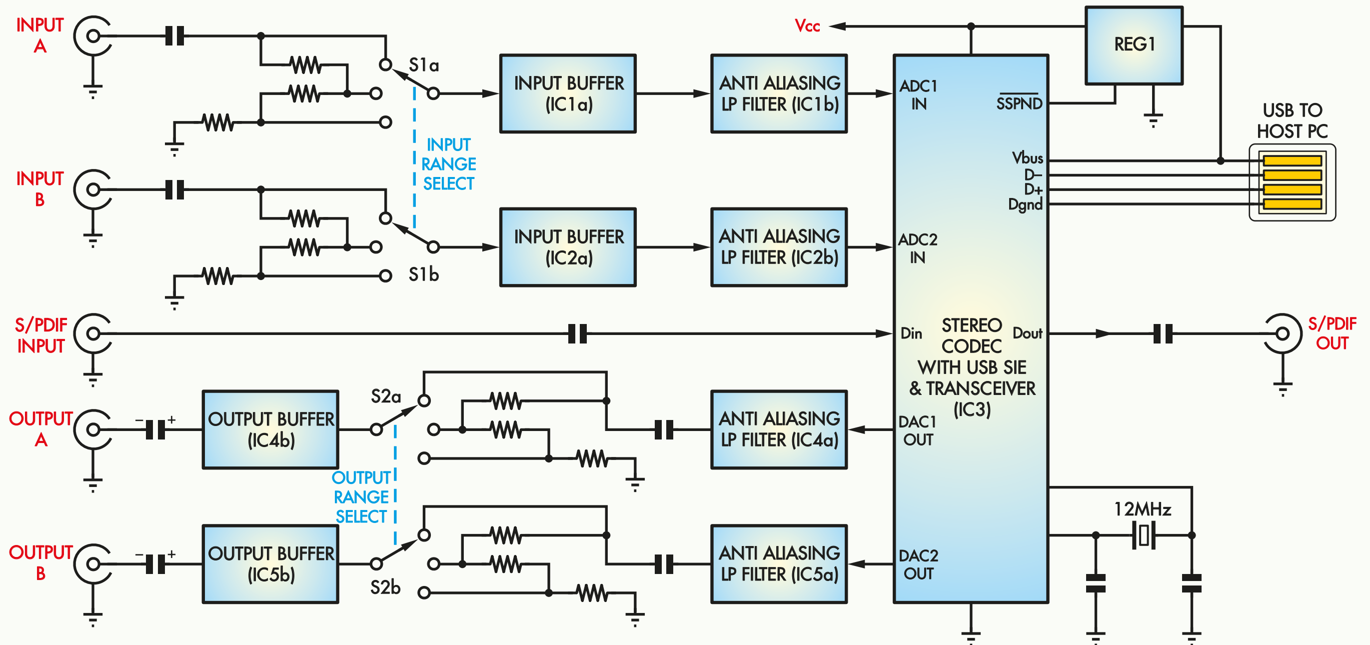


Fig.1: block diagram of the *USB Virtual PC Instrument Interface.* It's based on a PCM2902 stereo audio CODEC with an inbuilt serial interface engine and USB transceiver.

SP3 and later versions of Windows, using the *USBaudio.sys* drivers.

Another nice feature of the PCM2902 is that it includes an output and an input for S/PDIF serial digital audio. It can process and analyse S/PDIF signals (from a DVD player or set-top box, for example), as well as being able to generate S/PDIF testing signals.

The basic configuration of the new interface is shown in the block diagram of Fig.1. It shows the PCM2902 (IC3), with its USB port at upper right. The analogue input and output circuitry is all to the left, with the two ADC inputs at upper left and the two DAC outputs at lower left. The S/PDIF input can be seen at centre left, while the S/PDIF output is shown at centre right.

Each analogue input channel has an input voltage divider and range switch which allows the input signals to be either passed straight through or attenuated to prevent overload. The input dividers and switches provide three input ranges for each channel: ×1, ×0.1 and ×0.01. This allows the input channels to handle signals of 1.7V p-p (peak-to-peak), 17V p-p and 170V p-p, respectively.

An input buffer (IC1a and IC2a) follows the range switches in each input channel. These then feed the signals to anti-aliasing low-pass filters to remove any possible signal components above about 23kHz (which would cause aliasing). The outputs of the LP filters in turn feed into the two ADC inputs of the CODEC (IC3).

The analogue 'generator' output channels are almost a mirror image of this configuration. The outputs of the DAC first pass through more anti-aliasing LP filters to remove any sampling 'hash' and are each then fed to another voltage divider/switch combination to provide three output ranges: ×1, ×0.1 and ×0.01, producing maximum output signal levels of nominally 0-2.12V peak-to-peak, 0-212mV p-p and 0-21.2mV p-p. The signals from the output range switches then pass through buffer stages IC4b and IC5b to the output connectors.

Circuit details

So that's the basic configuration. Now we can refer to the diagram of Fig.2 for the full circuit details.

The input circuitry for channel A is shown at upper left, while that for channel B is shown below it. Both channels are virtually identical, with channel A using the two op amps inside IC1 and channel B using those inside IC2. IC1 and IC2 are Microchip MCP6022 devices, selected because they offer impressive bandwidth, noise and distortion performance when operating from a relatively low single-supply voltage, which in our case is only 4V.

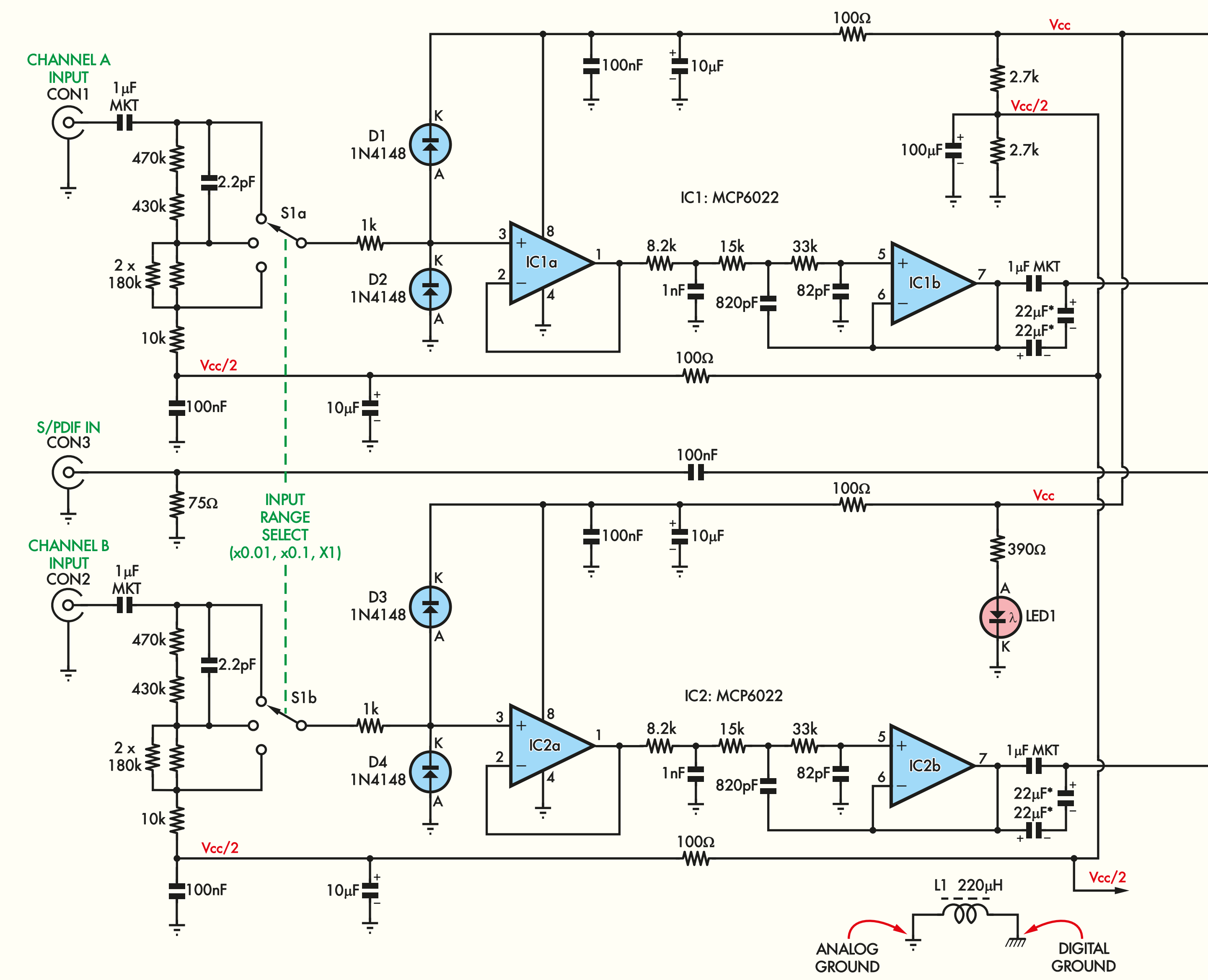
The input signals from CON1 and CON2 are fed through 1µF DC blocking capacitors to the input dividers and the two sections of range switch S1. The signals selected by S1a and S1b then pass through 1kΩ current-limiting resistors before being applied to the inputs of IC1a and IC2a, with diodes D1/D2 and D3/D4 used to limit the voltage swing at each input to a maximum of Vcc + 0.65V and a minimum of –0.65V.

Note that since the pin 3 inputs of IC1 and IC2 are biased at Vcc/2 (ie, half the supply voltage), this allows the voltage swing to be over the full supply range.

The outputs of LP filter stages IC1b and IC2b are each fed to the ADC inputs of IC3 (pins 12 and 13) via non-polarised coupling capacitors of approximately 12µF. These are made up from two series 22µF tantalum electrolytics connected in parallel with a 1µF metallised polyester capacitor. This has been done to extend the low-frequency response of the input channels to an acceptable level, with the modest input impedance (30kΩ) of the ADC inputs.

The S/PDIF input connector (CON3) is terminated via a 75Ω resistor. It is then connected to the digital input (pin 24) of IC3 via a 100nF coupling capacitor.

The two analogue output channels of the interface are shown at lower right in Fig.2, connected to the DAC outputs of IC3 (pins 16 and 15). Again, the two output channels are virtually identical, with IC4a and IC5a providing the LP



USB VIRTUAL PC INSTRUMENT INTERFACE

Fig.2: the complete circuit diagram of the USB interface unit. IC1a and IC1b, and IC2a and IC2b are the input buffers and low-pass filters for the Channel A and Channel B inputs, while IC4a and IC4b, and IC5a and IC5b provide filtering and buffering for the output signals. IC3 is the stereo audio CODEC – it provides the ADC and DAC stages, generates the USB signals and handles S/PDIF input and output signals.

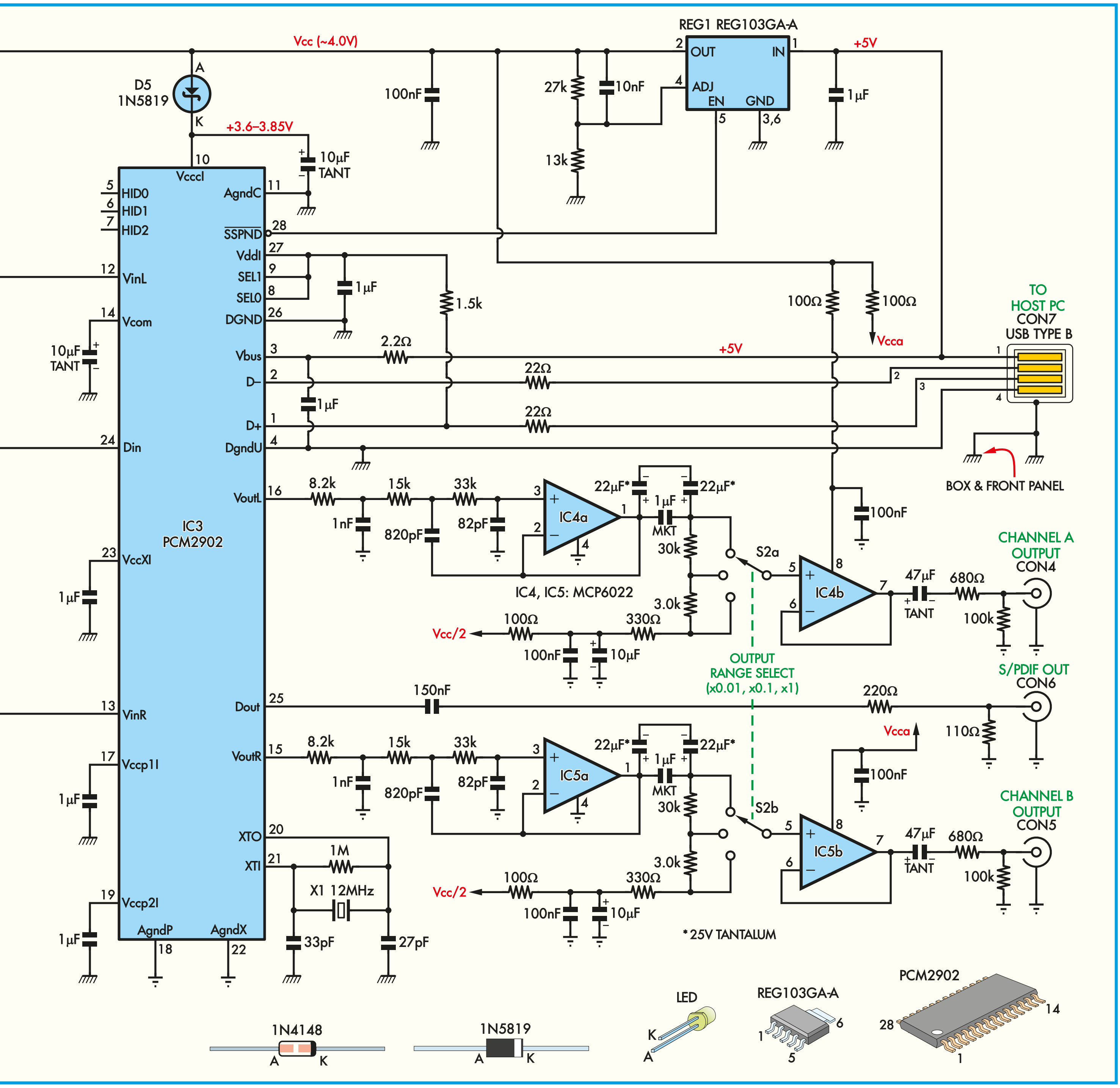
filtering and IC4b and IC5b forming the output buffers. IC4 and IC5 are again the same MCP6022 devices used in the input channels.

The two sections of switch S2 are used for output range switching, in conjunction with their voltage dividers. As with the input channels, the outputs of IC4a and IC4b are coupled to their respective dividers via 12µF coupling capacitors, to achieve an acceptable low-frequency response. That's also the reason for the 47µF capacitors used to couple the outputs of IC4b and IC5b to output connectors CON4 and CON5. The 680Ω resistors connected in series with each output provide short-circuit protection.

The S/PDIF digital output of IC3 (pin 25) is coupled to output connector CON6 via a 150nF capacitor and two resistors, selected to give the S/PDIF output a source impedance very close to the correct value of 75Ω.

As with the September 2013 Interface, the USB port of the PCM2902 CODEC (IC3) connects to the USB host connector CON7 via the recommended component values. The power for all of the interface circuitry is derived from the V_{bus} pin (1) of CON7, but is connected to the rest of the circuit via REG1, a REG103GA low dropout (LDO) regulator, which can be enabled or disabled via its EN input (pin 5).

This is done so that the current drain of the interface can be switched down to a very low value when the host



PC's USB controller indicates to the CODEC's serial interface engine (SIE) that it should go into 'suspend' mode.

When the SSPND output of IC3 (pin 28) rises to a high logic level to indicate the end of suspend mode, REG1 is turned on and delivers supply voltage (Vcc – approximately 4.0V) to the rest of the circuit – including the ADC and DAC circuitry inside IC3 itself. This receives a supply voltage of around 3.8V, via Schottky diode D5.

LED1 is driven from the Vcc line via a 390Ω resistor. LED1 indicates when the *Interface* has been activated (it remains off in suspend mode), as well as serving as a power-on indicator when the *Interface* is in use.

L1 is used to provide a connection between the digital and analogue grounds within the circuit – a connection which represents a low impedance at low frequencies but a higher impedance at high frequencies. This helps to keep digital hash out of the analogue sections of the circuit and improves the overall noise performance.

Construction

All the parts used in the *USB Interface* are mounted on a double-sided PCB coded 24109121 and measuring 160mm × 109mm, available from the *EPE PCB Service*. This fits inside a diecast aluminium box measuring 171mm × 121mm × 55mm, to provide physical protection as well as effective shielding.

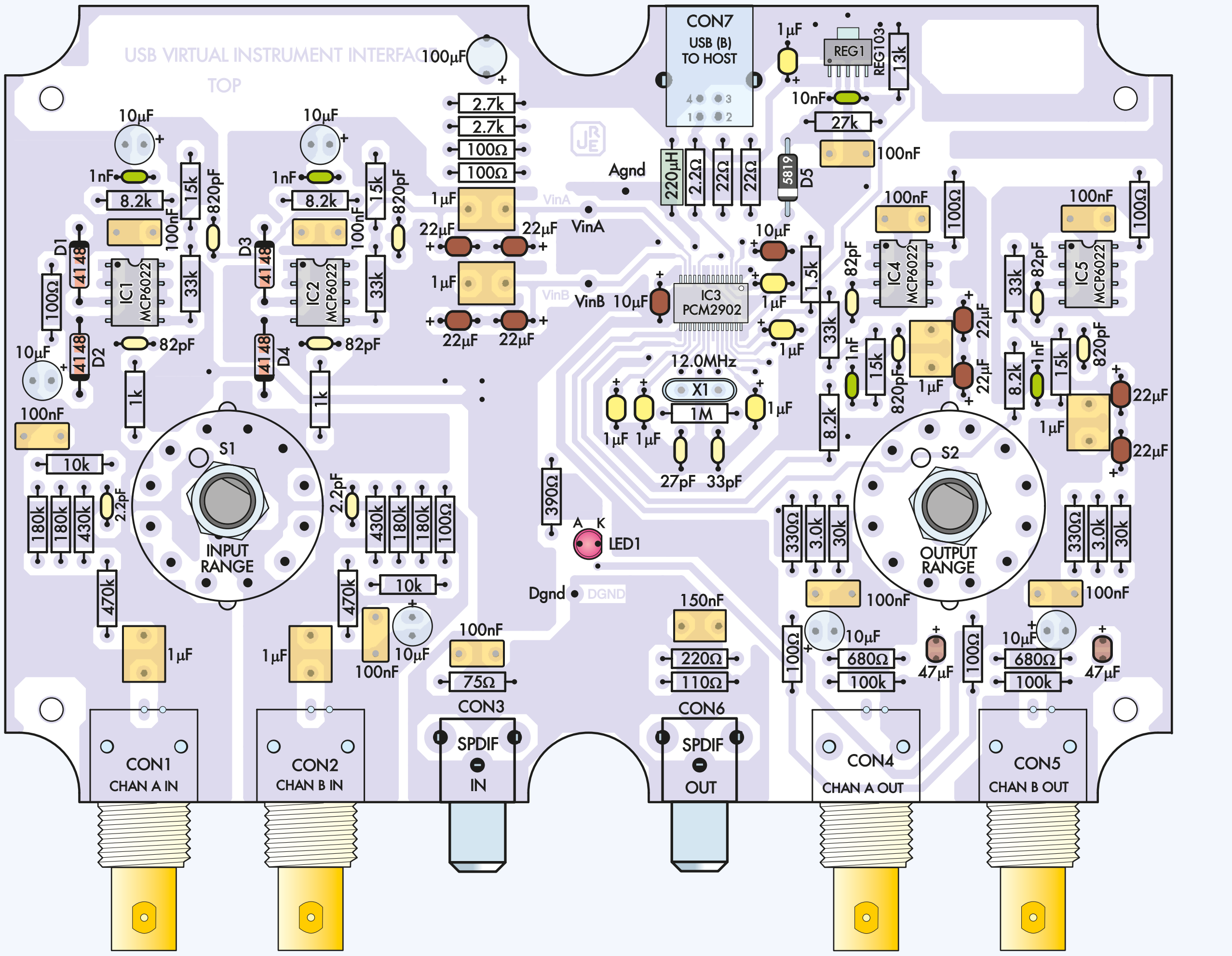


Fig.3: install the parts on the PCB as shown here, starting with the surface-mount device IC3. Note that this layout shows the tracks on the top side of the PCB only; the tracks on the bottom have been omitted for clarity.

The unit is built into a diecast metal case that provides necessary shielding.

The PCB and lid assembly is slipped into the case as shown here. Don't forget to file away the metal lip at the top front of the case.

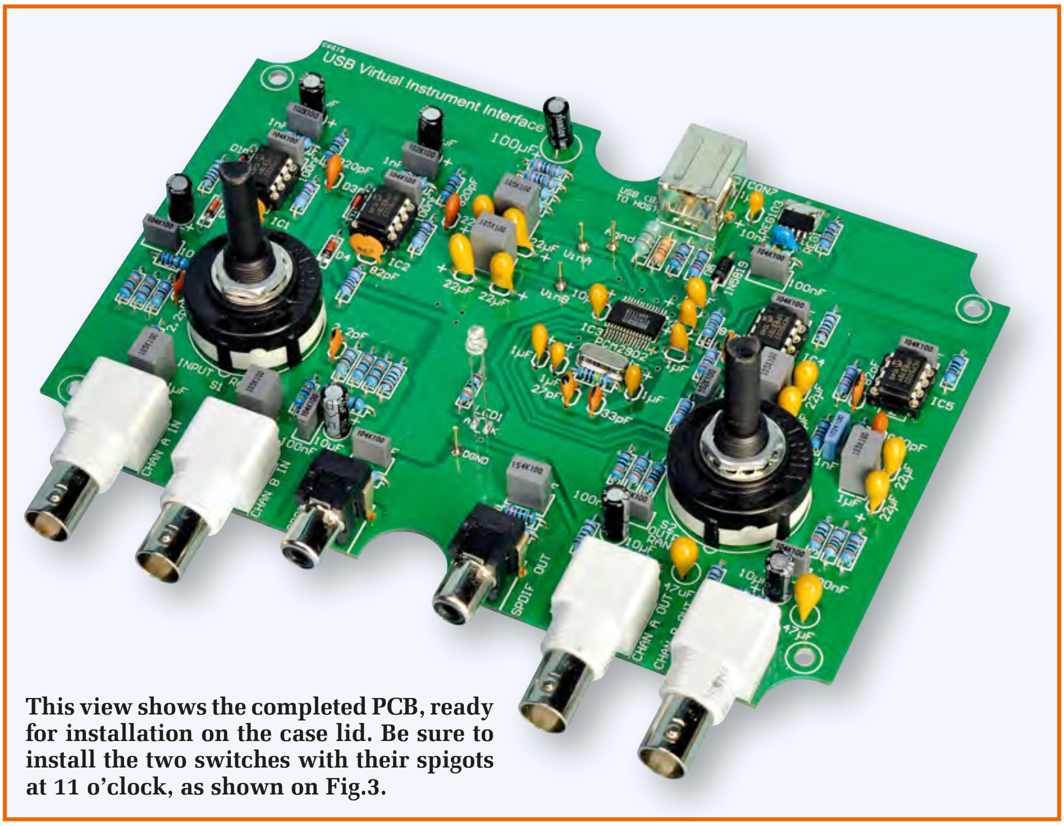
The PCB is mounted on four M3 × 25mm tapped spacers behind the lid of the box. The spindles of switches S1 and S2 pass through matching holes in the lid, as does the body of LED1.

USB connector CON7 is mounted at the rear of the PCB, and when the PCB and lid are fitted to the box, CON7 is accessed via a rectangular hole in the rear. All of the other I/O connectors (CON1-CON6) are mounted along the front of the PCB, with the input sockets to the left and the output sockets to the right.

These all pass through matching holes at the front of the box, when the PCB and lid are fitted. Hence, there is no wiring at all, apart from a single lead which connects the metal box to the earth of the PCB.

Fig.3 shows the parts layout on the PCB. You should follow it closely regarding the placement and orientation of the various components.

Begin the PCB assembly by fitting the two SMD components, IC3 and



This view shows the completed PCB, ready for installation on the case lid. Be sure to install the two switches with their spigots at 11 o'clock, as shown on Fig.3.

REG1 (it's easier to solder these in place when none of the other components are installed). Use a temperature-regulated iron with a fine chisel or conical point and hold each device in position carefully using a toothpick or similar tool while you tack-solder two pins that are well separated from each other.

These will hold the device in position while you solder the rest of the pins; make sure that the originally tacked pins are properly soldered as well. Don't worry if you accidentally create solder bridges between adjacent pins – these are almost inevitable and can be removed at the end of the soldering procedure using fine solder wick braid (an illuminated magnifier is handy when it comes to checking for solder bridges).

Once IC3 and REG1 are installed, you can fit the various passive components, starting with the resistors. These should be all 0.25W 1% metal film types, with the exception of the 2.2Ω unit just below CON7. This one needs to be a 0.5W or 0.625W type. Fit the 220µH RF inductor (L1) at this stage as well, just below CON7.

Now fit the various capacitors. Make sure that you don't confuse the 10µF tag tantalum types with the 10µF aluminium electrolytics and take care to fit all of these polarised components the correct way around. To help in this regard, Fig.3 shows the tantalum capacitors in brown, while the aluminium electros are shown as circles filled with pale blue.

After all of the capacitors are in place you can install the 12MHz clock crystal for IC3, which fits just to the front of IC3 and alongside the 1MΩ biasing resistor.

Next, install the 1N4148 diodes (D1-D4), which are located just to the left of the sockets for IC1 and IC2. The last diode to fit is D5 (1N5819) which goes midway between IC3 and REG1.

The input and output connectors (CON1-CON7) are next. Then fit the 8-pin sockets for IC1, IC2, IC4 and IC5, taking care to orient them with their notched ends towards the rear of the board, as shown in Fig.3.

Switches S1 and S2 can now be installed. Before you fit them, their spindles should be cut to a length of 16mm so they'll protrude through the front panel by the correct amount when the board assembly is fitted to it. The plastic spindles can be cut quite easily using a hacksaw and any burrs smoothed off using a small file. Then the switches can be fitted to the board. Orient them as shown in Fig.3, with their spigots at 11 o'clock. Press them down firmly against the top of the PCB and then solder all of their pins to the pads underneath.

Now try turning the switch spindles to check that they are correctly set for three positions. If not, you'll need to first rotate each switch fully anticlockwise, then remove the nut and lockwasher before lifting up the stop pin washer and refitting it with the pin passing down into the correct hole (ie, between the moulded 3 and 4 numerals). Finally, refit the lockwasher and nut to hold everything in place.

The final component is LED1, located just below the centre of the board with its cathode 'flat' towards the right. It is mounted in the upright position, with the lower surface of its body about 24mm above the top surface of the board. Just tack-solder one lead to hold the LED in place while the board is fitted behind the box lid.

You will be able to adjust the height of the LED later, so that it protrudes nicely through the front panel. Both solder joints can be finalised then.

The last step in completing the PCB assembly is to plug the four MCP6022 ICs into their sockets, each one with its notch end towards the rear of the board and also making sure that none of their pins become buckled. It's also a good idea to earth yourself before handling them, because they can be damaged by electrostatic discharge.

Preparing the lid and the box

Before the completed PCB assembly can be attached to the box lid, you'll need to drill holes in the lid to match the screws for the mounting spacers. In addition, you need to drill clearance holes for LED1 and the spindles of S1 and S2. The locations and sizes of all of these holes are shown in Fig.4, which is reproduced actual size so it can be used as a drilling template if you wish. As you can see, there are only seven holes to be drilled in all, so preparing the lid is quite easy.

The drilling diagram for the box is shown in Fig.5. Six holes need to be

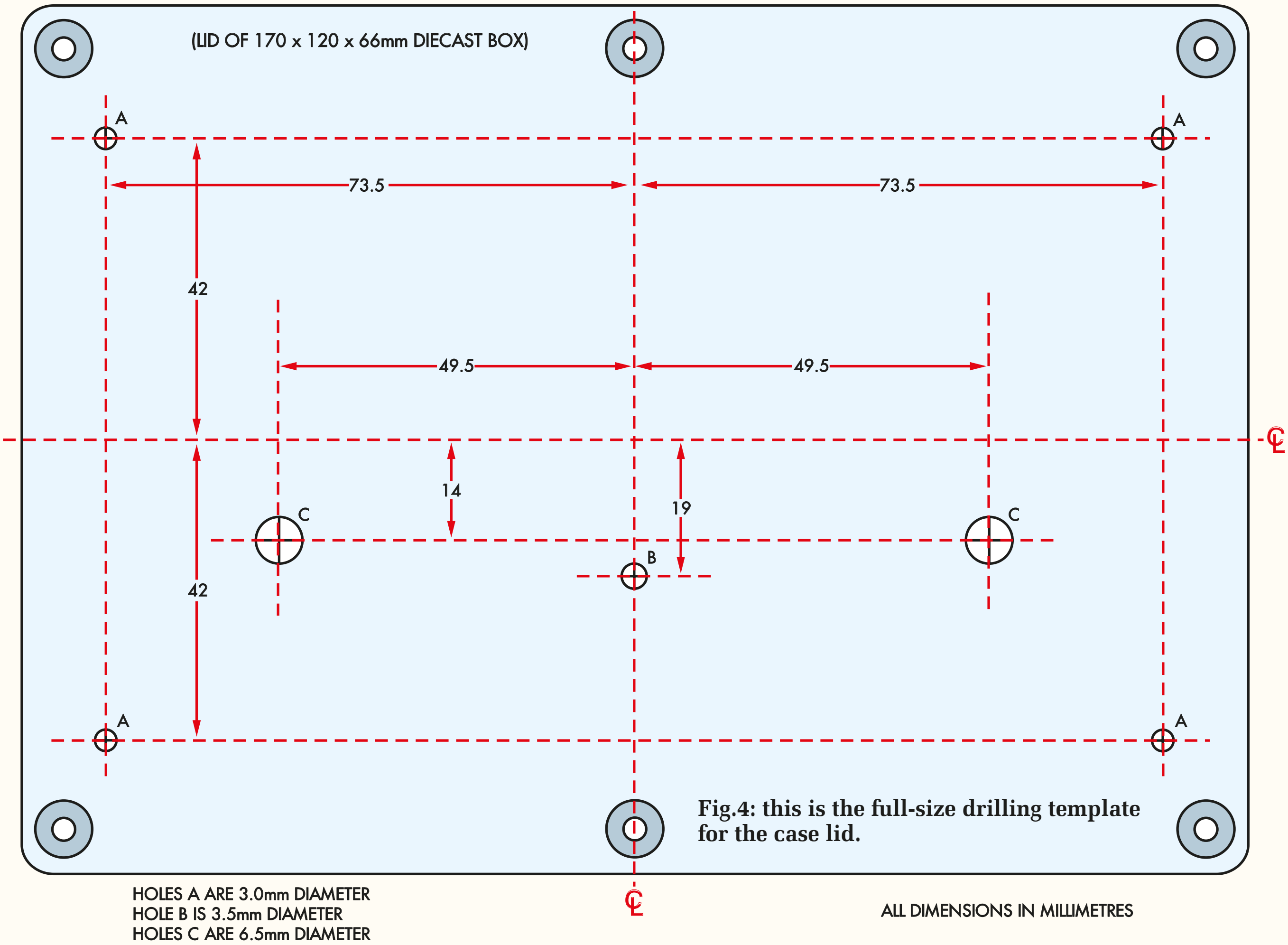


Fig.4: this is the full-size drilling template for the case lid.

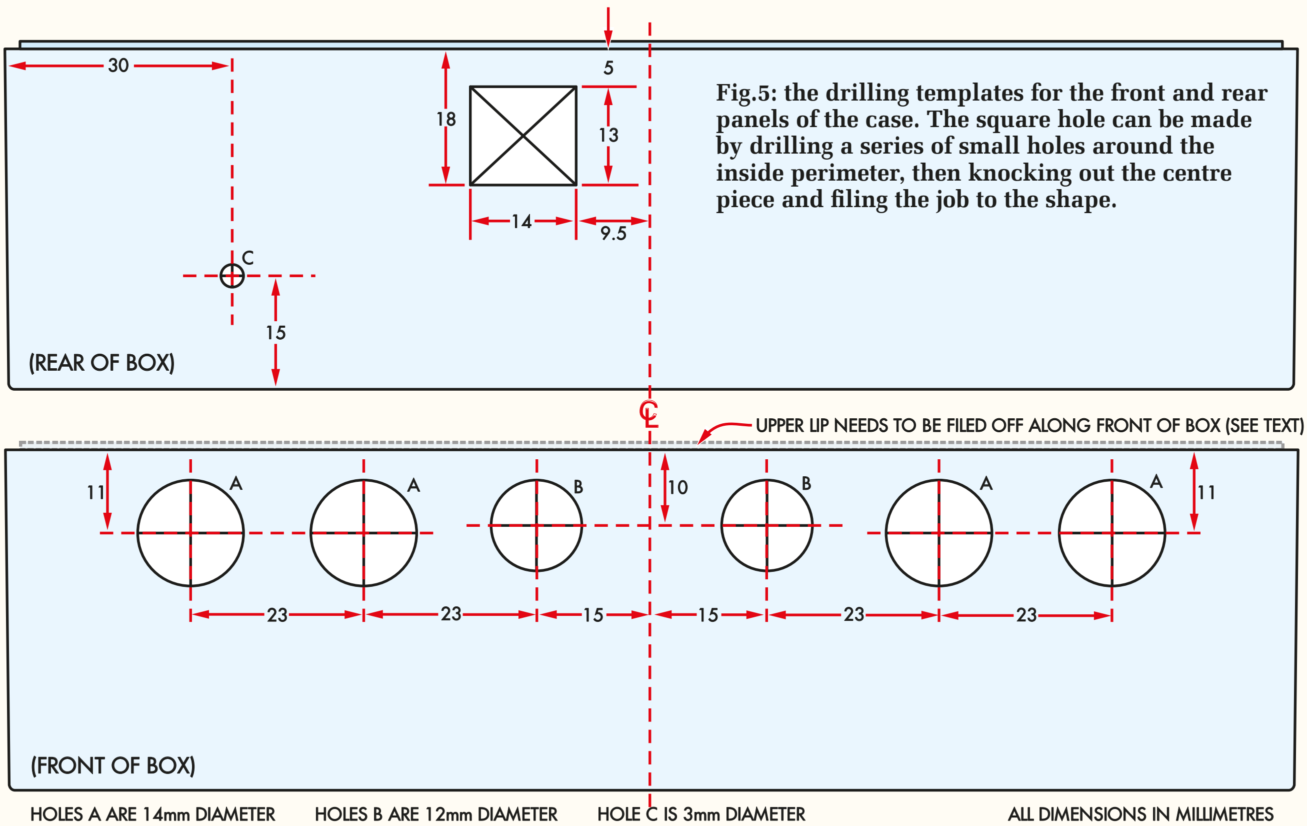
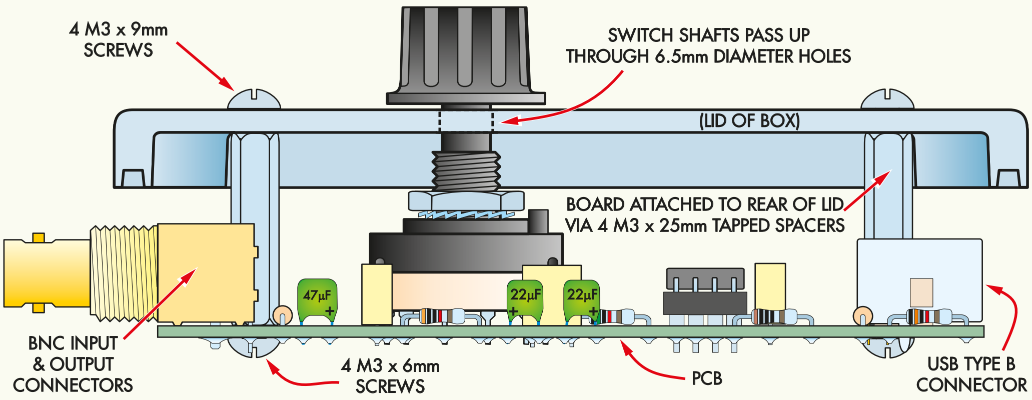


Fig.5: the drilling templates for the front and rear panels of the case. The square hole can be made by drilling a series of small holes around the inside perimeter, then knocking out the centre piece and filing the job to the shape.



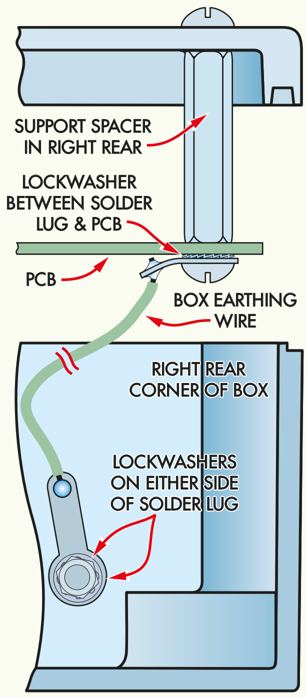


Fig.6 (above): this diagram shows how the PCB is secured to the back of the lid on four M3 × 25mm tapped spacers. The supplementary diagram at right shows how the PCB's ground track is connected to the metal case via an earth wire and two solder lugs.

The small metal lip that runs along the top front of the case must be filed away to allow the PCB lid assembly to slide into place.

drilled using a pilot drill and then carefully enlarged to the correct size using a tapered reamer. The rectangular hole for USB connector CON7 can be made by drilling a series of small holes around the inside perimeter, then knocking out the centre piece and filing the job to the final rectangular shape.

When all holes are complete, you will need to file away the small lip running along the top of the front of the box, as indicated by the note in Fig.5. This is necessary because when the lid and PCB assembly are being introduced into the box during final assembly, if the lip is still present it just prevents the front of the PCB from being lowered enough for BNC connectors CON1, CON2, CON4 and CON5 to pass through their matching holes.

A professional front panel will be available for sale from *EPE*. This is basically a screen-printed PCB and is supplied with all the holes pre-drilled.

Final assembly

The PCB and lid assembly is shown in Fig.6. Four M3 × 25mm tapped spacers are attached to the rear of the lid using four M3 × 9mm machine screws (which also pass through the matching holes in the dress front panel, on the top of the lid). These screws should be tightened firmly, without causing buckling of the dress panel around the screw heads.

Next, the PCB can be offered up to the lower ends of the spacers, taking care to ensure that the spindles of S1 and S2 align with their matching holes in the lid and that the body of LED1 enters its own matching hole. Then, when the PCB is resting on the spacers the complete assembly can be turned over and three M3 × 6mm screws installed to attach the board to three of the four spacers: the two at the front corners of the PCB and the one at the rear corner furthest from USB connector CON7.

When these three screws have been fitted and tightened up to hold the board and lid together, the final screw can be fitted in the remaining corner spacer hole. This M3 × 6mm screw is also used to terminate an earthing wire from the box – so in this case it must be fitted with a 3mm solder lug and a star lockwasher, before being screwed down against the exposed metal pad around this board mounting hole.

Make sure you tighten this screw down securely, using a Phillips-head screwdriver and a spanner or small shifter to grip the spacer and prevent it from turning.

Now check the positioning of LED1 in its hole in the front panel. Adjust it if necessary before soldering both its leads to the PCB.

That done, you need to fit a 120mm-long earth wire between the case and the PCB. This is attached at the case end via a 3mm solder lug that's secured by an M3 × 9mm screw to one corner of the box. Fit a star lockwasher to the screw, then add the solder lug and follow this with another star lockwasher. The other end of the earth wire is soldered to the lug previously attached to one corner of the PCB.

Once this wire is in place, remove the nuts from the front of the BNC input and output connectors (leaving the lockwashers in place) and lower the front of the lid and PCB assembly into the box until the BNC connectors pass through their matching holes in the front of the box. This will then allow the rear of the lid/PCB assembly to be lowered into the box as well, until the lid is sitting comfortably on the top of the box.

PC Instrument Interface: Parts List

- 1 diecast aluminium box, 171mm × 121mm × 55mm
- 1 PCB, available from the *EPE PCB Service,* code 24109121, size160mm × 109mm
- 1 front panel PCB, code 24109122
- 1 12.00MHz HC49U/US crystal (X1)
- 1 220µH RF choke, axial leads (L1)
- 2 4-pole 3 position rotary switches (S1,S2)
- 4 PCB-mount BNC connectors (CON1-CON2, CON4-CON5)
- 2 PCB-mount switched RCA sockets (CON3, CON6)
- 1 USB type-B connector, PCB-mount (CON7)
- 4 8-pin DIL sockets, machined pin type
- 2 instrument knobs, 24mm dia.
- 4 M3 x 25mm tapped spacers
- 5 M3 x 9mm machine screws
- 4 M3 x 6mm machine screws
- 1 M3 nut
- 2 3mm solder lugs
- 3 3mm star lockwashers
- 1 120mm-length of insulated hookup wire

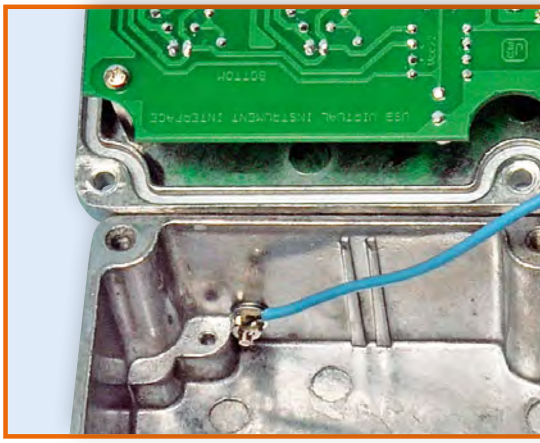
Semiconductors
- 4 MCP6022 dual op amps (IC1,IC2,IC4,IC5)
- 1 PCM2902 audio CODEC (IC3) (Element14 8434700)
- 1 REG103GA-A low-dropout regulator (REG1) (Element14 1207256)
- 1 3mm high-intensity red LED (LED1)
- 4 1N4148 100mA diodes (D1-D4)
- 1 1N5819 1A Schottky diode (D5)

Capacitors
- 1 100µF 16V RB electrolytic
- 2 47µF 16V tantalum electrolytic
- 8 22µF 16V tantalum electrolytic
- 6 10µF 16V RB electrolytic
- 2 10µF 16V tantalum electrolytic
- 6 1µF monolithic ceramic
- 6 1µF MKT polyester
- 1 150nF MKT polyester
- 10 100nF MKT polyester
- 1 10nF MKT polyester
- 4 1nF polyester (greencap)
- 4 820pF 50V disc ceramic
- 4 82pF 50V disc ceramic
- 1 33pF 50V NP0 disc ceramic
- 1 27pF 50V NP0 disc ceramic
- 2 2.2pF 50V NP0 disc ceramic

Resistors (0.25W, 1%)

1 1MΩ	2 2.7kΩ
2 470kΩ	1 1.5kΩ
2 430kΩ	2 1kΩ
4 180kΩ	2 680Ω
2 100kΩ	1 390Ω
4 33kΩ	2 330Ω
2 30kΩ	1 220Ω
1 27kΩ	1 110Ω
4 15kΩ	8 100Ω
1 13kΩ	1 75Ω
2 10kΩ	2 22Ω
4 8.2kΩ	1 2.2Ω 0.5W
2 3.0kΩ	

Note: the PCB and front panel are available from *EPE*.



The lid can now be secured in place using four M4 screws (supplied with the box). Finally, refit the BNC connectors with their mounting nuts and then fit the knobs to the spindles of S1 and S2. Your *Virtual Instrument Interface* is now complete.

Checkout time

The only setting up adjustments you may need to make are in the operating system of the PC, as explained shortly. Checking out the *Interface* basically involves little more than connecting it to a spare USB port on either the PC itself or to a spare downstream port on an external hub connected to it.

Because the PCM2902 CODEC includes firmware which identifies itself as a *'Generic USB Audio CODEC'*, it usually installs automatically when you connect it to a PC running Windows XP (SP3), Vista or Windows 7.

After a few seconds, you should hear a greeting from the PC's sound system to indicate that the operating system has recognised that a new Plug and Play USB device has been connected. It then shows pop-ups from the System Tray as it identifies the device and automatically installs the standard USB audio drivers for it. LED1 on the Interface should also light as soon as the drivers are installed.

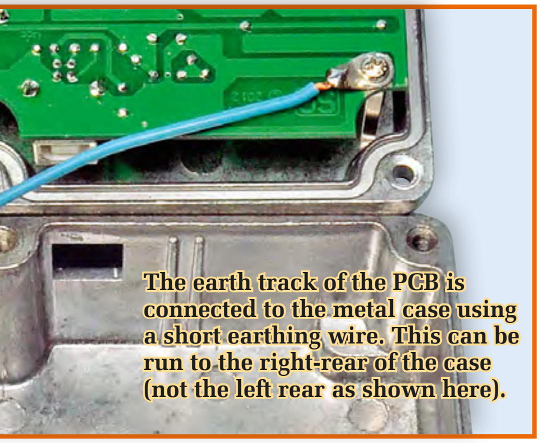
The next step is to check that this has all taken place correctly. In Windows XP, click the Start button, launch the Control Panel and double click on *'Sounds and Audio Devices'*. This should bring up the Sounds and Audio Devices Properties dialog. If you then click on the *'Audio'* tab you should see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

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

PCM2902 version differences

The PCM2902 IC specified in this project (and the USB Stereo Recording/Playback Interface from September 2013) is the most common type currently available. However, Texas Instruments also has two newer versions of this chip: the PCM2902B and PCM2902C.

All three versions are pin-compatible and should work without any circuit changes. The later versions have some minor advantages: (1) the B and C versions are USB 2.0 compliant, whereas the original is only USB 1.1 compliant; (2) the original chip had a one-sample recording delay between the left and right channels which has been fixed in the later revisions; and (3) the later versions are more tolerant of malformed S/PDIF input data. In addition, the PCM2902C identifies its analogue inputs as line level inputs rather than microphone inputs, so you don't have to adjust the input gain before using it. It also has an onboard digital volume control.



The earth track of the PCB is connected to the metal case using a short earthing wire. This can be run to the right-rear of the case (not the left rear as shown here).

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

If you are using Windows 7, launch the Control Panel and select *'Hardware and Sound'*. Then double-click on *'Sound'*, which should bring up the dialog box shown in Fig.7. The *'Playback'* tab will be automatically selected, showing that the default playback device (labelled 'Speakers') is the 'USB Audio CODEC'.

If you then select the *Recording* tab, this should show that the default recording device (labelled '*Microphone*') is again the USB Audio CODEC, as shown in the upper dialog in Fig.8. If you then click on the *Microphone* to select it and then click on the *Properties* button, this will open up the *Microphone Properties* dialog (the lower one in Fig.8), to confirm that the *Interface* is installed as a *Generic USB Audio* device.

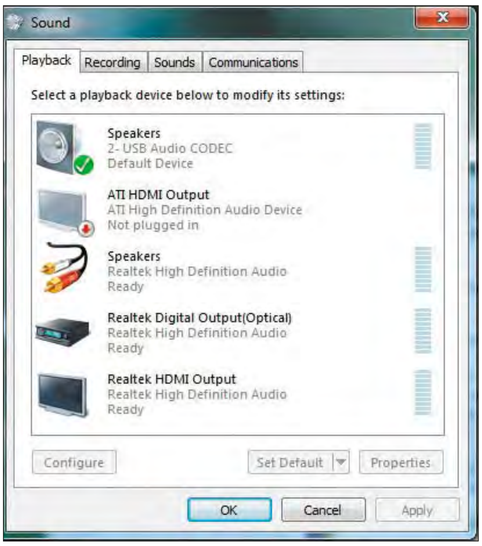


Fig.7: the Windows 7 *Sound* dialog box. The default playback device should be the 'USB Audio CODEC'.

Features and specifications

A 2-channel virtual test instrument USB interface to suit to any Windows-based PC, powered from the PC's USB port. The two input channels and two output channels can all operate simultaneously. Also provided is an S/PDIF input and output.

When used in conjunction with a suitable software package the Interface allows the PC to be used as a 2-channel audio DSO and spectrum analyser combined with an AC DMM and a frequency counter, plus a 2-channel AF signal and function generator able to provide low-distortion sinewaves, a number of standard waveforms, white and pink noise, arbitrary waveforms and even DTMF signals and musical tones. Features of the Interface include:

- Input channels provide three switched sensitivity levels: x1.0, x0.1 and x0.01
- Nominal input sensitivity (x1.0 range) is 500mV RMS (1.414Vp-p/-3.8dBu).
- Maximum input level (x1.0 range) before clipping is 600mV RMS (1.70Vp-p/-2.2dBu).
- Input impedance (both channels) is 1MΩ//20pF.
- Effective noise floor of the input channels is at –99dBu (2.5µV).
- Two high-quality 16-bit ADCs capable of operating at sampling rates of 8, 11.025, 16, 22.05, 32, 44.1 and 48ksamples/s.
- Frequency response of input channels is as follows:
  21Hz – 8kHz +0/–0.15dB
  12Hz – 12.6kHz +0/–0.5dB
  6Hz – 16.3kHz +0/–1.0dB
  1.5Hz – 20kHz +0/–2.0dB
  <1Hz – 22kHz +0/–3.0dB
- Output channels provide three switched output levels: x1.0, x0.1 and x0.01.
- Nominal output level on the x1.0 range is 500mV RMS (1.414Vp-p/–3.8dBu).
- Maximum output level (x1.0 range) before clipping is 750mV RMS (2.12Vp-p/–0.28dBu).
- Output impedance (both channels) is 675Ω.
- Two high quality 16-bit DACs capable of operating at sampling rates of 32, 44.1 and 48ksamples/s.
- Frequency response of the output channels is as follows:
  4.6Hz – 17.0kHz +0.15dB/–0.5dB
  3.1Hz – 18.7kHz +0.15dB/–1.0dB
  1.2Hz – 20.5kHz +0.15dB/–2.0dB
  <1Hz – 22.0kHz +0.15dB/–3.0dB
- Crosstalk between channels, overall:
  below –62dB from 20Hz – 5kHz
  below –59dB from 1Hz – 10kHz
  below –56dB from 10kHz – 20kHz
- Crosstalk between output and input channels:
  as for between channels shown above
- THD+N for both channels, overall (ie, output-> input) for output/input levels of 0.5V RMS: at 100Hz, 0.075%; at 1kHz, 0.075%; at 5kHz, 0.1%
- S/PDIF input and output both handle 16-bit stereo signals at sampling rates of 32, 44.1 and 48ks/s.
- Fully compliant with the USB 1.1 specification
- Installs automatically on Windows XP SP3 and later Windows operating systems (plus Mac and Linux systems) using the standard USBaudio.sys drivers – no special or custom drivers required.
- Fully compatible with Windows-based Virtual Instrument software such as Virtins MI 3.2 (standard and Pro versions).
- Low current drain from PC via USB cable: less than 65mA

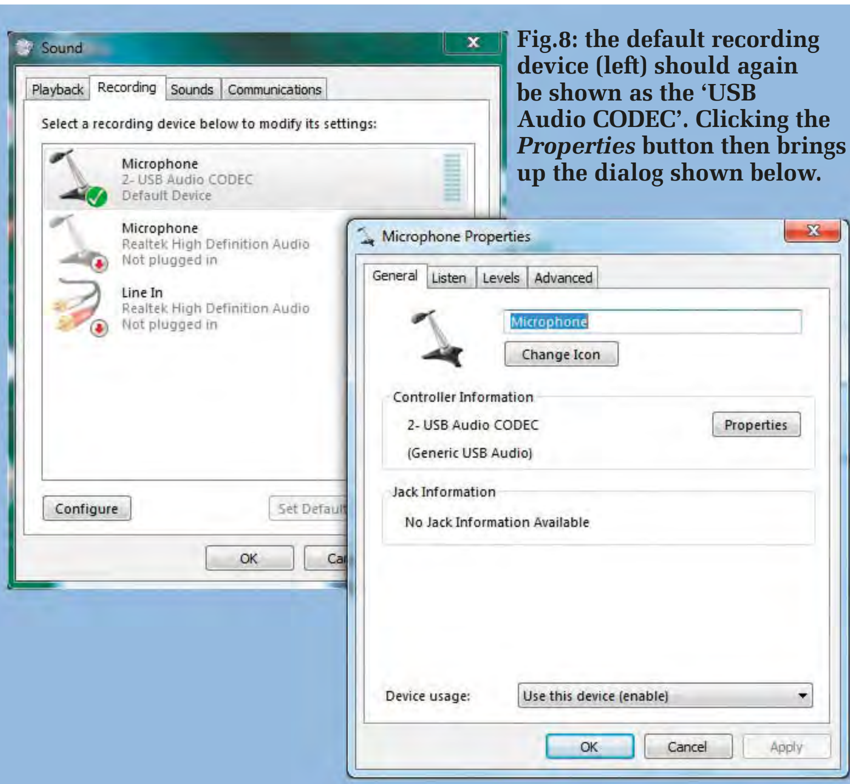


Fig.8: the default recording device (left) should again be shown as the 'USB Audio CODEC'. Clicking the *Properties* button then brings up the dialog shown below.

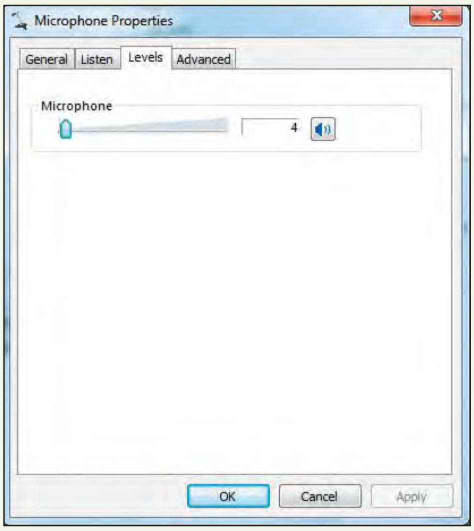


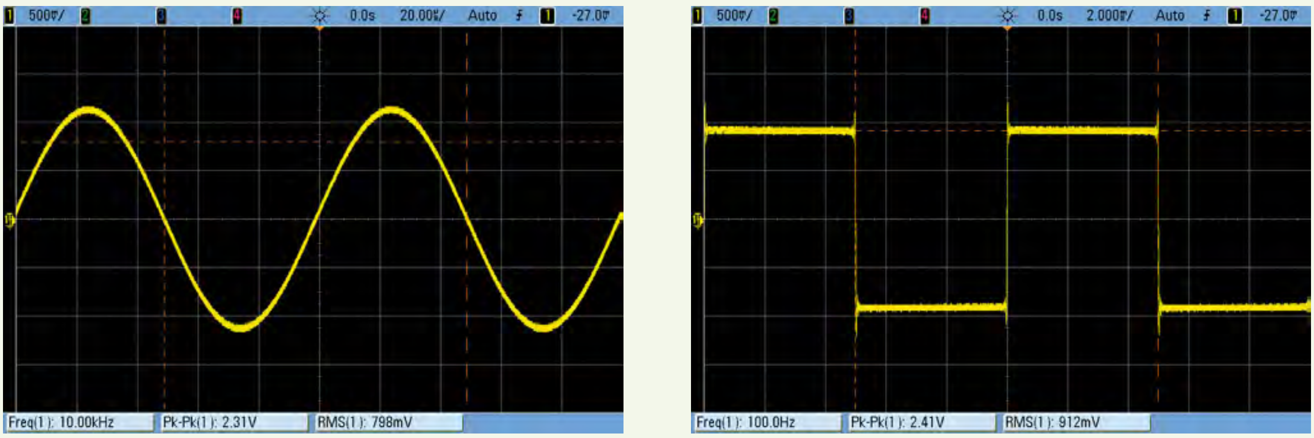
Fig.9 selecting the Levels tab in Fig.8 brings up this dialog box. The Microphone slider control should be dragged to the left to give a level reading of '4' (see text).

Finally, you need to select the *Levels* tab at the top of the *Microphone Properties* dialog. This will display the Microphone mixer level control slider, as shown in Fig.9. Move the slider towards the lefthand end until the number displayed in the box to its right is '4' (see Fig.9).

This is the correct setting for our *Virtual Instrument Interface*, because the PCM2902 leads Windows to believe it is providing amplified signals from two microphones when it's really providing 'line level' inputs. By setting the slider to '4', we trick Windows into believing the signals are effectively coming from line level inputs.

Once you have set the 'Microphone' slider to 4, all that is necessary is to back out of these dialogs by clicking on the 'OK' buttons in turn until you return to the Control Panel. This can then be closed and your *Virtual Instrument Interface* will now be installed and ready for use. Of course before you can do so, you'll need to install the Virtual Instrument Software you're planning to use with it. For details on installing and using Virtins' Multi-Instrument 3.2 please refer to the review article elsewhere in this issue.

The USB socket is accessed via a square hole in the rear side panel of the case. Note that the case lid is held on using just four screws (one at each corner). The other two holes in the lid are covered by the front panel and are not used.



These two scope grabs show waveforms generated by the Virtins' Multi-Instrument 3.2 software and processed through the *Virtual PC Instrument Interface*. A 10kHz sinewave is shown at left, while at right is a 100Hz square wave.

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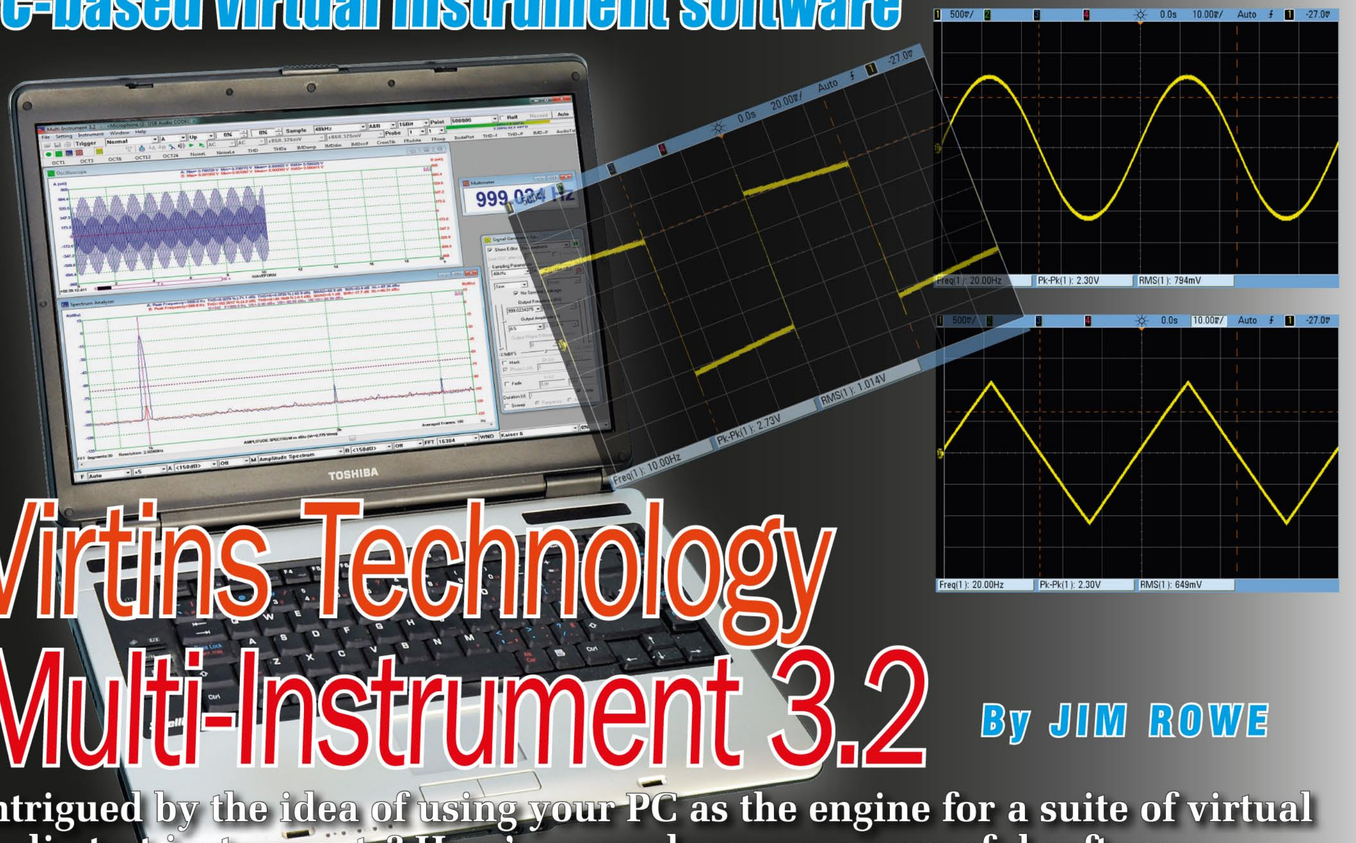
PC-based virtual instrument software



Virtins Technology Multi-Instrument 3.2

By JIM ROWE

Intrigued by the idea of using your PC as the engine for a suite of virtual audio test instruments? Here's a run-down on a powerful software package that will let you use it as a 2-channel audio scope combined with a powerful spectrum analyser, a 2-channel audio signal/function generator and an audio DMM which even includes a frequency counter!

Testing domestic audio gear using a good-quality sound card via a PC running a virtual audio test instrument package (for example, TrueAudio's TrueRTA) is a popular option for hobbyists. However, while we've found that TrueRTA and other applications have many worthwhile features, including the ability to make accurate frequency response and noise level plots, they often have irritating limitations with regard to distortion and crosstalk measurements and plots.

Recently though, we became aware of another software package called Multi-Instrument 3.2, developed by a Singapore-based firm called Virtins Technology. Virtins has specialised in PC-based virtual instrument technology since it was founded in the early 1990s, and in addition to the Multi-Instrument software package, it currently markets a range of virtual digital storage oscilloscopes (DSOs) together with its own real-time audio analyser.

VMI 3.2 is the latest version of a software package first released in late 2004, for use with PC sound cards. It supports all Windows-compatible sound cards and interfaces and Virtins' own virtual instruments – plus many industrial ADC/DAC cards like the DAQmx series from National Instruments.

An evaluation version of VMI 3.2 can be downloaded free from their website. It's a fully-featured version, which 'expires' after 21 days unless you buy a licence from them online. There are three performance levels to choose from when it comes to purchasing: 'Lite' costing US$49.95; 'Standard' costing US$99.95; and 'Pro' costing US$199.95. There are also various add-on functions, like a waterfall plot/spectrogram, data logger, LCR meter and a vibrometer, plus an option which allows you to create, save and execute a series of device test plans.

After downloading and trying out the evaluation version of Virtins Multi-Instrument 3.2 (VMI 3.2) for a week or two, we were motivated to develop the *USB Virtual Instrument Interface* featured elsewhere in this issue.

A virtual instrument suite

In Standard form, VMI 3.2 is a suite of the following virtual instruments:

2-channel digital oscilloscope – bandwidth from below 10Hz to 96kHz, depending on the capabilities of your sound card or ADC hardware. The sampling depth can be 8, 16 or 24 bits, again depending on your sound card. There is a range of triggering modes and display modes, such as A and B, A + B, A – B, A × B and Lissajous (A against B). Each frame of data can be provided with a date/time stamp and the data can also be recorded continuously on the PC's hard disk.

2-channel spectrum analyser – a selection of seven different display modes: amplitude/power spectrum, phase spectrum, auto correlation and cross correlation functions, coherence function, transfer function (Bode plot) and impulse response. The FFT window size can be selected from 16 different options, from 128 to 4,194,304 points, while there is a choice of no less than 55 different windowing functions, including rectangular, triangular, Hanning, Hamming, Blackman, Gaussian, cosine, Poisson and so on.

The overlap between windows can also be set to any desired percentage, and there's a choice of many different display and scaling options for both the Y axis and the frequency axis. Parameters which can be measured using the spectrum analyser include bandwidth, crosstalk, THD, THD+N, SINAD, SNR and noise level (NL) in a specified frequency band. It's also possible to measure IMD (SMPTE/DIN, CCIF etc).

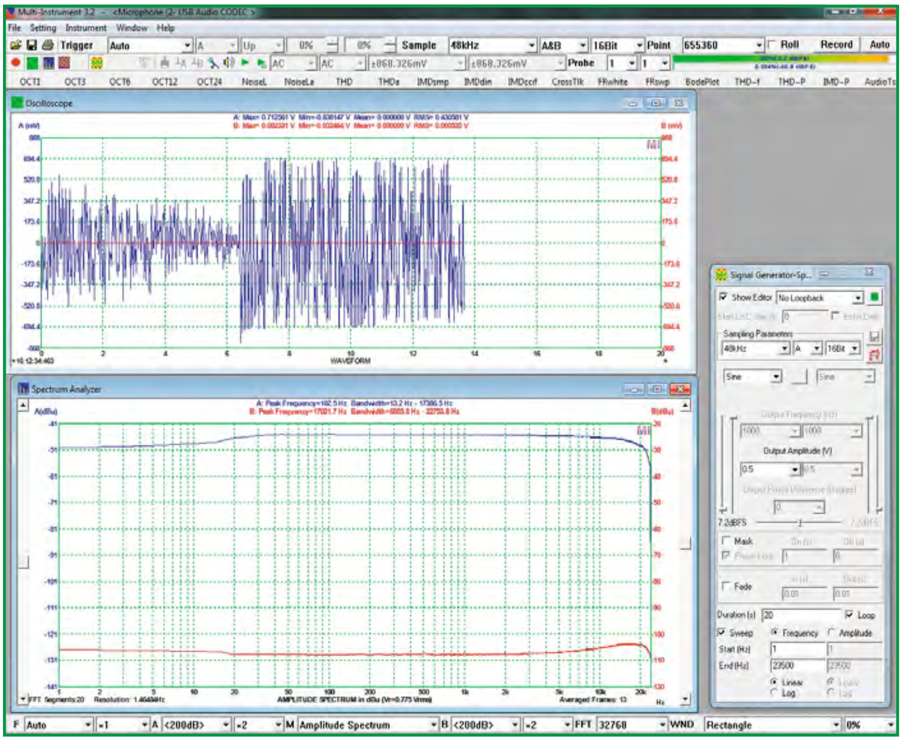


Fig.1: the main screen has four horizontal function bars along the top, with icons to activate the scope, spectrum analyser, DMM and generator. Here, the scope window is at upper left, with the analyser window below it. The smaller, narrower window at lower right is for the signal generator.

2-channel digital signal generator – a wide choice of waveforms and associated functions, including sine, rectangle (with adjustable duty cycle), triangle, sawtooth and multi-tones like DTMF. There's also a choice of white or pink noise, maximal-length sequences with length adjustable between 127 and 16,777,215 samples, unit impulse and unit step, notes from the tempered musical scale and arbitrary waveforms (which may be stored on hard disk).

In addition, the generator can be set to provide any desired phase difference between the two output channels, and it can mask their outputs in order to provide 'burst' test signals. It can also provide sinewave signals sweeping either linearly or logarithmically between any two selected frequencies and at any desired speed.

It's also possible to set the exact output frequency to a value which minimises 'spectral leakage' when you are using the spectrum analyser.

AC multimeter – able to display RMS volts, dBV, dBu, dBrelative and dBA/B/C, plus cycle RMS and cycle mean. It can also function as a frequency counter, a tachometer (RPM), a straight counter, a duty cycle indicator and a frequency/voltage converter.

Calibration and compensation

VMI 3.2 also supports calibration of the input and output channels of your interface/sound card, so that absolute values in engineering units can be used for display, analysis or export. It is also able to account for external attenuator settings (such as the input switch settings in the Virtual Instrument Interface), as well as being able to compensate for hardware characteristics such as the frequency response deviations of the interface/sound card. Once measured, these can be saved as 'reference curves' and loaded in whenever they are needed.

Zooming and scrolling in both the X and Y axes are supported in all graphs displayed by the scope and spectrum analyser, to allow inspection of fine details. In any case, VMI 3.2 provides a 'cursor reader' for each graph, allowing you to determine the exact X and Y readings for any specific point just by clicking on it and holding the mouse button down. There are also two markers which can be set by double clicking, for comparison purposes.

Another nice feature of VMI 3.2 is a row of 16 'hot panel setting' buttons along the top of the screen. These are pre-configured to set up all the instrument panel controls and settings for specific tests. However, you are free to reconfigure any or all of these buttons as you wish, for your own most-frequently performed tests. As part of the reconfiguring, you are even able to change the legend on the button being 'reprogrammed'.

It's also quite easy to save any desired screen layout and combination of instrument settings as the default 'skin' for VMI 3.2 when you start it up each time. In short, it offers a high degree of customisation.

All data collected by the VMI 3.2 oscilloscope or spectrum analyser can be saved, either as a wave file or a text file. All graphs can also be exported as bitmap (.BMP) files or printed out directly. And waveform files saved in either .WAV or .TXT form can be imported into the Generator to generate that waveform again.

System requirements

VMI 3.2 is compatible with all versions of Windows from Windows 95 to Windows 7, either 32-bit or 64-bit. Virtins suggest that for optimum results, your monitor should have a horizontal resolution of at least 1024 pixels.

As you've no doubt gathered from the above, VMI 3.2 has an almost bewildering array of functions and facilities. Fortunately, there is a 283-

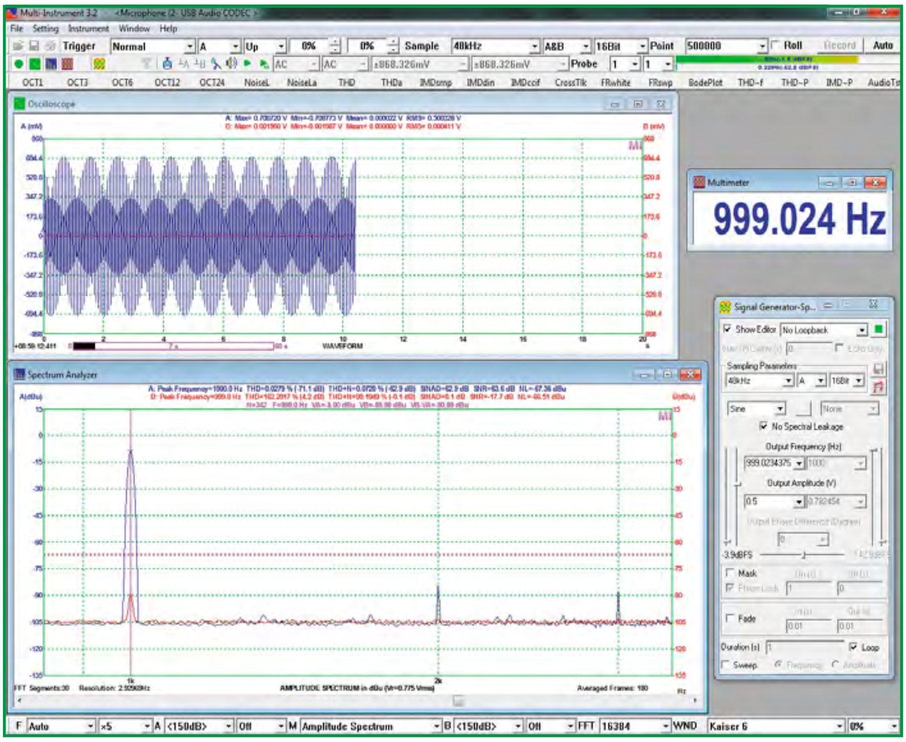


Fig.2: the DMM function is displayed in its own window (shown here at upper right) and this window can be adjusted for size and position on the screen. In this screen grab, it is shown displaying the generator frequency in use.

page user manual which can be downloaded in PDF format. And there are tutorial articles on FFT spectrum analysis, including one on FFT basics and another comparing the umpteen different FFT windowing functions.

Trying it out

I installed a copy of VMI 3.2 Standard on an Acer AX1800 desktop personal computer running Windows 7 Home Premium (64-bit). It installed without a hitch and very soon I was looking at a main screen much like that shown in Fig.1.

It has four horizontal function bars along the top, starting with the usual Menu bar (File – Setting – Instrument...). There's a scope triggering and sampling parameter toolbar for the scope and spectrum analyser, followed by an 'Instrument and Miscellaneous' toolbar with icons to activate the scope, spectrum analyser, DMM and generator – plus settings to adjust scope input sensitivity, take into account whether there's an external input attenuator and so on.

There's also a coloured bargraph on the righthand end of this bar, showing you the amplitude of any input signals at the scope/analyser inputs. Finally, there's the row of 'hot panel' toolbar buttons, shown here with their preprogrammed default functions.

You activate the various instruments by clicking on their icons, with each instrument opening in its own window in the main part of the screen. In the case of the scope and analyser windows, you can adjust their size and position in the usual way.

In Fig.1, you can see the scope window at upper left, with the analyser window below it. The smaller and narrower window at lower right is for the generator, which is deliberately designed to be as compact as possible so that most of the screen is free for you to make the other two windows as large as possible.

Unlike the scope and analyser windows, the generator window can't be continuously adjusted in terms of size, but it can be truncated or 'shrunk' into just the upper 20% or so (by unticking the 'Show Editor' button) once you have set up the generator. In any case, it automatically varies in terms of screen height according to the operating mode selected.

For example, if you don't activate sweeping, the window contracts up from the bottom to remove the bottom 20% or so.

The DMM

If you activate the DMM, it is displayed in its own window, which can be adjusted in size and position. You can see it at upper right in Fig.2, displaying the generator frequency in use. Note that in this case, the generator has been set to a frequency very close to 1kHz, but not exactly so. This was done by selecting the 'No Spectral Leakage' option in the generator window, to change the frequency to that nearest 1kHz which would give the 'sharpest' FFT resolution in the analyser.

Because there are so many display options for each of the instruments in the VMI 3.2 package, providing for their setting could easily take up a lot of screen space and encroach into the important data display area. But the software designers have been clever, because each of the main instrument display windows (scope, spectrum analyser and DMM) has its own 'View Parameter Toolbar', which only appears along the bottom of the screen when that instrument's display window has been selected.

So, if you select the scope window, its parameter toolbar appears at the bottom; select the analyser window instead and its parameter toolbar appears – that's the one you can see along the bottom of Fig.1. Similarly, if you select the DMM window, its own parameter toolbar is shown.

This makes it easy to adjust the function and display parameters for each instrument, without sacrificing a lot of screen area. As you can see, the spectrum analyser's parameter toolbar allows you to adjust many of the important parameters, most of them via pop-up menus (which again minimises screen space).

Before we leave Fig.1, I should perhaps explain the displays that you can see in the three instrument windows. In this case, VMI 3.2 had been set up to do an overall frequency response and inter-channel crosstalk test of my new *USB Virtual Instrument Interface*, with a short cable looping the channel A generator output back to the channel A input and the channel B input terminated in a shielded 50Ω resistor.

As you can see, the generator was set to produce sinewaves of 0.5V RMS, sweeping linearly from 1Hz to 23.5kHz over a period of 20 seconds. Up at the top you can see that the scope and analyser were set to sample both input channels (A and B) at 48kHz and 16 bits, for a total record length of 655,360 points – which, if you work it out, takes 13.6 seconds (655,360 ÷ 48,000).

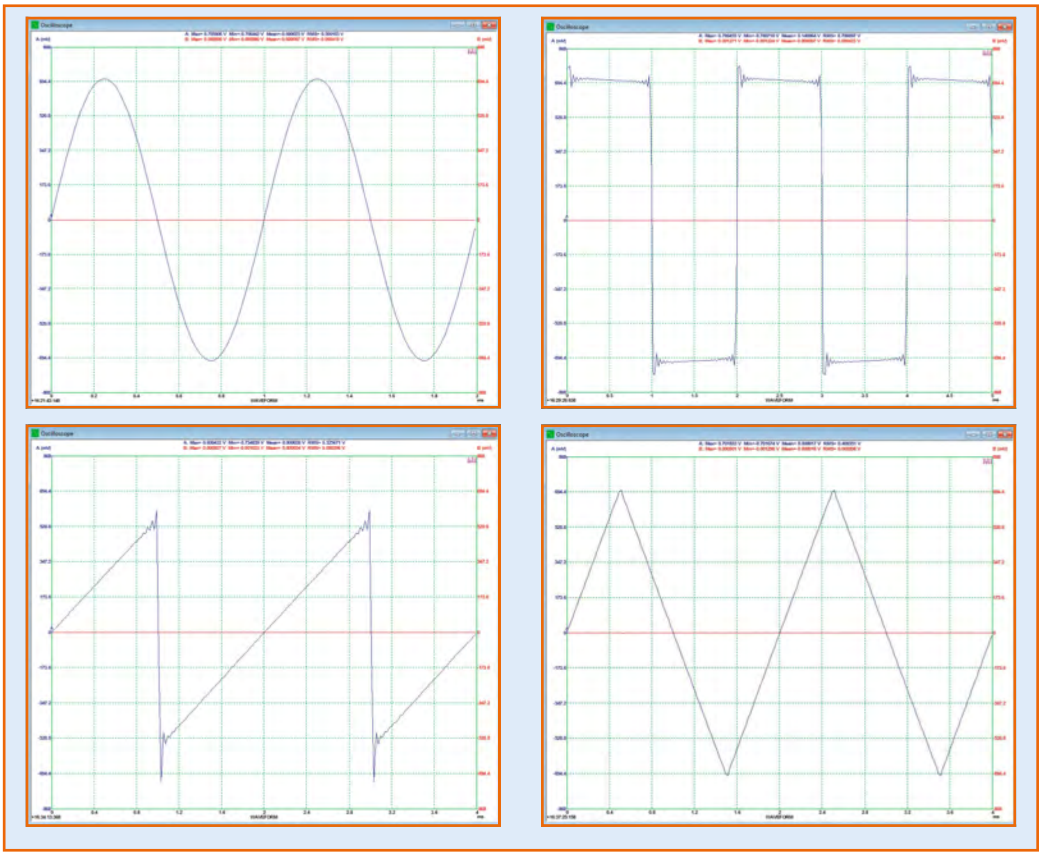


Fig.3-6: these four screen grabs show a 1kHz sinewave, a 500Hz square-wave, a 500Hz sawtooth and a 500Hz triangular wave, as generated by the VMI 3.2 software and displayed in the 'scope' window on a PC.

Down in the bottom analyser toolbar, you can see that an FFT size of 32,768 had been selected, resulting in a total of 20 FFT segments (655,350 ÷ 32,768) and an analyser frequency resolution of 1.46484Hz (48,000 ÷ 32,768). A rectangular window was also selected, with no overlap between windows.

Aliasing effects

I should comment on the strange display in the upper scope window; for this kind of test, it is badly affected by aliasing because of the way the signal is sweeping between 1Hz and 22.3kHz over the sweep period. But the spectrum analyser display below it shows the real results of the test – the overall frequency response of the Interface's channel A in blue near the top and the crosstalk into the channel B input in red near the bottom.

It's not easy to read off the exact values of either curve from the display as shown, although if you use VMI 3.2's cursor reader facility you can get it to show the exact value of both curves numerically, just at the top of the graph itself. In addition, the analyser parameter toolbar at the bottom allows you to zoom into the graph in terms of frequency and also in terms of amplitude – so you can expand either or both curves as much as you need, shifting along to any frequency range and shifting each curve up or down so you can inspect them visually in minute detail. Not bad, eh?

There's no problem about exporting or printing any of the analyser displays at any time, either. All you have to do is pause the analyser and click the relevant buttons.

Other capabilities

Now let's look at Fig.2 again, as this illustrates a few more aspects of VMI 3.2's capabilities (in addition to the DMM window).

When the Fig.2 screen grab was taken, I'd been using VMI 3.2 to measure the overall distortion and noise performance of the *USB Virtual Instrument Interface's* channel A output and input at 1kHz. As before, these were linked via a short cable and the channel B input terminated with a 50Ω resistor.

The generator had been set to produce a 999.024Hz sinewave of 0.5V RMS and the analyser to take 500,000 samples per record. The FFT size had been set to 16,384, with a Kaiser6 window function. This gave 30 FFT segments per record and a frequency resolution of 2.92969Hz.

Again, don't take too much notice of the upper scope window showing the severely aliased display of 500,000 samples of a 1kHz waveform taken over 10.4s. But there's quite a deal of information to be gleaned from the lower analyser window, because just before the grab was taken I zoomed the horizontal frequency axis by five times and then moved along to show just the range between 800Hz and 3.5kHz.

As a result, you can clearly see the fundamental peak of the 1kHz generator signal, together with the second and third harmonic peaks generated by distortion in the *USB Virtual Instrument Interface's* channel A output and input circuitry (blue graph). You can also see the crosstalk into the channel B input circuitry (red graph).

Above the graphs, the analyser displays the calculated THD (0.0279%) and THD+N (0.0720%) figures for channel A (blue text), along with the SINAD, SNR and NL. It also does these calculations for channel B, but these are not important because they represent crosstalk distortion.

Since I had placed the reading cursor at the 1kHz peaks (vertical red line on the graphs), the analyser has also calculated the amplitude of the fundamental peaks in both channels and displayed them in dBu on the third line from the top. The channel A peak is –8.00dBu, while the channel B peak is –88.99dBu. You don't have to subtract one from the other to work out the crosstalk at 1kHz either, because the analyser does that as well and displays it at the end of the line (–80.99dB).

Generator waveforms

The remaining screen grabs from VMI 3.2 and the accompanying scope grabs (Figs.7-12) indicate the variety of waveforms that can be delivered by VMI 3.2's signal generator.

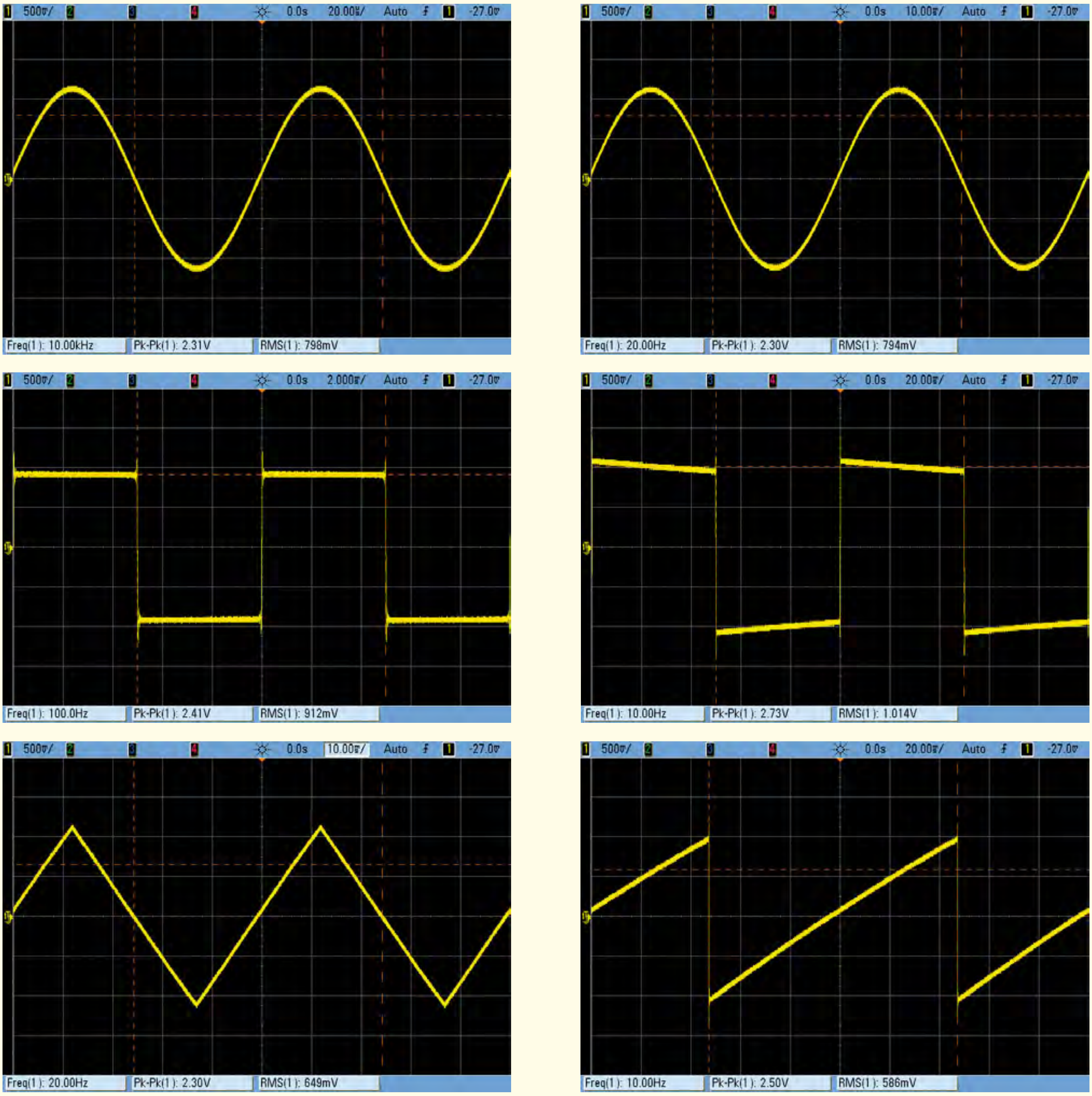


Fig.7-12: these scope grabs show sinewaves at 10kHz and 20Hz; square waves at 100Hz and 10Hz; a triangle wave at 20Hz; and a sawtooth at 10Hz. The overshoot visible on the square wave signals is probably due to the characteristics of the anti-aliasing LP filter in the *USB Virtual Test Instrument Interface* output channels, while the droop visible at the top and bottom of the 10Hz square wave is due to the low frequency roll-off in the same output channels.

For example, Figs.3-6 show a 1kHz sinewave, a 500Hz square-wave, a 500Hz sawtooth and a 500Hz triangular wave, as displayed on VMI 3.2's own scope. Figs.7-12 are a series of scope grabs showing sinewaves at 10kHz and 20Hz; square waves at 100Hz and 10Hz; a triangle wave at 20Hz; and a sawtooth at 10Hz.

The overshoot visible on the square wave signals is probably due to the characteristics of the anti-aliasing LP filter in the *USB Virtual Test Instrument Interface* output channel, while the droop visible on the top and bottom of the 10Hz square wave is due to low-frequency roll-off in the same output channels.

There's no doubt that Virtins Multi Instrument 3.2 is capable of delivering professional-grade results, especially if you were to use it with the highest quality ADC and DAC interface hardware. It's extremely flexible, yet at the same time quite user friendly.

Overall, Virtins VMI 3.2 represents excellent value for money – especially the Standard version at its current price of only US$99.95. For further information, see **virtins.com**

Do you believe in magic?

TechnoTalk

Mark Nelson

Practical electronicists ought not to believe in snake-oil products, no matter how seductive the claims made for them... but, we also need to keep an open mind. Mark Nelson puts aside his scepticism for a moment.

ONE thing that constantly amazes me is the amount of pure-snake-oil products offered to hi-fi enthusiasts. The suppliers must think their customers are incredibly gullible — and I guess some of them actually are.

You don't believe me? Just open a British hi-fi magazine – among the excellent informative articles you may see advertisements for:

- Mains plugs with rhodium-plated pins for better audio listening
- 'Sublime' glass platter mats for sheer three-dimensional detail resolution
- Overlay mats for realising better sound from CDs
- 'Interconnects' (you mustn't call them 'cables' or 'connecting leads', oh no!) made from oxygen-free copper with crystals aligned in the direction of the music
- Other interconnects containing 'a particular inorganic chemical' to improve sonic qualities
- Replacement capacitors of guaranteed 'musical' sound quality
- Long-grain pure silver wire for building better amplifiers.

You may wonder who buys these expensive accessories (they do not come cheap). The answer is 'audiophools', who by and large are not ignorant peasants, but people who genuinely aspire to the best auditory experience possible. They appreciate high-end sound and musicality, if not music for its own sake, for which the manufacturers of these add-ons rob them blind.

Aggressively analogue

Not all of these unnecessary accessories find customers; most 'audiophools' are aggressively analogue and will not countenance those silver beer mats. A few, however, will embrace CDs – just as long as these are the re-mastered gold substrate variety. In all this pursuit of aural excellence, the established techniques developed and proven over the years by audio professionals are studiously ignored. So, signal cables made of sensible, affordable copper are rejected in favour of sexier affairs made of pure silver (or else from refined virgin unobtainium). Sensible, solid XLR connectors with contacts having large surface areas are abandoned for slender phono plugs with expensive gold plating. Proper balanced audio cables with a grounded lapped foil screen are ignored in favour of interference-prone twin-line.

The results of mains-related quackery may be positively dangerous too. There's a story – although it may be urban legend – of one audiophool who short-circuited his house fuses in order to reduce the internal resistance of the mains supply, thus improving his equipment's voltage regulation. His house burned down.

Not all nonsense

None of the foregoing should offend true audiophiles, who take a rational, down-to-earth attitude to audio enjoyment. You can read some refreshing candour in some of the Internet discussion groups for high-end audio; one pundit recently suggested that for genuine 'liquid sound' the only solution was to use mercury-filled speaker cables (and then devalued this excellent advice by admitting this was a joke).

As I said, many true audiophiles are aggressively analogue and not without reason. Many prefer the sound of vinyl records to CDs or digital downloads, or favour a 'warm valve sound' to solid-state amplification. A scientific vindication of this preference was reported in 2000, when a German psychologist (Jürgen Ackermann) conducted blind tests as part of his doctoral thesis. He conducted an experiment with 53 hi-fi enthusiasts, musicians, and 'normal' people with no special relation to music or its reproduction. The subjects were tasked with rating pieces of music on how enjoyable they were, how well performed and how the music affected their psychological state.

The participants reported a decrease in tension and nervousness of around 60 per cent, as well as an increase of 120 per cent in their sense of well being when listening to a valve hi-fi system compared to a solid-state system. The listeners were asked to rate individual playback sessions in which, unknown to them, the comparison was between vinyl and CDs. Apparently, the subjects gave vinyl the higher marks and remarkably, this held good both for guinea pigs who later insisted they could not hear any difference between vinyl and CD, as well as those who consciously preferred digital.

Warmer sound

Hollow-state protagonists will tell you that valves (and analogue recordings) have a more full-bodied resonance than transistor equipment, with a 'roundness' to the sound that solid-state gear cannot achieve. It is said that guitarists prefer the warmer, richer sound to the 'harsher' or more 'brittle' effect of early transistor guitar amps. A more scientific evaluation would explain this by stating that valve designs produce predominantly low-order harmonics (which are musically related), while transistor designs generally produce a full range of harmonic distortion, including objectionable high-order harmonics. One assumes some people find the high-order distortion sensibly disagreeable.

Where is this leading us?

By now you are probably wondering what's the point of all this. You've invested heavily in solid-state audio gear and are not going to ditch it now for a valve amp the size of a microwave oven and developing as much heat as a small furnace, whatever distortion it creates. The good news is you don't have to!

Recreating a 'valve sound'

A company called iFi-audio.com has just brought out the iTube, a 'micro-sized' (their term) component for use with any 'separates' audio installation. It claims to re-equalise harsh, 'ringing' digital sources that normally cause listening fatigue. Operating at line level, it forms a buffer between your audio sources (turntable, radio tuner, CD player and so on) and the main amplifier (which must be as distortion-free as possible). Additional circuitry offers a '3D holographic sound' binaural system based on 'lost' Blumlein ideas for headphone listening. A single valve is used in the design, a General Electric 5670 (equivalent to 2C51) from unused old stock, described by valvophiles as 'a nice little tube that works well'. The iTube is available from 16 British hi-fi outlets for £275, and while it is by no mean an impulse purchase, it should certainly appeal to the discerning audiophile who enjoys trialling different sound experiences. Is it magic? Only the buyer – I mean listener – can decide!

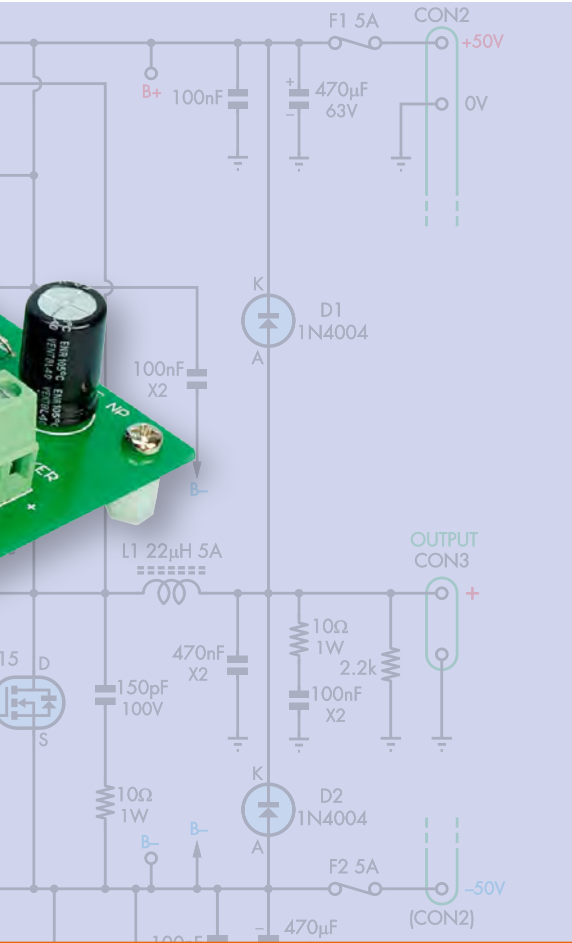
250W into 4Ω
150W into 8Ω

Building the CLASSiC-D Amplifier

Part 2: By John Clarke

World's first DIY high-power high-performance Class-D amplifier: 250W into 4Ω,150W into 8Ω

Following on from last month, we now describe the construction of the *CLASSiC-D Amplifier*, power supply options and its accompanying *Loudspeaker Protector*. We also describe how to test the completed modules and show the connection details for mono, stereo and bridged modes of operation.



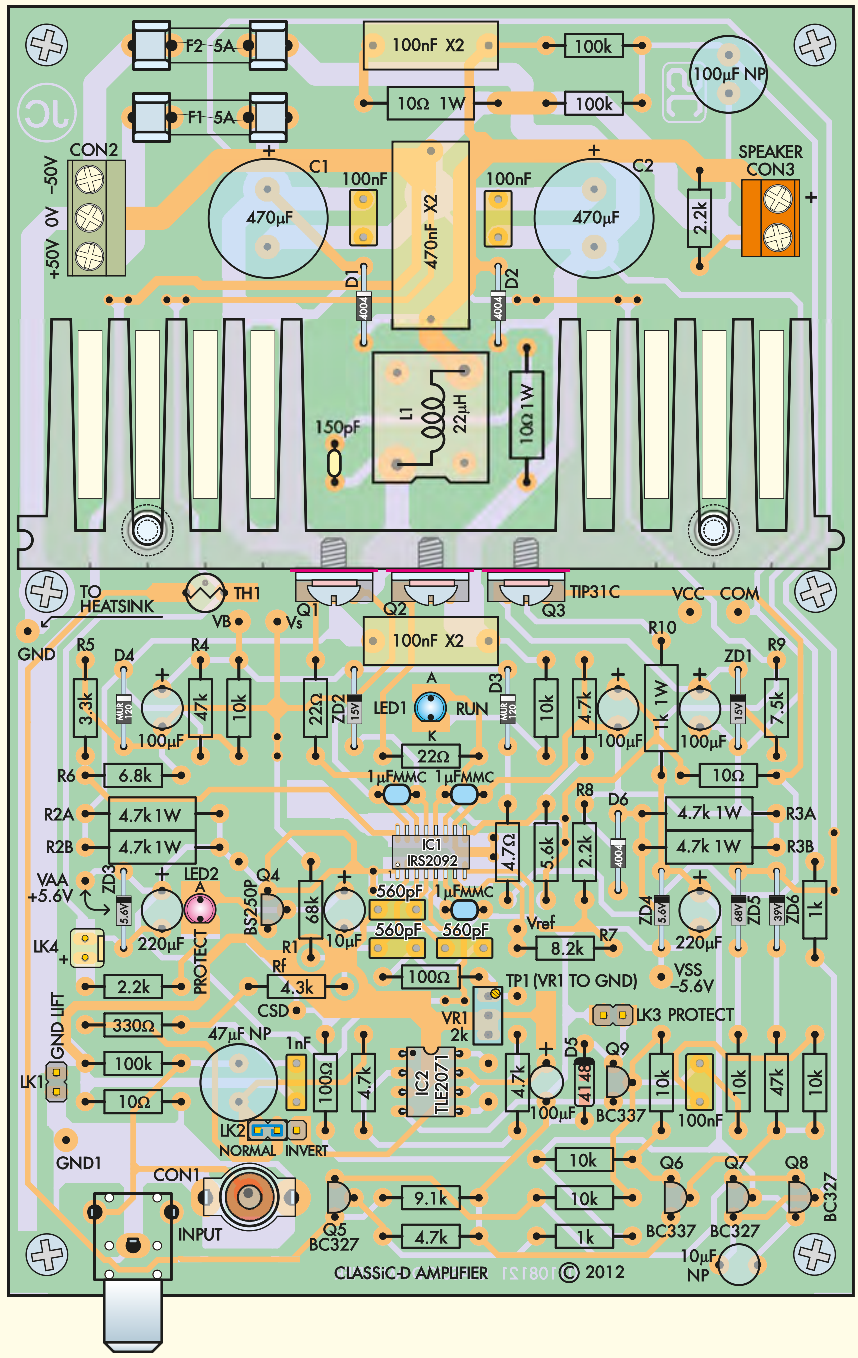


Fig.16: follow this PCB parts layout diagram to build the *CLASSiC-D* module. The component values shown are for a ±50V supply, but note that 12 resistors and two Zener diodes (ZD5 and ZD6) must be selected to suit different supply voltages – see Table 1 and Table 2. Take care with component orientation.

THE *CLASSiC-D Amplifier* module is relatively straightforward to assemble, with all parts mounted on a PCB coded 01108121 and measuring 117mm × 167mm. Fig.16 shows the parts layout.

Start by checking the PCB for any defects, such as shorted tracks, undrilled holes and incorrect hole sizes. The PCBs supplied by the *EPE PCB Service* and kit suppliers will be double-sided, plated through, solder masked and screen printed. These are of high quality and are unlikely to require any repairs, but it's always best to check before the parts are soldered in place.

Having checked the PCB, begin the assembly by soldering IC1 in place. This is a 16-pin SOIC package (ie, surface mount) and is (relatively) easy to solder in place due to its (relatively) wide 0.05-inch pin spacing.

The IC is mounted on the top of the PCB and must be oriented as shown on Fig.16 (ie, pin 1 dot at lower left). It's installed by first carefully aligning it with its pads and soldering pin 1. That done, check that it is correctly aligned. If not, remelt the solder and readjust it so that the pins all sit on their corresponding pads.

The remaining pins can then be soldered, starting with the diagonally opposite pin (pin 9). Don't worry if you get solder bridges between the pins. Once the soldering has been completed, these bridges are easily removed using solder wick.

Once IC1 is in place, the remaining low-profile parts can be installed, ie, the resistors, diodes and Zener diodes. Note that the components shown on Fig.16 are for the nominal ±50V supply version. However, as mentioned last month, you can also run the amplifier from lower supply voltages. Table 1 shows the component changes required for the relevant resistors and Zener diodes, while Table 2 shows the type numbers for the Zener diodes.

Table 1: Component values vs supply voltages			
Supply Voltage	±50V	±35V	±25V
R_F (gain)	4.3kΩ	6.2kΩ	8.2kΩ
R2A, R2B, R3A, R3B	4.7kΩ 1W	3.3kΩ 1W	2.2kΩ 1W
R4	47kΩ	27kΩ	13kΩ
R5	3.3kΩ	2.4kΩ	1.8kΩ
R6	6.8kΩ	7.5kΩ	8.2kΩ
R7	8.2kΩ	8.2kΩ	8.2kΩ
R8	2.2kΩ	1.8kΩ	1.5kΩ
R9	7.5kΩ	4.3kΩ	2.2kΩ
R10	1kΩ 1W	220Ω 1W	100Ω 1W
ZD5	68V 1W	47V 1W	30V 1W
ZD6	39V 1W	30V 1W	20V 1W

This table shows the resistor and Zener diode values that must be selected to suit ±50V, ±35V DC and ±25V supply rails. At ±50V, the amplifier will deliver 150W into 8Ω or 250W into 4Ω; at ±35V, it will deliver 60W into 8Ω or 120W into 4Ω; and at ±25V, it will deliver around 25W into 8Ω or 50W into 4Ω.

Next, the resistors are mounted on the the PCB; you should use a multimeter to check each one as it is installed, just to make sure (some colours codes can be difficult to decipher). Note that the diodes and Zener diodes must be oriented as shown on the overlay, with the cathode (striped end) of each device facing towards the top edge of the PCB.

IC2 goes in next and can either be mounted in an IC socket or directly soldered to the PCB. Make sure it's oriented correctly, with its notched pin 1 end towards the heatsink.

Follow with the PC stakes and the 2-way and 3-way pin headers. There are 11 PC stakes, and these are located at the TP1, GND1, GND, V_{AA}, V_{SS}, CSD, Vref, COM, V_{CC}, Vb and Vs test points. Note that 2-way header LK4 is a polarised type (it connects via a 2-way cable to the Loudspeaker Protector circuit PCB).

The two LEDs, MOSFET Q4 and transistors Q5-Q9 can now go in. Note that LED1 is the blue LED, while LED2 is red. If they come with a clear lens and you don't know which is which, most multimeters have a diode test facility that will drive an LED sufficiently for you to see what colour it is. At least, this should work for the red LED – the blue LED may not light due to its higher forward voltage.

Be sure to install each LED with its anode (the longer lead) towards the heatsink.

Make sure also that you use the correct transistor in each location. Q4 is a BS250P MOSFET, while BC327s and BC337s are used for Q5-Q9. Don't get the BC327s and BC337s mixed up. Leave Q1, Q2 and Q3 (ie, the heatsink transistors) out for the time being.

The capacitors are next on the list. Note that the electrolytic types must be oriented correctly, the exceptions being the 100µF, 47µF and 10µF NP (non-polarised) types, which can go in either way around. Be careful not to get an NP electrolytic mixed up with a polarised electrolytic of the same value.

Trimpot VR1 can now installed with its adjusting screw towards the heatsink. Follow this with inductor L1, screw terminal blocks CON2 and CON3, the fuse clips and the vertical and horizontal RCA input sockets (CON1). Note that the screw terminal blocks must be installed with their wire entry openings facing outwards.

Note also that each fuse clip has an end stop, so make sure they go in the right way around otherwise you will not be able to install the fuses later on.

Heatsink mounting

The heatsink is a standard 100mm × 33mm × 75mm (W × D × H) unit, but this must be cut down to 30mm high if the amplifier is to go in a 1U rack case. This can be done using a fine-toothed hacksaw and the job filed to a smooth

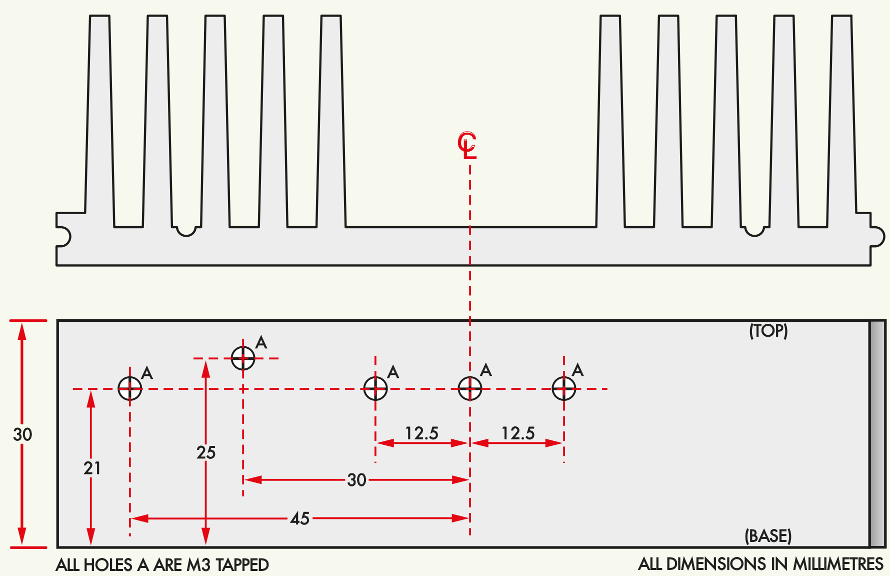


Fig.17: this diagram can be copied and used as a drilling template for the heatsink. You can either drill the holes to 2.5mm and tap them to accept M3 screws or you can drill 3mm holes (see text). Use plenty of light machine oil lubricant when drilling and tapping, and clear away the metal swarf on a regular basis. The completed holes must be deburred using an oversize drill.

finish. Alternatively, you can leave the heatsink at its full height if space is not an issue.

Before installing the heatsink, you need to drill and tap five holes to accept M3 screws. Fig.17 shows the drilling details and this should be copied (or downloaded from the *EPE* website, **www.epemag.com**), attached to the heatsink and used as a drilling template.

Use a 1mm pilot drill to start the holes, then drill each one to 2.5mm diameter (all the way through) so that it will accept an M3 tap. Take it slowly when drilling these holes, and be sure to clear any metal swarf from the drill on a regular basis, to prevent the aluminium from binding to the drill. It's also important to use a lubricant to prevent such problems and aid cutting, eg, light machine oil.

The same goes when tapping the holes. Undo the tap and remove the swarf on a regular basis and use plenty of lubricant.

Alternatively, if you don't want to tap the heatsink, you can simply drill 3mm holes through the heatsink. The various parts are then later secured using M3 × 10mm screws (instead of M3 × 5mm for the tapped version), with nuts fitted inside/between the heatsink fins.

Carefully deburr each hole using an oversize drill. In particular, make sure that the mounting area for transistors Q1-Q3 is perfectly smooth and free of metal swarf.

The heatsink can now be fastened to the PCB using two 3/16-inch × 20mm-long machine screws that go in from the underside of the PCB (the screws cut their own threads in the holes). It's simply a matter of positioning the heatsink on the board and installing the screws.

Thermistor TH1 is held against the heatsink using a bracket made from a chassis-mount 45° 6.4mm spade lug. This is bent to shape using pliers as shown in Fig.19. Once it's made, install TH1 on the PCB, leaving its leads about 6mm long, then fit the clamp so that TH1 is held firmly in contact with the heatsink.

Transistors Q1-Q3 can now go in. Fig.18 shows the mounting details. Note that each transistor must be isolated from the heatsink using an insulating bush and silicone washer. Q1 and Q2 are both IRFB5615 MOSFETs, while Q3 is a TIP31C – don't get them mixed up.

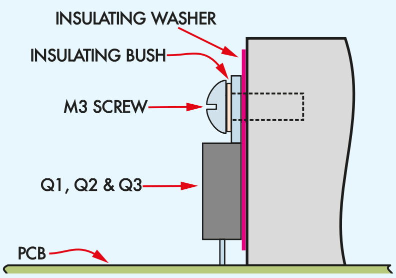


Fig.18: the mounting details for transistors Q1-Q3. They must be isolated from the heatsink using an insulating washer and bush.

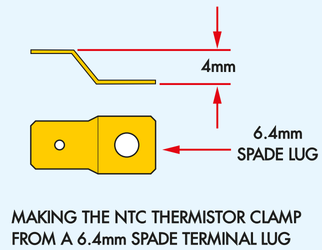
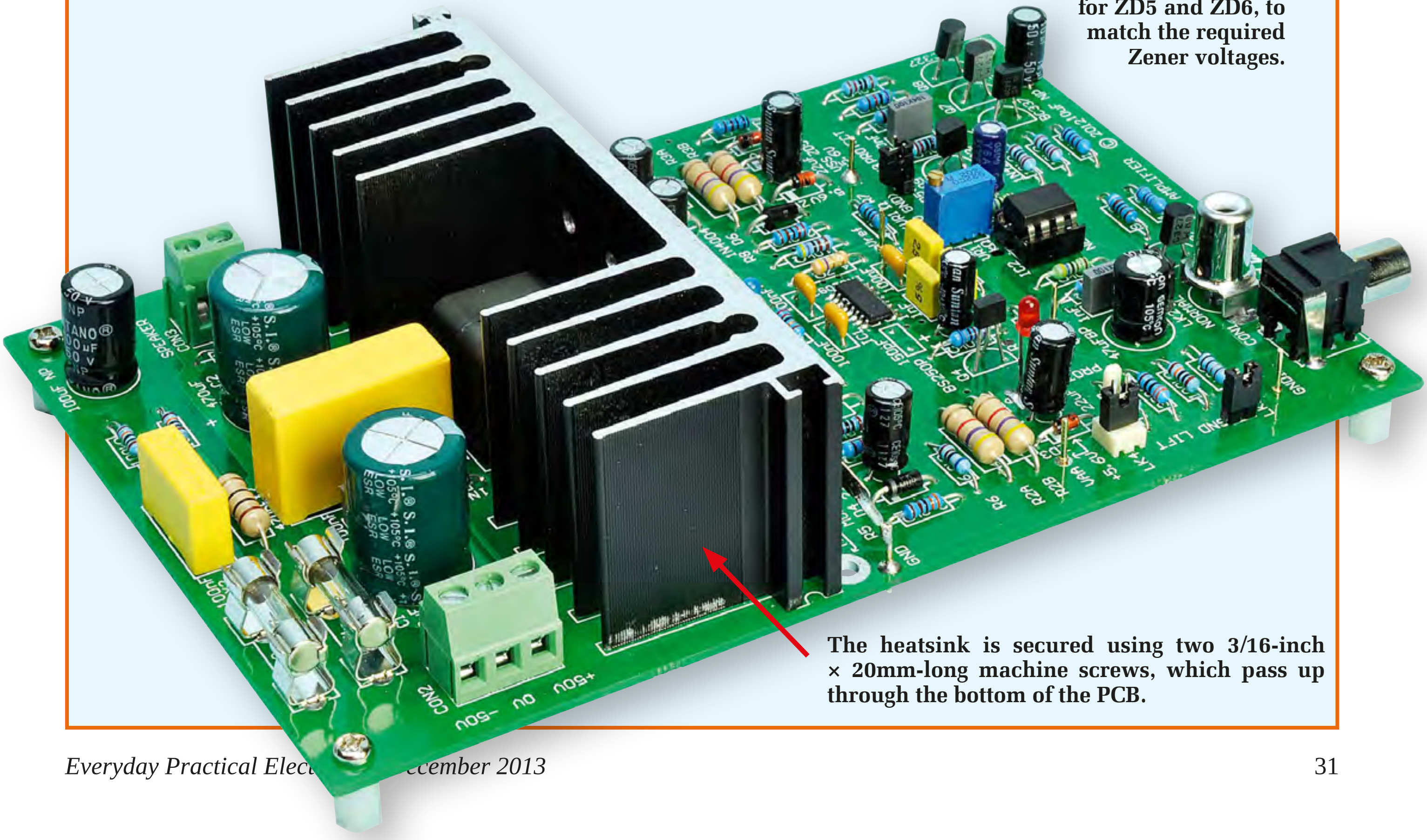


Fig.19: the thermistor clamp is made from a 6.4mm spade lug, bent to give a 4mm step, as shown here.

Table 2: Zener Diode Type Numbers

Zener Voltage	1W Type Number
5.6V	1N4734
15V	1N4744
20V	1N4747
30V	1N4751
39V	1N4754
47V	1N4756
68V	1N4760

Use this table to select the correct Zener diode types for ZD5 and ZD6, to match the required Zener voltages.



The heatsink is secured using two 3/16-inch × 20mm-long machine screws, which pass up through the bottom of the PCB.

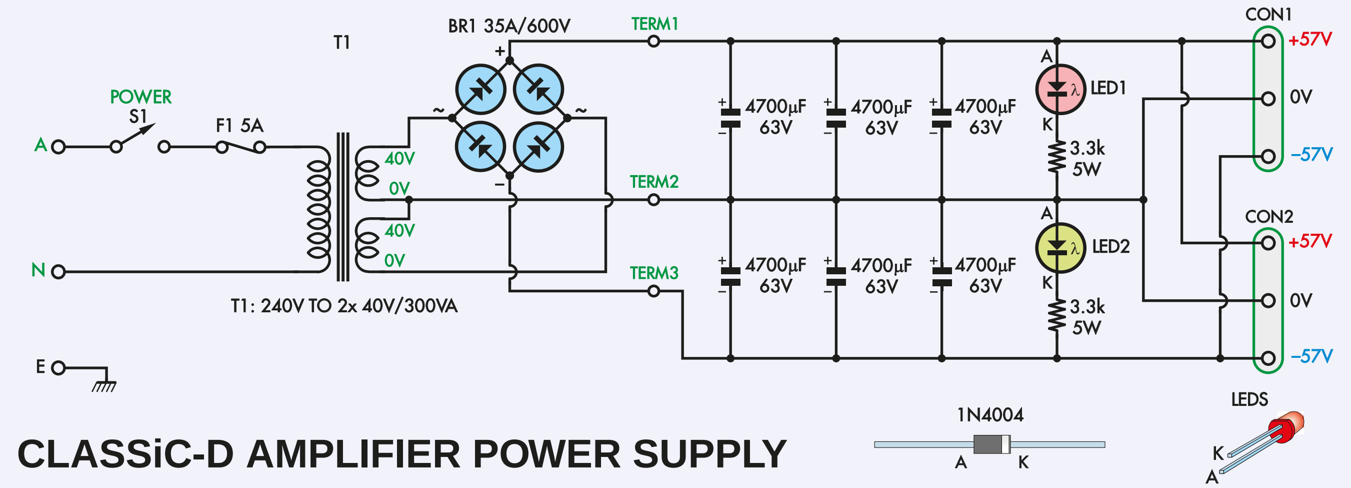
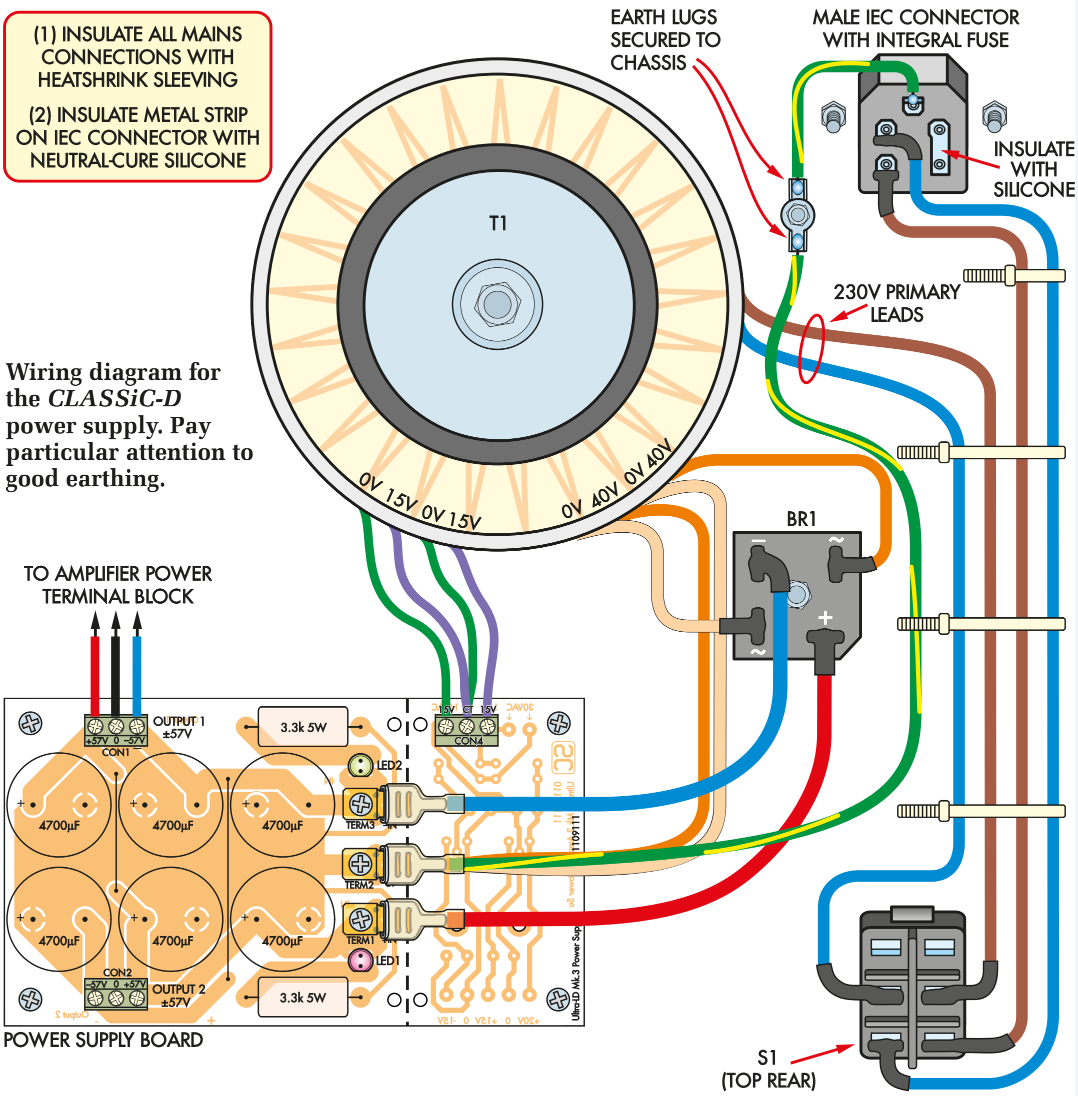


Fig.20: the power supply is based on a toroidal transformer (T1) with two 40V windings. These drive bridge rectifier BR1 and six 4700µF filter capacitors to produce the ±57V (nominal) rails.

AS EXPLAINED last month, the Ultra-LD Mk.3 Power Supply can be used to power the *CLASSiC-D* amplifier. This has a nominal output of ±57V but is still perfectly suitable for use with the *CLASSiC-D* and will result in slightly higher output power than a ±50V supply.

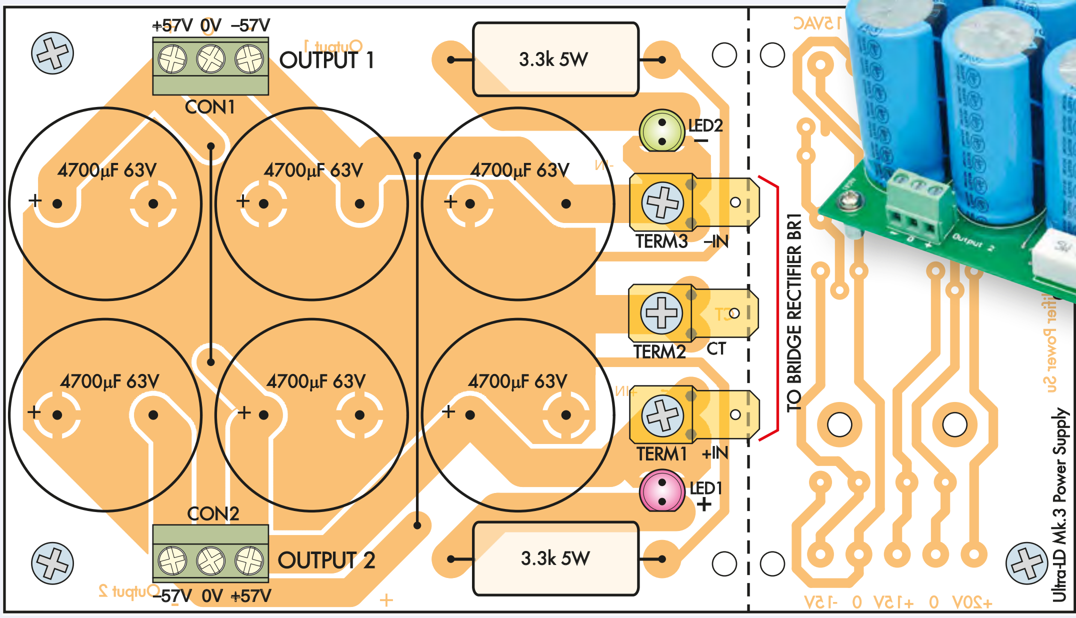


Wiring diagram for the *CLASSiC-D* power supply. Pay particular attention to good earthing.

Fig.20 shows the circuit details of the power supply. It's based on a toroidal mains transformer (T1) with two 40V windings. These are connected together to give 80VAC centre-tapped, and this arrangement drives bridge rectifier BR1. This in turn feeds six 4700µF 63V electrolytic capacitors (ie, 14,100µF on each side) to provide balanced ±57V DC rails to power the amplifier.

Two LEDs are connected in series with 3.3kΩ 5W current-limiting resistors across these ±57V supply rails. These serve two purposes: (1) they provide a handy indication that power is present on the supply rails, and (2) they discharge the filter capacitors when the power is switched off (see warning panel).

Note that the specified transformer also has two 15V windings and these were used in the original design to drive a second bridge rectifier and associated filter capacitors.



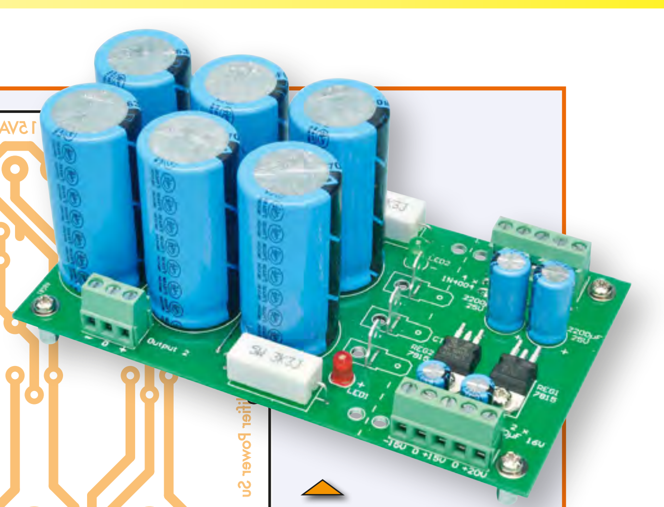


Fig.21: install the parts on the power supply PCB as shown here. The two LEDs indicate when power is applied and remain lit until the 4700µF capacitors discharge after switch-off.

Above: the power supply from the Ultra-LD Mk.3 Amplifier. The parts associated with the 3-terminal regulators on the righthand side of the PCB are not required for the *CLASSiC-D*.

Two 3-terminal regulators were then used for regulated ±15V supply rails. These are not required for the CLASSiC-D; their parts have been deleted from the circuit and Fig.21.

Power supply assembly

All parts except for the transformer and bridge rectifier are mounted on a PCB coded 01109111. Begin by fitting the two wire links using 0.71mm or 1mm-diameter tinned copper wire, then install the two LEDs. These sit flush against the PCB with the flat side of the lenses oriented as shown on the overlay.

Follow with the two 3.3kΩ 5W resistors. These should be stood off the board by about 2mm, to allow the air to circulate beneath them for cooling (use a cardboard spacer during soldering).

The two 3-way terminal blocks go in next with their wire entry sides facing outwards. That done, fit the three Quick-Connect (spade) terminals to the board using M4 machine screws, nuts and washers. If you can't get single-ended chassis lugs, cut one side off double-sided lugs.

Finally, fit the six 4700µF electrolytic capacitors. Be sure to orient them correctly and make sure that they all sit flush with the PCB.

The completed PCB assembly, along with the transformer and bridge rectifier should be housed in an earthed metal case (this case can also house the amplifier module). The wiring diagram shown opposite provides the mains wiring details for the power supply. Keep wiring neat with cable ties and clips.

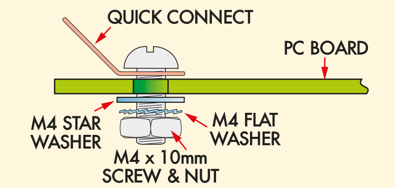


Fig.22: here's how the spade lugs are fastened to the power supply PCB. Alternatively, you can use solder spade lugs – see photo.

WARNING: HIGH VOLTAGE

High DC and high AC voltages are present in this circuit. The power supply uses a total of **80V AC and the amplifier power supply rails are a total of 114V DC**. Do not touch any part of the amplifier circuitry when power is applied, otherwise you could get a severe electric shock.

The two LEDs on the power supply board indicate when power is present. If they are lit, then the power supply and amplifier boards are potentially dangerous.

Power Supply Parts List

1 300VA transformer with two 40V AC 300VA windings (or two 35V AC windings)
1 35A 400V chassis-mount bridge rectifier
1 PCB, available from the *EPE PCB Service,* code, 01109111, 141 × 80mm
2 3-way PCB-mount terminal blocks, 5.08mm pitch (CON1-2)
3 chassis-mount male spade connectors
3 M4 × 10mm screws, nuts, flat washers and shakeproof washers
4 M3 × 9mm tapped nylon spacers
4 M3 x 6mm machine screws
150mm 0.7mm diameter tinned copper wire

Semiconductors
1 5mm red LED (LED1)
1 5mm green LED (LED2)

Capacitors
6 4700µF 63V electrolytic

Resistors
2 3.3kΩ 5W

It's simply a matter of attaching these transistors to the heatsink and tightening their mounting screws, then flipping the board over and soldering the leads. That done, use a multimeter to check that the metal tab of each device is electrically isolated from the heatsink (you should get a high megohm or open-circuit resistance reading). Note that the heatsink is anodised, so in order for the multimeter probe to make good contact it must be touched against a bare metal area. Alternatively, if the mounting holes have been tapped, you can simply test for shorts between the device tabs and the mounting screws.

If the meter does show a short, undo the mounting screw for that device and locate the source of the problem before re-attaching it.

Finally, the heatsink must be connected to the GND PC stake on the PCB. That's done by attaching a solder lug to the heatsink at top left using an M3 × 5mm machine screw, then running a short length of tinned copper wire back to the adjacent GND stake. If the hole isn't tapped, then be sure to scrape away the anodising under the solder lug.

If necessary, this earthing arrangement can later be changed when the amplifier is installed in a metal case. In that case, the heatsink should be earthed to the metal chassis itself.

Testing the amplifier module

With the assembly now completed, it's time to go through the test procedure. Just follow these step-by-step instructions:

STEP 1: install a jumper shunt across the LK3 (Protect) header, just to the right of trimpot VR1. This places the amplifier in the PROTECT mode, so that it will not start up when power is applied.

STEP 2: install a jumper link on LK1, a jumper on LK2 (near the RCA sockets) in the NORMAL position and a jumper on LK4 to allow the PROTECT LED to light.

STEP 3: monitor the resistance between TP1 and GND and adjust VR1 to give a reading of 850Ω. This sets the quiescent operating frequency for the amplifier to about 500kHz.

STEP 4: insert fuses F1 and F2, then connect a power supply to the *CLASSiC-D* module, making sure the polarity is correct. As mentioned last month, the Ultra-LD Mk.3 Power Supply can be used. The circuit and the parts layout for this supply are shown in the accompanying panel.

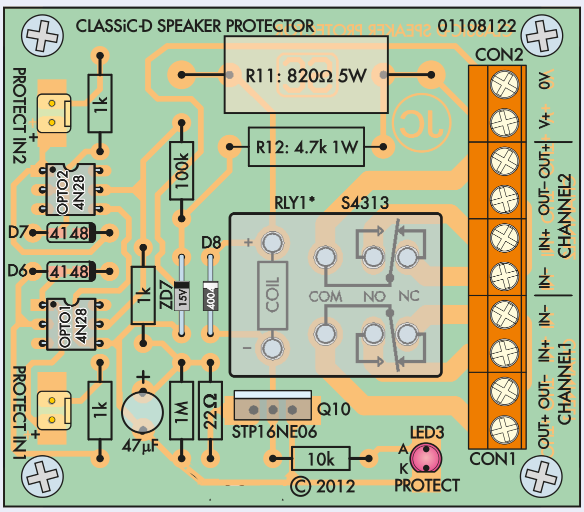
STEP 5: switch on the power supply and check that the protect LED (LED2) lights. **Note that high voltages are present on the power supply and amplifier PCBs during operation. Do not handle or touch the power supply or the amplifier module with power applied, otherwise you could get a severe shock.**

STEP 6: check that the ±50V (or thereabouts) supply rails are correct at CON2 (note: these rails will depend on the power supply used). If these are correct, check that V_{AA} (near ZD3) is at +5.6V (ie, measure between V_{AA} and GND). Similarly, check that both V_{SS} (near ZD4) and CSD are at –5.6V.

STEP 7: check that V_{CC} is around +14 to 15V (measure between V_{CC} and COM), then check the voltage across the output terminals at CON3 (ie, the speaker terminals). This should be around 1.57V with a 50V supply, but will drop to only 6mV or less with an 8Ω or 4Ω load connected.

STEP 8: check the voltage between V_B and Vs. This should be above 9V, but will rise to 14V or 15V when the amplifier is actually running (ie, when it is no longer in PROTECT mode).

If any of the voltages in the above steps are incorrect, switch off immediately and check that all parts are



V+	50V	35V	25V
R11	820Ω 5W	330Ω 1W	22Ω 0.5W
R12	4.7k 1W	2.7k 0.5W	1.5k 0.5W

*RLY1 HAS A 24V/650Ω COIL

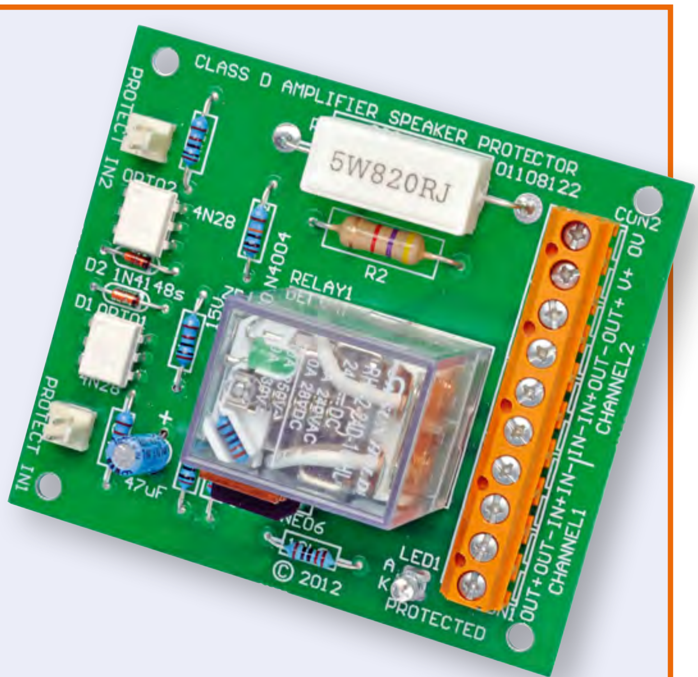


Fig.23: install the parts on the *Loudspeaker Protector* PCB as shown here. Note that resistors R11 and R12 have to be selected to suit the power supply voltage, as shown in the accompanying table. The 10-way screw terminal block is made by dovetailing five 2-way terminal blocks together before soldering them to the PCB.

correctly placed and oriented. You should also carefully check for shorts between IC1's pins (eg, solder bridges) and for shorts due to solder bridges on the underside of the PCB.

STEP 9: if the voltages are correct, switch off, remove PROTECT jumper LK3 and re-apply power. After a second or two, the PROTECT LED should turn off and the RUN LED (blue) should turn on instead.

STEP 10: if you have a scope or a frequency counter, the quiescent operating frequency can be measured at the Vs test point (near Q1). If you are building a stereo or bridged amplifier, the modules should be set to run at the same frequency under no signal conditions to minimise distortion. This can be adjusted using trimpot VR1.

Speaker protector

The *Speaker Protector* is built on a PCB coded 01108122 and measuring 76mm × 66mm, which is available from the *EPE PCB Service.* As usual, check the PCB for any faults (eg, shorted tracks, undrilled holes and incorrect hole sizes) before starting the assembly.

Fig.23 shows the parts layout on the PCB. Start by installing the resistors, diodes and Zener diodes. Resistors R11 and R12 have to be chosen to suit the supply voltage – see the table accompanying Fig.23. The resistor values shown on the PCB layout are for a 50V DC supply.

Optocouplers OPTO1 and OPTO2 can now be installed, taking care to orient them correctly. Follow these with the 47µF capacitor, LED3 and MOSFET Q10. The five 2-way screw terminal blocks can then be dovetailed together (to make a 10-way strip) and soldered in place. Make sure the wire entry side faces outwards and that the blocks all sit flush against the PCB.

Finally, complete the assembly by soldering the polarised 2-way headers and the relay in place.

Testing the speaker protector

The *Loudspeaker Protector* should now be tested, as follows:

STEP 1: connect the supply to CON2 (ie, to V+ and 0V), switch on and check that ZD7 has 15V across it. The relay should switch on, while the PROTECT LED (LED3) should be off.

STEP 2: connect a 9V battery between the two header pins for PROTECT IN1 (bottom left), with the positive side of the battery going to the '+' input.

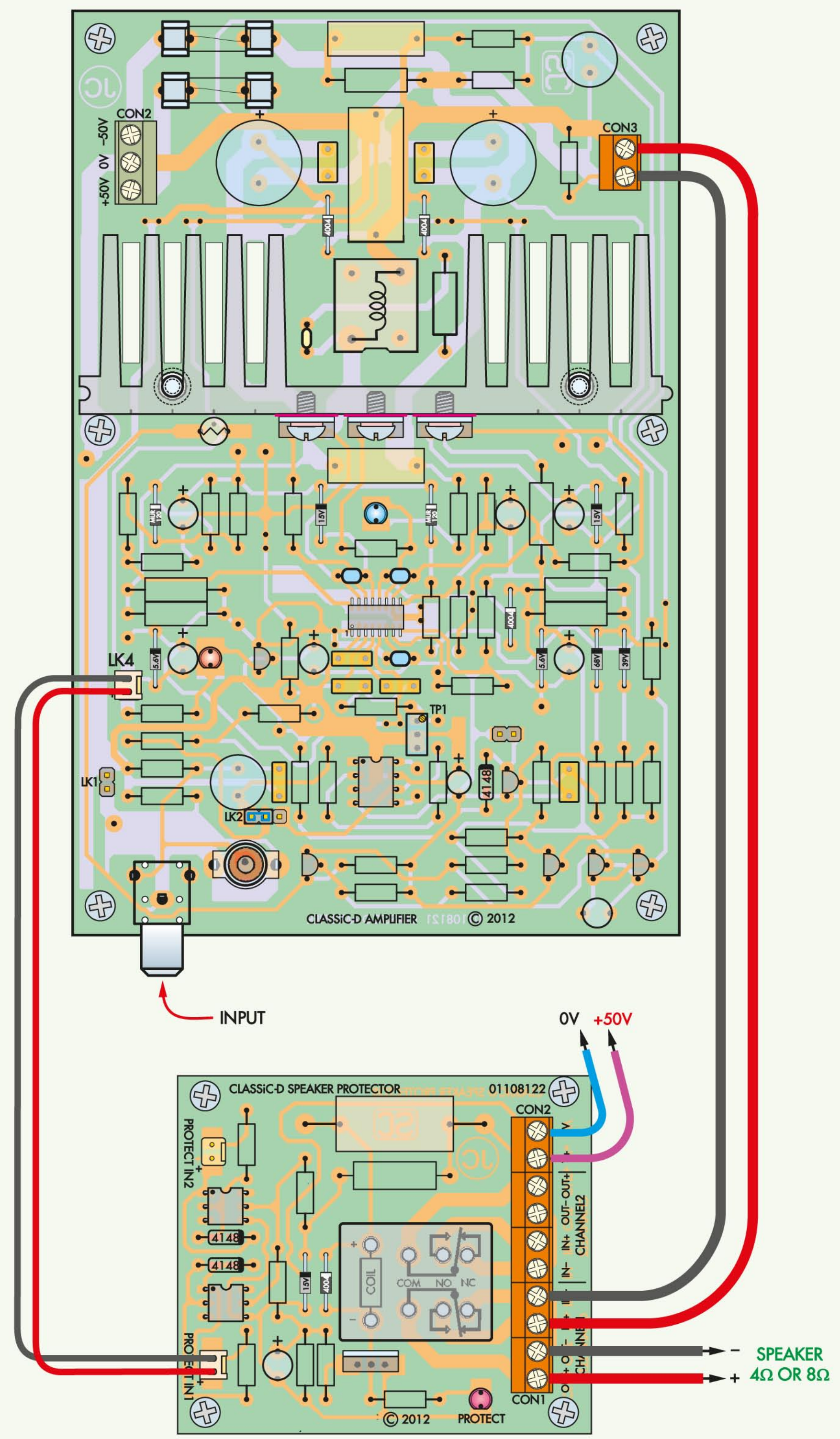


Fig.24: follow this wiring diagram to connect a single CLASSiC-D amplifier module and its accompanying *Loudspeaker Protector* module for mono operation (power supply connections not shown). The loudspeaker can be either a 4Ω or 8Ω type.

The relay should immediately switch off and the PROTECT LED switch on.

STEP 3: check that the relay also switches off if the 9V battery is connected to the PROTECT IN2 header.

Speaker protector connections

As stated last month, the *Loudspeaker Protector* can be used with a either a single *CLASSiC-D* module or with two modules connected in either stereo

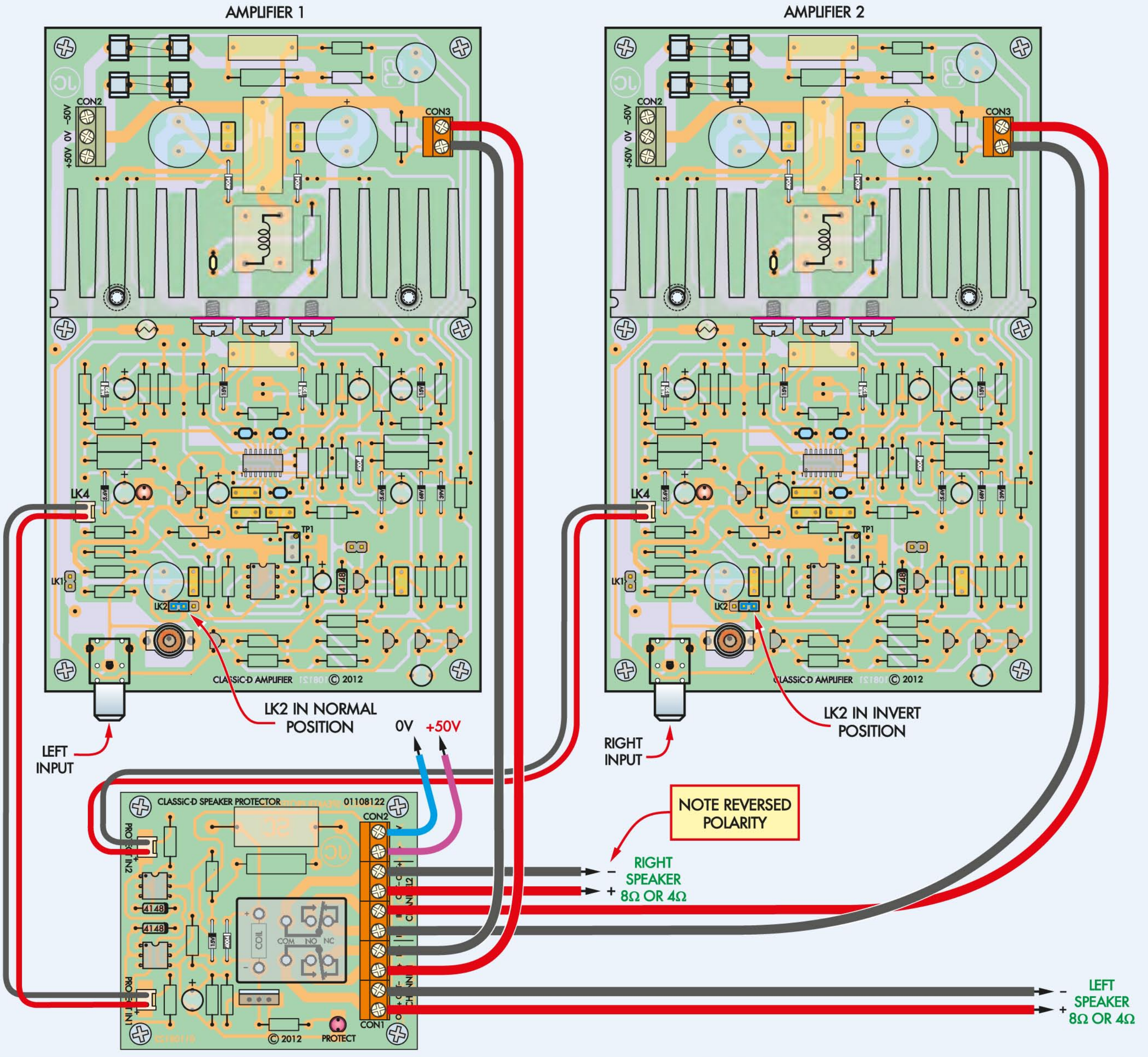


Fig.25: the wiring layout for stereo operation. Use heavy-duty hook-up wire for the amplifier output connections and to the loudspeakers. The wiring from LK4 on each amplifier module and the supply leads to the *Loudspeaker Protector* can be run using medium-duty cable. Note the swapped speaker polarity for the right channel.

or bridge mode. Figs.24-26 show the mono, stereo and bridge mode wiring configurations.

The connection from LK4 on each amplifier module is run via a 2-way polarised header lead. This lead is made up using two lengths of medium-duty hook-up wire, terminated at both ends in 2-way header plugs.

It's important to ensure that the loudspeaker connections are correct. In mono and stereo configuration, the positive speaker output from each amplifier module (ie, from CON3) goes to an IN+ input on the *Loudspeaker Protector*. Similarly, the 0V output must go to the corresponding IN– input.

This is necessary to ensure that the positive side of the loudspeaker is connected to the 0V rail via the NC relay contact when the relay is off. It also ensures that any arcing between the NO contact and the wiper is quenched when the relay turns off. This arcing can be caused by the high voltage DC that's applied to the NO contact if one of the MOSFETs in the amplifier fails and shorts the contact to the supply rail.

Note that for a stereo configuration, the second amplifier is set to INVERT mode and the speaker lead polarity is swapped following the *Loudspeaker Protector*. This is done to avoid supply pumping, as explained last month.

For the bridge mode configuration, the loudspeaker (this must be 8Ω or more) is connected between the positive output of the Amplifier 1 and the OUT+ terminal of one channel on the *Loudspeaker Protector*. The 0V output from Amplifier 2 connects to the IN– terminal of the *Loudspeaker Protector*, to break the arc across the relay contacts as before.

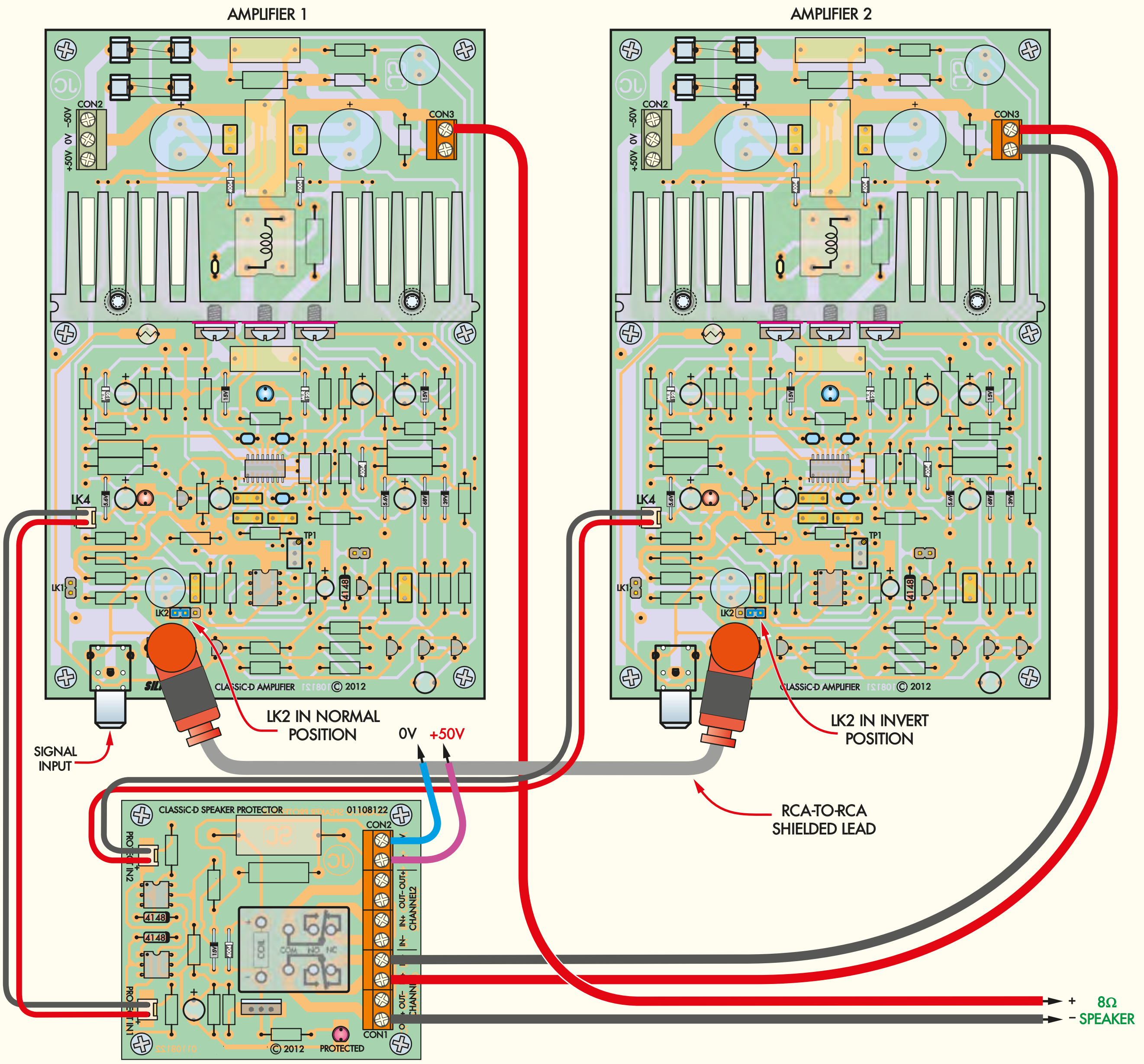


Fig.26: the bridge mode configuration uses just one relay channel on the *Loudspeaker Protector*. An RCA-to-RCA shielded lead is connected between the signal inputs of the two amplifiers, while LK2 is set to NORMAL on one amplifier and to INVERT on the other. Note that the loudspeaker must be an 8Ω (or higher) type for bridged operation.

In addition, Amplifier 2 must be set to INVERT mode using LK2, while Amplifier 1 operates with LK2 in the NORMAL position.

The completed modules can be mounted in a metal case, along with the power supply. Make sure the case is securely earthed and be sure to use an IEC mains input connector with an integral M205 5A fuse.

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Where to buy kits and parts

Both Jaycar and Altronics have full kits available for the CLASSiC-D amplifier module and its Loudspeaker Protector. The details are as follows:

Jaycar
CLASSiC-D Amplifier Kit (includes pre-mounted SMD IC) – Cat. KC-5514
CLASSiC-D Speaker Protector Kit – Cat. KC-5515

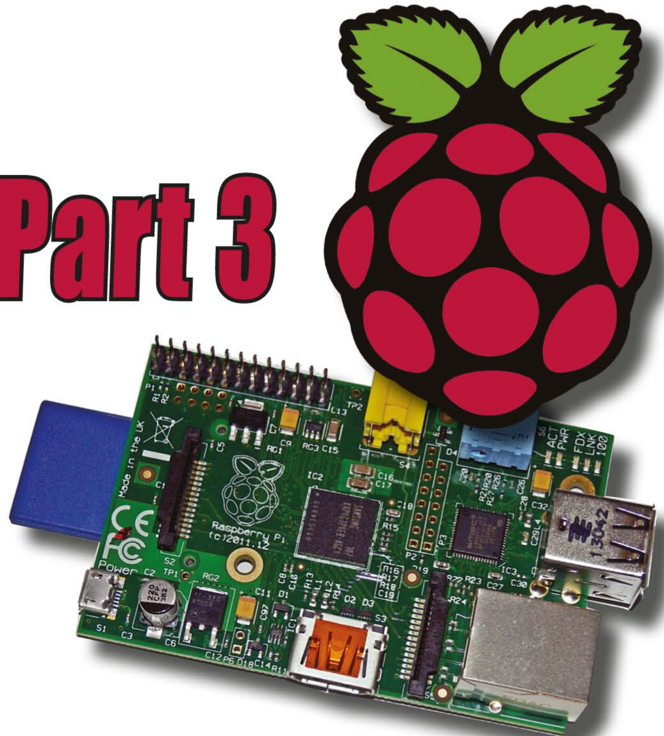
Altronics
CLASSiC-D Amplifier Kit – Cat. K 5181
CLASSiC-D Speaker Protector Kit – Cat. K 5182
Power Supply Kit (Ultra-LD Mk.3 Supply) – Cat. K 5168

PCBs: PCBs for the CLASSiC-D Amplifier, Loudspeaker Protector and the Ultra-LD Mk.3 Power Supply can be purchased separately from *EPE*.

Teach-In 2014
Raspberry Pi – Part 3

by Mike and Richard Tooley

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



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

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

This series will teach you about:

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

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

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

What will I need?

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

This month

Following on from last month's introduction to interfacing, this month's *Teach-In 2014* delves further into practical aspects of connecting the Raspberry Pi to the real world. We will construct a simple eight-channel output driver that you can use to interface relays, actuators and motors. *Python Quickstart* will show you how to define your own functions and make effective use of them in your code and *Pi World* will conclude this instalment with some suggestions for further reading.

Python Quickstart

Last month, we looked at how to implement a block of repeated code (known as a *loop*). Many simple programs involve repeatedly executing a series of commands and so loops can save a great deal of typing. Another useful technique that not only saves typing but also helps make your code more readable and allows you to re-use your code is defining your own functions.

User-defined functions

User-defined functions (UDFs) are usually short blocks of code that can be called from anywhere in your program. Functions are usually defined at the start of a program after first importing any required library modules. Once defined, UDFs can be called as many times as they are needed. UDFs also support the ability to pass one or more variables in from the main program and have values returned to the main program for subsequent processing. Let's look at a very simple UDF that does nothing except print a message. First, UDFs are defined in the following way:

```
# Warn user that he/she is about to quit
def warn():
    print('You have selected Quit')
    print('Are you sure?')
```

To make use of the UDF you would simply include the following line later in your program:

```
warn()
```

When the line of code is executed (and the UDF has been called) the following lines will appear in the console:

```
You have selected Quit
Are you sure?
```

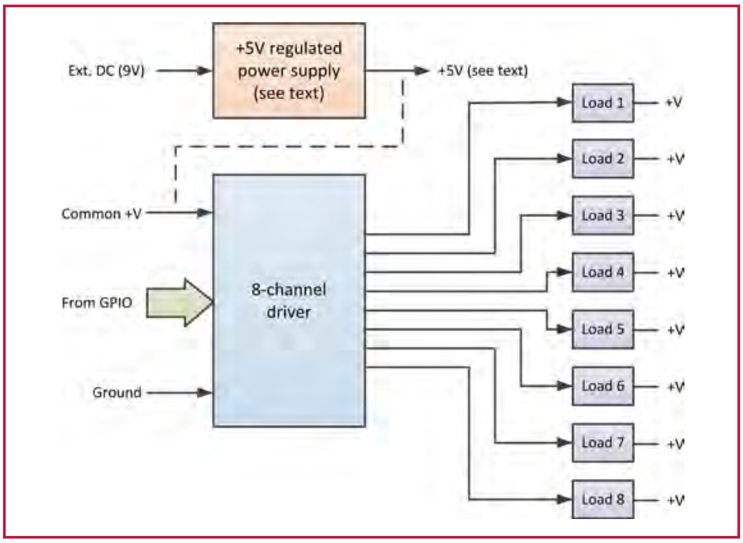


Fig.3.1. Simplified block schematic of eight-channel output driver

Passing parameters

To pass one or more values into a UDF we place variables inside the parenthesis that follows the name of the UDF, as shown in the next example:

```
# Function to convert Celsius to Fahrenheit
def c_to_f(x):
    return(9/5 * x + 32)
```

Notice how the value returned by the UDF (in this case it is the Fahrenheit equivalent of a Celsius temperature) appears in the return statement. To make practical use of this UDF we would need something along the following lines:

```
# Get a temperature and convert it!
cS = input('Enter a temperature in deg.C: ')
c = float(cS)
print(cS + ' deg.C is equivalent to ' + str(c_to_f(c)) + ' deg.F')
```

Note that the Celsius value entered at the keyboard is a string (`cS`) and this needs to be converted to a floating point value (`c`) that can be passed into the UDF. The returned value then needs to be converted from a floating point value to a string (using `str()`) before it can be printed. If you enter the program into the IDLE editor and then run it you will see something like the following:

```
Enter a temperature in deg.C: +120
+120 deg.C is equivalent to 248.0 deg.F
```

Now, here's an example of passing two values into a UDF and returning values that are subsequently used in a main program:

```
# Function to determine time constant of a C-R circuit
def cr_time(x, y):
    return(x * y)

# Function to determine the cut-off frequency of a C-R filter
def cr_freq(x, y):
    return(0.159 / (x * y))

# Get values of C and R
cS = input('Enter value of capacitance in uF: ')
c = float(cS)
rS = input('Enter value of resistance in Mohm: ')
r = float(rS)

# Print the results
print('Time constant is %.3f seconds' % cr_time(c, r))
print('Cut-off frequency is %.3f Hz' % cr_freq(c, r))
```

The typical output from this program is shown below. Note that the print library function can incorporate formatting (in this case the `%.3f` displays the values returned by the two UDFs to three places after each decimal point).

```
Enter value of capacitance in uF: 0.22
Enter value of resistance in Mohm: 0.15
Time constant is 0.033 seconds
Cut-off frequency is 4.818 Hz
```

Dealing with non-numeric input

Unfortunately, neither of the two examples that we've just described can cope with an input that is anything but a number. If you run either of the programs and enter non-numeric characters (other than + and –) you will find that the program terminates in a rather ugly fashion and it would be good practice to warn the user when he or she enters a value that the program can't use. To do this, we can add a couple of lines to the program that will allow us to exit to a more meaningful message, as shown in the following example. Note that we need to import the `sys` library in order to display a message when the program exits due to an error. In a later *Teach-In* we will deal with the tricky question of input validation, but for the moment this is at least an improvement on what we had before:

Don't forget to clean up!

We mentioned this last month, but it's worth repeating: at the end any program, and before the program makes an exit back to the operating system, it is good practice to clean up by setting the mode of all of the I/O channels to what you've decided is their default input state. To do this you can add a single line of code at the end of your program:

```
GPIO.cleanup()
```

Note that, in order to save space, we have not included this line in any of the sample fragments of code shown in this issue of Teach-In, but we do advise you to include it in your own code.

```
import sys

# Function to convert Celsius to Fahrenheit
def c_to_f(x):
    return(9/5 * x + 32)

# Get a temperature and convert it!
cS = input('Enter a temperature in deg.C: ')

try:
    c = float(cS)
except ValueError:
    sys.exit('You must enter a number!')

print(cS + ' deg.C is equivalent to ' + str(c_to_f(c)) + ' deg.F')
```

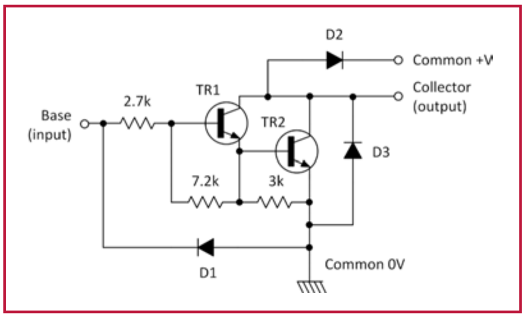


Fig.3.3. Simplified internal circuitry of one channel of the ULN2803

Pi Project

Last month, in *Pi Project*, we explained the electrical characteristics of the Raspberry Pi's general purpose input/output (GPIO) port. We also introduced the techniques for configuring the port for simple I/O operations, such as flashing an LED or sounding a buzzer. This month, we shall be further developing that theme by describing a simple eight-channel output driver that can be used to interface a *Raspberry Pi* to components and devices that make relatively high current and/or high voltage demands, such as relays, motors, actuators and sounders.

Eight-channel output driver

The simplified block schematic of our eight-channel output driver showing loads and power supply is shown in Fig.3.1.The circuit is based on a single ULN2803 integrated circuit. This handy device is an octal (eight-channel) high voltage/high current driver array. The pin connections for a ULN2803 are shown in Fig.3.2. Note that the common ground connection is taken to pin-9, while the positive supply is taken to pin-10. The device is capable of handling load currents of up to 500mA and voltages up to 50V. The input of the ULN2803 is compatible with standard 5V TTL and CMOS devices, but it will operate quite happily with the 3.3V logic available from the Raspberry Pi's GPIO output pins.

The simplified internal circuitry of each of the eight channels of a ULN2803 is shown in Fig.3.3. TR1 and TR2 are connected as a Darlington pair which ensures very high current gain (roughly equal to the product of the two individual current gains for TR1 and TR2). D1 provides input reverse polarity protection, and D2 and D3 protect the device from high voltages that might appear at the collector of TR1 and TR2 when switching an inductive load such as a relay, actuator or motor.

The complete circuit of the 8-channel output driver is shown in Fig.3.4. The eight input diodes (D1 to D8) provide reverse voltage protection for the Raspberry Pi's GPIO outputs. The eight outputs from IC1 are taken to an 18-way connector (P2). One set of pins on this connector is connected to the common positive supply (this will typically be +12V derived from a suitably rated external power supply). The pin connections for P2 are shown in Fig.3.5, and the individual pin assignments are given in Table 1.

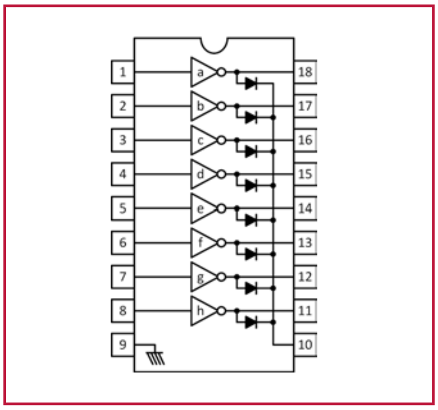


Fig.3.2. Pin connections for a ULN2803 (viewed from the top)

The Humble Pi prototyping board

We built our eight-channel output driver using a 'Humble Pi' prototyping board (see Fig.3.6). This handy board can be fitted with the 26-way connector (supplied with the Humble Pi) so that the board sits piggy-back style immediately above the Raspberry Pi. The result is an extremely neat and compact layout. The wiring diagram for the eight-channel output driver is shown in Fig.3.7.

Power supplies

The eight-channel output driver should be tested before connecting it to any external loads. In order to test the prototype we decided to make use of the simple on-board voltage regulator kit that can be supplied as an optional accessory for the Humble Pi (shown in Fig.3.6). This kit consists of a low-dropout voltage regulator (LD33V, LD50V, or equivalent), two capacitors, and a standard DC power connector. Note that when ordering a power supply kit for this particular application it would be worth specifying the use of a 5V regulator. The four additional power supply components can be quickly and

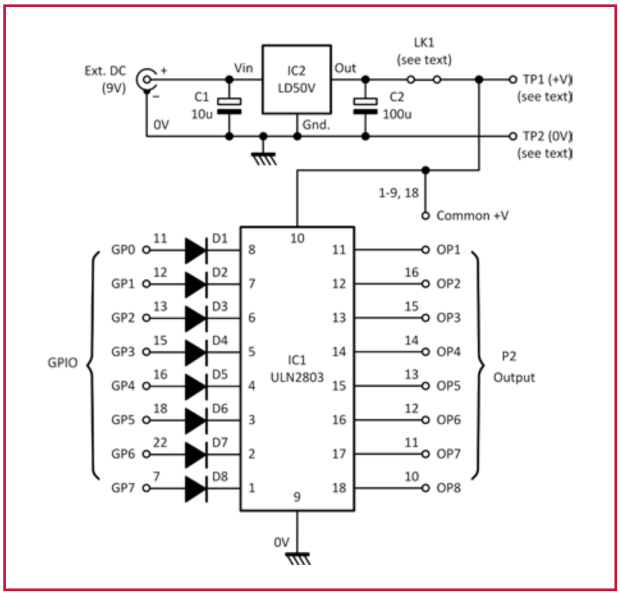


Fig.3.4. Complete circuit of eight-channel output driver

Table 1: Pin assignments for output connector P2

GPIO pin number	Humble Pi GP number	Output pin identifier
11	GP0	OP1
12	GP1	OP2
13	GP2	OP3
15	GP3	OP4
16	GP4	OP5
18	GP5	OP6
22	GP6	OP7
7	GP7	OP8

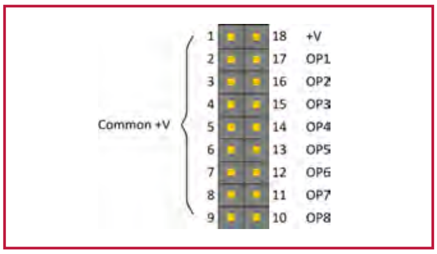


Fig.3.5. Pin connections for output connector P2

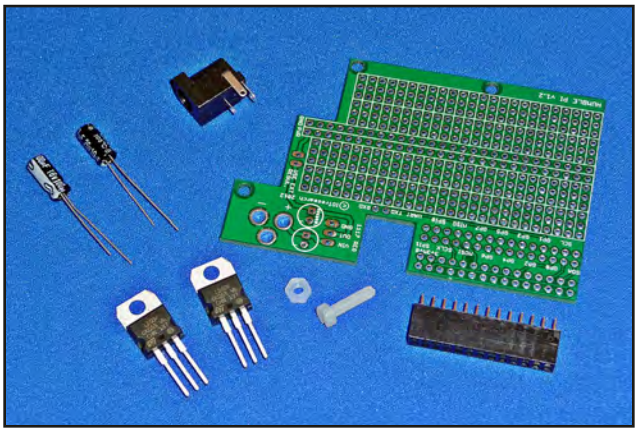


Fig.3.6. The Humble Pi prototyping board and optional power supply kit

easily fitted to the Humble Pi prototype board (see Fig.3.7 and Fig.3.8).

The link on the board (LK1) is left in place when testing with the on-board 5V supply (or when only 5V is required for the loads) but is removed when a higher voltage external supply is connected. After testing, the link can be removed and the external supply (eg, 12V or 24V) can then be connected to the two pins marked TP1 (+V) and TP2 (0V). Finally, don't be tempted to fit a conventional three-terminal regulator (eg, 7805 or 7812) to the Humble Pi board because these chips have different pin connections, as shown in Fig.3.9

Testing the interface

When the time comes to test the eight-channel output driver you will need to enter your code (see *Home Baking*) using an editor (or an IDE such as IDLE) before saving it to the folder in which you are currently storing your Python files (we created a folder called `Work_files` on the desktop for storing our files, but you can save them in any convenient location). To test the code you can then start LXTerminal (or an equivalent terminal utility) and enter the appropriate command (using `sudo` to gain root privileges, as explained in the boxed feature on the next page).

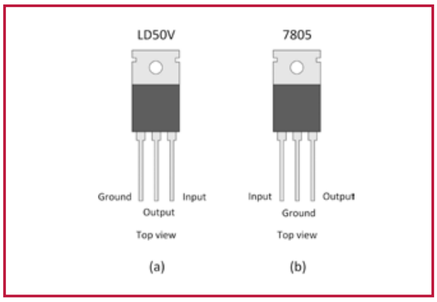


Fig.3.9. Pin connections for standard and low-dropout voltage regulators

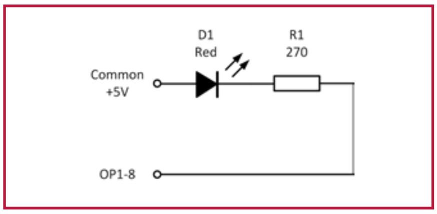


Fig.3.10. The simple LED test load

Prior to connecting real loads to the eight-channel output driver, testing can easily be carried out by simulating a load using an LED connected in series with a 270Ω current-limiting resistor, as shown in Fig.3.10. This can be connected to each of the outputs on P2 in turn before using a few lines of code to turn the respective channel on and off. The GPIO will need to be configured properly before you do this (see *Home Baking*).

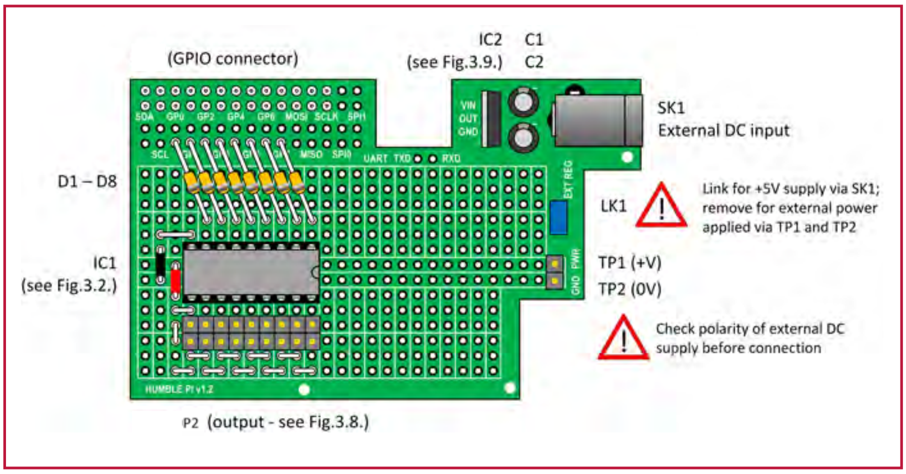


Fig.3.7. Component layout for the eight-channel output driver

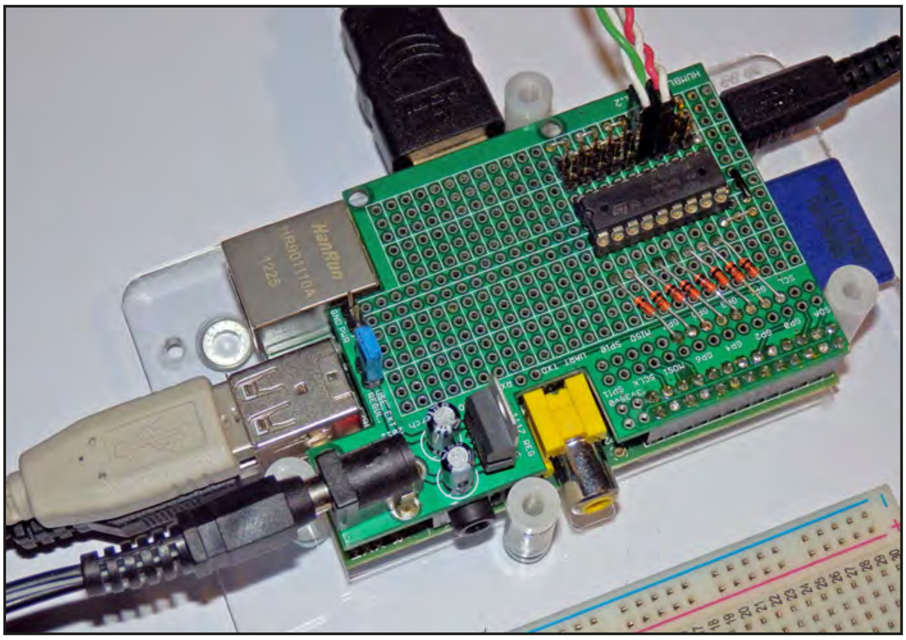


Fig.3.8. Finished prototype of the eight-channel output driver under test (note that the Humble Pi board fits neatly over the top of the Raspberry Pi)

Home Baking

In this month's *Home Baking* we will be looking at how the GPIO library module can provide you with easy access to the features of the GPIO port from within your Python code. In order to help you get your eight-channel output driver up and running quickly, all of the examples that we've provided relate to the Humble Pi prototyping board.

Initialising the GPIO

As mentioned last month, the GPIO library module provides easy access to the features of the GPIO port from within your Python code. However, before the library module can be used it needs to be imported into your code using a statement of the form:

```
import RPi.GPIO as GPIO
```

At this point, it is worth reminding you that if you don't have sufficient privileges the library import will fail and a run time error will be generated when this line of code is encountered during run time. To overcome this problem you need to execute your Python script as a 'superuser', but you can set this privilege level by simply using `sudo` before the script name. For example, if your script has the name `control.py` you would execute it using the command:

```
sudo control.py
```

Next we need to decide which mode of operation to use with the `GPIO.setmode` command. We have a choice of two commands:

```
GPIO.setmode(GPIO.BOARD)
```

This allows us to use the Raspberri Pi's own board numbering scheme while:

```
GPIO.setmode(GPIO.BCM)
```

allows us to use the numbering scheme adopted by the Broadcom chip.

Configuring the GPIO for the Humble Pi
The convention adopted by the Humble Pi breadboarding system follows the board numbering scheme – so, in this particular application, we will be using the `GPIO.BOARD` option. Here's a block of code that can be used to configure the GPIO:

```
# Configure the GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(11, GPIO.OUT)  # GP0/OP1
GPIO.setup(12, GPIO.OUT)  # GP1/OP2
GPIO.setup(13, GPIO.OUT)  # GP2/OP3
GPIO.setup(15, GPIO.OUT)  # GP3/OP4
GPIO.setup(16, GPIO.OUT)  # GP4/OP5
GPIO.setup(18, GPIO.OUT)  # GP5/OP6
GPIO.setup(22, GPIO.OUT)  # GP6/OP7
GPIO.setup(7, GPIO.OUT)   # GP7/OP8
```

Next (for safety reasons) we need to ensure that all of the output lines are initially turned off. This can be done with the following block of code:

```
# Initialise all lines to the OFF state
GPIO.output(11, False)
GPIO.output(12, False)
GPIO.output(13, False)
GPIO.output(15, False)
GPIO.output(16, False)
GPIO.output(18, False)
GPIO.output(22, False)
GPIO.output(7, False)
```

Switching the outputs on and off
Switching the output lines is easy; for example, to turn OP2 on we use this code:

```
# Turn OP2 on
GPIO.output(12, True)
```

While to turn OP2 off we use:

```
# Turn OP2 off
GPIO.output(12, False)
```

Notice that we've added comments to the code that will help us understand what the program does when the time comes to maintain or modify it.

Now for a complete example – let's assume that we have a light connected to OP2 and a camera connected to OP3. Let's also assume that we need to put the light on two seconds before the camera is to be operated and that the two signals must remain held on for a further two seconds before they are both turned off for an additional ten seconds, after which the entire 14-second cycle should be repeated indefinitely. We will need to import two libraries in this application; the `GPIO` library and the `time` library, as shown at the beginning of the sample code listed below.

A neat way to operate the lamp and camera is to make use of user-defined function UDFs that we described earlier in *Python Quickstart*. In the case of the lamp, the function that we will call to switch the light on is as follows:

```
def light_on():
   GPIO.output(12, True)
```

While to switch it off we will need this function:

```
def light_off():
   GPIO.output(12, False)
```

Running Python programs as root

Under the Debian (Linux) operating system it is important to be aware that you must have root (super user) privileges in order to execute a Python program. You can do this by specifying sudo along with the Python filename in the command line that you enter directly from within the terminal (eg, LXTerminal) program. Note that unless you have previously set the path to your Python source code, you will need to specify the full path to your file. For example, let's assume that you have created a Python module called `oc_driver` and saved it with the py extension in a folder called `Work_files` on your desktop. In order to run the program you could use the following (rather cumbersome) command line based on the full path to your file:

```
sudo python /home/pi/Desktop/Work_files/oc_driver.py
```

This works, but it is clearly rather longwinded, so let's look at an easier way of executing Python code from a particular directory. Assuming that you are logged in as the default user (pi) with the default password (`raspberry`) you could abbreviate the command as follows:

```
sudo python Desktop/Work_files/oc_driver.py
```

To make things even easier you could change your working directory by making use of Debian's cd command, as follows:

```
cd Desktop
cd Work_files
```

or by just using a single command line:

```
cd Desktop/Work_files
```

Then, to start Python and execute your program, simply enter the following command line:

```
sudo python oc_driver.py.
```

To go back to your home directory you can just type cd with no arguments or to move back to the root directory you can use:

```
cd /
```

To just move up one level (ie, back to the parent directory) you can use:

```
cd ..
```

If you wish to know which directory you've arrived at you can use the ls command by just typing:

```
ls
```

to list the files and folders in the current directory.'

Notice how we have used Boolean variables `True` and `False` to indicate the 'on' and 'off' states for the light.

Having defined these functions at the start of the code, we can go on to use them many times in the code that follows. So, to switch the light on we can just use:

```
light_on()
```

While to switch the light off we only need to use:

```
light_off()
```

Here we have the full code for our light and camera application:

```
import RPi.GPIO as GPIO
import time

# Configure GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(11, GPIO.OUT)  # GP0/OP1
GPIO.setup(12, GPIO.OUT)  # GP1/OP2
GPIO.setup(13, GPIO.OUT)  # GP2/OP3
GPIO.setup(15, GPIO.OUT)  # GP3/OP4
GPIO.setup(16, GPIO.OUT)  # GP4/OP5
GPIO.setup(18, GPIO.OUT)  # GP5/OP6
GPIO.setup(22, GPIO.OUT)  # GP6/OP7
GPIO.setup(7, GPIO.OUT)   # GP7/OP8

# Initialise with all lines OFF
GPIO.output(11, False)
GPIO.output(12, False)
GPIO.output(13, False)
GPIO.output(15, False)
GPIO.output(16, False)
GPIO.output(18, False)
GPIO.output(22, False)
GPIO.output(7, False)

# Light is assigned to OP2
def light_on():
   GPIO.output(12, True)

def light_off():
   GPIO.output(12, False)

# Camera is assigned to OP3
def camera_on():
   GPIO.output(13, True)

def camera_off():
   GPIO.output(13, False)

# Main loop
while True:
    light_on()
    camera_off()
    time.sleep(2) # Wait 2 seconds
    camera_on()
    time.sleep(2) # Wait 2 seconds
    camera_off()
    light_off()
    time.sleep(10) # Wait 10 seconds
```

Notice how the main loop of the program is based on the Python `while` construct and that the loop executes forever. To break out of the code you can just press the `Ctrl` and `C` keys at the same time – this will return control to the Python command line interface.

Refinements

The previous example used four user-defined functions to control two devices, but we can easily refine the program so that it only uses two UDFs. This can be achieved by passing a parameter into a single function that will either turn the respective output on or turn it off depending upon the value of the switch parameter (either `True` or `False`). Thus the function that we call in order to operate the light might look like this:

```
def light(switch):
   if switch:
      GPIO.output(12, True)
   else:
         GPIO.output(12, False)
```

The code that we need to turn the light on would then be:

```
light(True)
```

While to turn if off we would need to use:

```
light(False)
```

Our final example shows how this works:

```
import RPi.GPIO as GPIO
import time

# Configure GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(11, GPIO.OUT)  # GP0/OP1
GPIO.setup(12, GPIO.OUT)  # GP1/OP2
GPIO.setup(13, GPIO.OUT)  # GP2/OP3
GPIO.setup(15, GPIO.OUT)  # GP3/OP4
GPIO.setup(16, GPIO.OUT)  # GP4/OP5
GPIO.setup(18, GPIO.OUT)  # GP5/OP6
GPIO.setup(22, GPIO.OUT)  # GP6/OP7
GPIO.setup(7, GPIO.OUT)   # GP7/OP8

# Initialise with all lines OFF
GPIO.output(11, False)
GPIO.output(12, False)
GPIO.output(13, False)
GPIO.output(15, False)
GPIO.output(16, False)
GPIO.output(18, False)
GPIO.output(22, False)
GPIO.output(7, False)

# Light is assigned to OP2
def light(switch):
   if switch:
      GPIO.output(12, True)
   else:
         GPIO.output(12, False)

# Camera is assigned to OP3
def camera(switch):
   if switch:
      GPIO.output(13, True)
   else:
         GPIO.output(13, False)

# Main loop
while True:
    light(True)
    camera(False)
    time.sleep(2) # Wait 2 seconds
    camera(True)
    time.sleep(2) # Wait 2 seconds
    camera(False)
    light(False)
    time.sleep(10) # Wait 10 seconds
```

'A further refinement would be to use UDFs to configure the GPIO and then to initialise it. These UDFs (along with the others that we have defined) can then easily be copied and re-used in other applications. If you've read this far you should be gaining a good appreciation of just how powerful and extensible the Python programming language is!'

Pi World

In this month's *Pi World* we have four books to recommend for your Raspberry Pi bookshelf. Although different, all of these titles will provide you with an excellent source of background information on the Raspberry Pi and all are available from the *EPE Readers Book Service* (see page 68 for ordering information).

Raspberry Pi Manual A practical guide to the revolutionary small computer

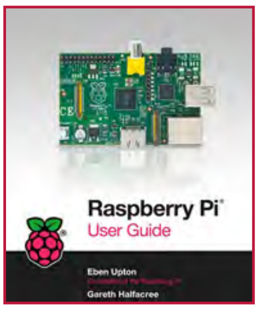
Gray Girling (Foreword by Eben and Liz Upton)
Haynes, ISBN 978 0 85733 295 0

In many respects this book has become *the* definitive guide to the Raspberry Pi. Published in the familiar Haynes Manual format, the 169-page manual comprises of seven sections packed with information presented in a clear, concise and well-illustrated format. The book is published in hardback and uses colour throughout. The individual sections are presented in a logical sequence, starting with a useful introduction and ending with several handy appendices.

The *Raspberry Pi Manual* assumes little previous knowledge, but nonetheless is designed for readers who are able to assimilate the information and put it to good use. It is essentially a practical book with plenty of hands-on content. To this end, material is presented as a series of 'recipes' that readers can incorporate in their own projects. So, if you have little previous knowledge and if you only intend purchasing one book on the Raspberry Pi, then this has to be the one.

Raspberry Pi User Guide

Eben Upton and Gareth Halfacre
Wiley, ISBN 978 1 118 46446 5

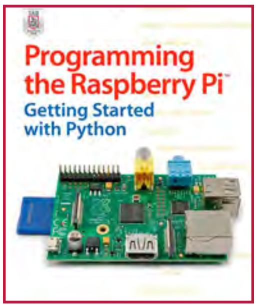


Upton was one of the co-creators of the Raspberry Pi, and this book aims to tell you everything that you need to know in order to get up and running. The book has 13 chapters and two appendices. After a brief introduction that deals with the history of microcomputers, the book's three main parts deal with: connecting the board; using the Pi as a media centre, productivity machine and web server; and programming and hacking.

With a mixture of hardware and software (including programming related content) there is something in this book for every reader. The book also has useful chapters on Linux system administration, troubleshooting, network configuration and partition management. For electronics buffs, the chapter on hardware hacking provides a reasonably comprehensive introduction to the GPIO port, UART serial bus, I^2C bus and SPI bus, as well as a brief introduction to electronic components.

Programming the Raspberry Pi

Simon Monk
McGraw Hill, ISBN 978 0 07 180783 8

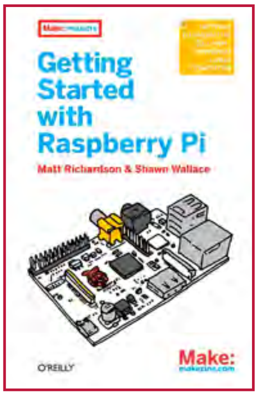


This book explains the basics of program development for the Raspberry Pi. It will show you how to configure your Raspberry Pi and also how to navigate files and folders. The book provides a good introduction to the IDLE editor and there are numerous examples of Python code to get you started. The book also includes chapters on how to write and use your own libraries, modules and classes, as well as adding web features, developing interactive games (using Pygame) and interfacing with external hardware using the GPIO port.

For those who would like to give their programs a more polished appearance, Simon Monk's book provides a brief introduction to the *Tkinter* graphical user interface (GUI). For the hardware enthusiast, the book provides an overview of several of the currently available prototyping boards; with practical examples that include a clock and a small robot. So, whether you are software or hardware orientated, this book will provide you with plenty of food for thought and will quickly get you up and running with Pi and Python programming.

Getting Started with Raspberry Pi

Matt Richardson and Shawn Wallace
published by O'Reilly
ISBN 978 1 449 34421 4



The last of our four books is a relatively slim volume (164 pages) that aims to provide you with a useful and reasonably comprehensive guide to getting a Raspberry Pi up and running for the first time. The book also describes a variety of interesting practical applications, including the use of webcams and other peripherals with the Raspberry Pi. There's even a chapter for Arduino fans that shows how the Raspberry Pi can be used together with an Arduino single-board computer.

Getting Started with Raspberry Pi provides just the right amount of detail to get you up and running, and each chapter includes a section on 'Going Further' with handy links to on-line sources. On the downside, some of the hand-drawn sketches in the book are a little rough, but that does not detract from the overall usefulness of the book. Finally, it's worth noting that the book does not have an index, but perhaps the authors will do something about this in a future edition?

In next month's *Teach-In 2014* with Raspberry Pi

In next month's *Teach-In 2014* we will be entering the analogue world. Our *Pi Project* deals with the construction of a simple eight-channel analogue input board based on the Humble Pi. In *Python Quickstart* we will be taking a first look at the serial (SPI) interface with some sample code for temperature sensing and analogue data logging applications. For good measure, *Pi Class* will be introducing a variety of must-have software applications for the Raspberry Pi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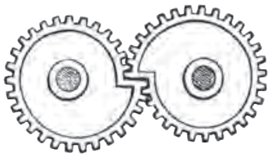
Max's Cool Beans

By Max The Magnificent

It's sometimes hard for me to describe how my mind works – it's typically bouncing around from topic to topic with the agility of a young, fearless mountain goat (the rest of me staggers along behind trying to keep up).

507 Mechanical Movements

A few months ago, I ran across a reference to a book that was originally published in 1868 – *Five Hundred and Seven Mechanical Movements* by Henry Brown. As I get older, I've become increasingly interested in the mechanical side of things. I'm also becoming aware that there is a lot more to mechanical movement than simple circular gears and pulleys and suchlike. Consider the following asymmetric pair of 'scroll gears' from the '507 book'. Note that their axes are off-center, so they create a linearly increasing or decreasing gear ratio. If you apply a constant speed to the first gear, the second gear will start out with a slower speed and higher torque, and will transition linearly to a higher speed and lower torque, and *vice versa* (see: **http://youtu.be/bcd8SUZs6qE**).



***Scroll gears from* 507 Mechanical Movements**

This just amazes me – I'd never have conceived something like this by myself in a thousand years. Just as amazing, this book is still in print! You can get it for £3.99 from Amazon (**www.amazon.co.uk/dp/1603863117**).

3D printers

I was so intrigued by the concept of the scroll gears, along with some of the other mechanical movements in the book, that I started to think about replicating them to play with so as to get a better feel for how they worked. Originally, I was thinking about using an X-Acto knife to cut the shapes out of some sort of project board, but then I saw an article about 3D printers…

In the not-so-distant past, 3D printers cost tens-of-thousands of dollars (they still can for the industrial versions), but the price has fallen dramatically in the home-use market. I ran across a company called Solidoodle (www.Solidoodal.com) that sells the Solidoodle 3D printer (2nd generation) for a base price of $499.

The Solidoodle3D printer

This little beauty is capable of printing 3D objects up to a six-inch cube (150mm) with a resolution of 0.1mm in the X, Y, and Z planes, which I think is pretty astounding. I'm a weak-willed man. I couldn't resist. I immediately ordered it. Actually, I also added the $99 heated base-plate upgrade (this is necessary if you want to print larger objects, which – of course – I do).

The other thing I'll need is 3D software to capture my design. According to Solidoodle, their printing software accepts 3D files in STL format, which I now know is a universal file format. As they say: 'As long as your 3D design software can Save/Export as an STL file, you should be good to go.' I've been looking around. There are all sorts of 3D drawing packages out there, some costing thousands of dollars. As a starting point, I'm going to play with 'SketchUp Make' (**www.sketchup.com**), coupled with an STL format reader/writer plug-in, both of which are free (I like free).

My Solidoodle 3D printer literally arrived just a few minutes ago as I pen these words. The box is sitting next to me on the office floor. As soon as I finish writing this column, I'm going to dive in to see what's there – I can't wait to start playing!

3D scanners

For the mechanical-type objects I want to create, using a 3D drawing package to drive my 3D printer is the way to go. In the case of more 'organic' objects, however, a 3D scanner offers a very attractive route. The idea is that you place the object you wish to replicate on your 3D scanner, which then 'scans' the item and outputs the 3D drawing files you will use to feed your 3D printer. This does, of course, assume that you are already in possession of an object that you wish to scan.

Once again, these little scamps used to be horrendously expensive, but the price for home-use versions is plummeting. For example, the folks at MakerBot (**www.makerbot.com**) have recently announced the MakerBot Digitizer (see this rapscallion in action at: **http://youtu.be/9GfnKKczec0**). With a scan volume of up to an eight-inch cube (200mm) and dimensional accuracy of ±2mm, this really isn't bad for $1,400.

In fact, a number of other scanners are either available or 'in the works', including the MATTERFORM (scan volume = 190mm-diameter cylinder up to 248mm in height; accuracy = ±0.2mm; $600) and the DIMBODY (scan volume of 300mm cube; accuracy = ±0.1mm; $1,400).

I'm not really bothered about a 3D scanner at this moment (after all, I've not even unpacked my 3D printer yet), but maybe somewhere down the line... Until next time, have a good one!

The Solidoodle 3D printer (2nd generation)

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

PIC-ing up where we left off!

WELCOME back to *PIC n' Mix*. It's been a hectic summer this year as we relocated the *PIC n' Mix* laboratory (aka the family home) from the UK back to Dublin, Ireland. Having emptied the shipping boxes and found the important bits – the kettle and the soldering iron – it's time to return to all things PIC.

The Dublin scene

Dublin is quite a good location for an electronics hobbyist. There are two Maplin stores in the town, plus a store called MakeShop which sells electronics kits that you can construct on-site in the shop's own workshop area. They even let you use their facilities to build or repair your own electronic projects, which is quite neat. MakeShop is owned and operated by the local university for the local population, not just the students.

Dublin also boasts a 'Maker Space', called Tog Dublin Hackerspace. Maker Spaces are community-run facilities where groups of hobbyists get together and rent building space – sometimes just a room or a workshop – to keep communal tools, provide space in which to work on projects and generally hang out together. The group can purchase expensive tools (like 3D printers or milling machines) that an individual may find it difficult to justify purchasing. We will be reporting more on Maker Spaces early in the new year.

The town also hosts Ireland's first 3D printer shop, '3D Print Ireland'. Originally an Internet cafe based in the south of the city, they started a 3D print bureau in May this year, and now have two Ultimaker 3D printers on-site. They can provide support for design and 3D scanning, and offer evening courses in 3D printing. Well worth a visit and a chat with the staff if you find yourself in Dublin on a wet afternoon.

Let's return to our own microcontroller project, starting with a re-cap of where we left off at the beginning of the summer.

PIC development board

Over the course of the previous half a dozen articles we have been developing a low cost, low power circuit, capable of maintaining low power consumption even when using an LCD or maintaining a real-time clock. You might be asking, 'What is the point of creating yet another development board?' Well the point here is a focus on a very low cost combined with very low power. Cheap enough that a board could be dedicated to a project (an Arduino would be too expensive to do that more than a few times) and low power enough to be useful in a battery-powered environment.

We could continue to add various other parts to the circuit, such as FET switches, servo motor drivers and the like, but at this point we start to move away from a general-purpose module, add cost and tie up I/O pins that may be needed for other uses. We will keep things to the minimum. Well, the minimum as we see it – oscillator, decoupling, a single LED for some feedback, a connector for programming and connectors for mounting the board on a PCB or breadboard.

That final point is quite important – designing the PCB so it can be easily wired or plugged onto a breadboard is something that we see as a highly useful feature, as so many projects start life on a breadboard, and often the first things that need construction are the processor, oscillator and programming interface. This just means positioning the I/O connector header on a 0.1-inch spacing, and making the board wide enough to fit across the two rows of pins on a breadboard, as seen in Fig.2. Whether the board is populated with a header strip so that it can be pushed onto a breadboard is your choice; we typically have at least one board configured like this (with a range of processors – two PIC18F boards, and one PIC32 board) so that project ideas can be quickly built and tested.

Coming up

Next month, we move the circuit off the breadboard and onto a proper PCB. To keep costs down (and to simplify production if you choose to build this yourself) the board will be single sided and make use of through-hole components.

For software, we will quickly cover a basic, generic assembly language project template for the board before moving onto the C language. This is particularly timely as we start to use the more complex peripherals on the processor, such as PWM and ADC, and start to build some more complex projects.

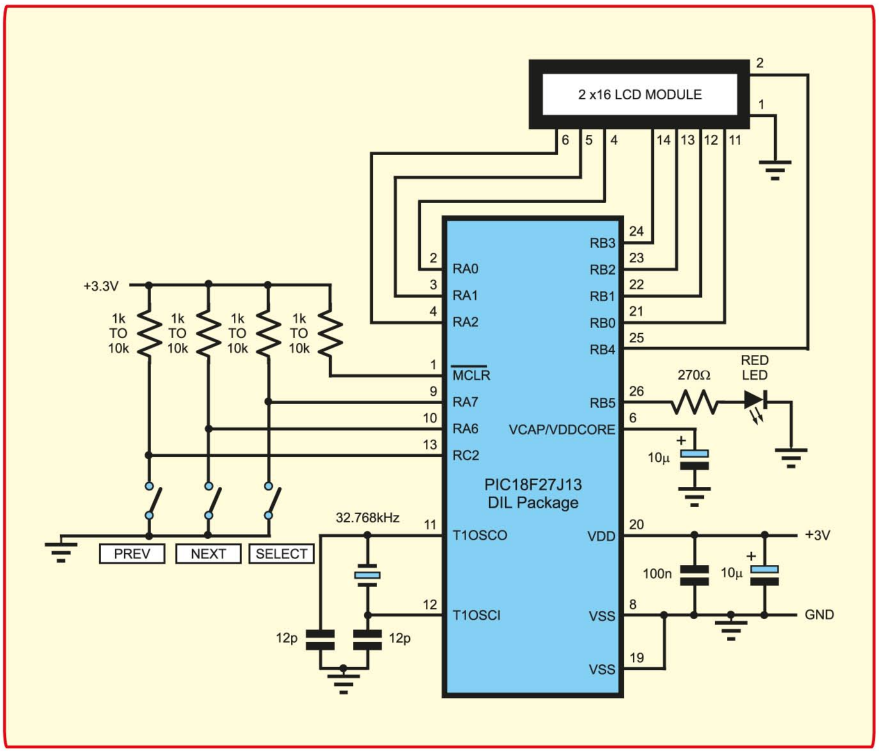


Fig.1. Low cost, low power PIC development circuit

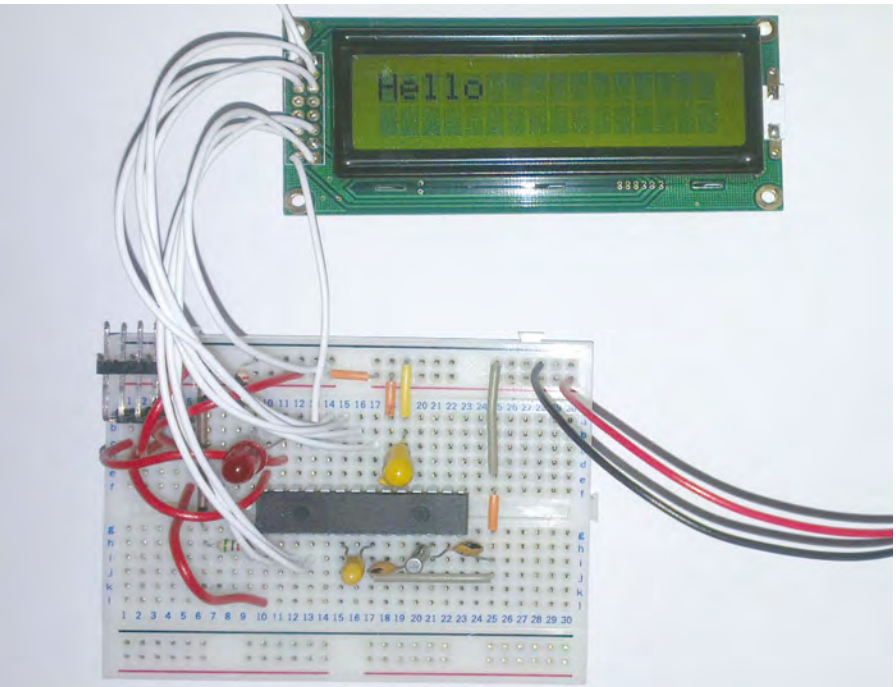


Fig.2. Breadboard layout of the PIC development circuit

We will continue to intersperse the series with the odd article on different but related subjects, including 'Maker Spaces' and the use of scripting languages such as Lua for simplifying very complex projects (such as the WIB internet device from last year.) We will also be playing with PIC32 processors again.

Finally, this month, a bit of Microchip gossip. It looks as though Microchip will soon be releasing a new PIC32 processor, called the PIC32MZ. Based on the MIPS14k processor design (the PIC32MX is based on the MIPS4K) the PIC32MZ will run at over 200MHz, have up to 2MB of Flash and 512KB of RAM. It will also be able to run code from an external RAM device. The main feature that makes it useful to us hobbyists is that it will be available in a 64 pin 0.8mm pitch surface-mount part, which is just about hand-solderable. Coupled with a scripting engine such as Lua, this could be a very interesting device indeed! Stay tuned. We will have more news on that subject next month.

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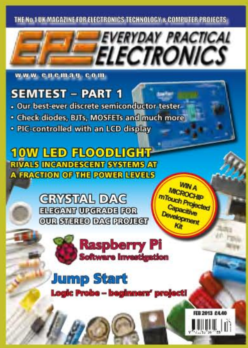

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INTERFACE

By Robert Penfold

An 8-bit ADC for Raspberry Pi

THE two previous *Interface* articles covered the basics of interfacing to the GPIO port of a Raspberry Pi computer. In this month's article we move on to a simple Raspberry Pi 8-bit analogue-to-digital converter. There are two approaches to interfacing to this type of circuit, which are the serial and parallel types. The parallel method is the easier of the two, in that it has a separate line to carry each bit of data from the computer to the converter chip. In the case of an 8-bit converter it is merely necessary to have eight output lines plus an earth (ground) connection to carry the data to the converter.

Serial or parallel?

It is not essential to have any form of handshaking to regulate the flow of data, and each time a fresh byte of data is available it can simply be output to the converter. The time taken for real world converters to adjust to a new output voltage is very short, but is finite, and there is a limit to the maximum rate at which data can be usefully output. In practice, this rate is likely to be higher than the computer is ever likely to achieve, but where necessary, a simple time delay can be used to prevent data being sent at an excessive rate.

The serial approach normally utilises some form of synchronous serial interface. This typically has one output for sending data, another output to provide a synchronising clock signal, and another line to provide handshaking or a strobe signal. Normally, this method of interfacing is relatively slow since the data is being output on a single line, one bit after another, whereas a parallel interface outputs data in complete bytes. With higher resolution converters the data is output 12 bits at a time, 16 bits at a time, or whatever. For many applications, the transfer rate of a serial converter is still more than adequate.

With its numerous input/output lines, the GPIO port of a Raspberry Pi computer is able to handle serial or parallel interfacing to a digital-to-analogue computer. With an 8-bit converter, the parallel approach is probably the easier one, but for 12 or more bits the serial method would probably be a more practical proposition. Anyway, in this example the converter chip used is an AD557JN 8-bit parallel converter (Fig.1).

On the level

There is a potential problem when using this chip, and many others with the Raspberry Pi's GPIO port. This is simply that the converter chip operates from a 5V supply and requires 5V logic levels at its inputs. The input/output lines of the GPIO port operate at 3.3V logic levels. This is of greater importance when driving the GPIO port from 5V logic circuits, where this will take the GPIO port's inputs to higher voltages than they are designed to handle. This is unlikely to cause any damage to the Raspberry Pi computer, although it is best not to put this type of thing to the 'acid test'. It could cause the Raspberry Pi to malfunction though, and 5V logic outputs should only drive GPIO inputs via some form of level converter circuit that will provide the correct 3.3V logic levels.

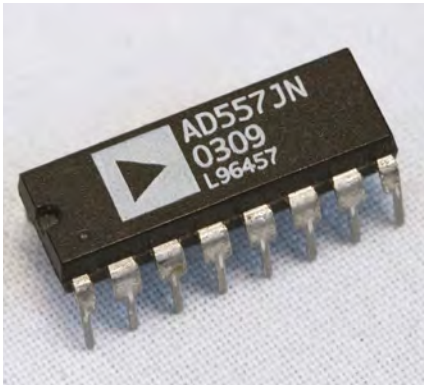

Fig.1. The AD577 is an 8-bit parallel digital-to-analogue converter. The 'JN' version of the AD577 is the easiest version to experiment with, as it has a standard 16-pin DIL encapsulation

Driving 5V logic circuits directly from the GPIO port will often work perfectly well. This is simply because 5V logic devices do not usually require a high (logic 1) level to be at anything approaching the full 5V. The minimum valid high logic voltage is usually about 1.8V to 2.2V, which is comfortably below the 3.3V high output level of a GPIO output. The AD557JN chip used here requires a minimum logic 1 voltage of 2V on both its control and data inputs, and the input current is low enough to avoid significant loading effects. I found no problems when driving it direct from GPIO outputs, and did not bother with any buffers or level converters in the final design.

The AD557 is a converter chip that has featured in previous *Interface* articles, and it is still a good choice for applications where its 8-bit resolution will suffice. The circuit diagram of Fig.2 shows one way in which the AD557JN converter chip can be used with the GPIO port. The 'JN' version of the chip has a standard 16-pin DIL encapsulation with the eight data inputs conveniently grouped together and in order on one side of the device (pins 1 to 8).

The manufacturer's labelling for the data inputs and outputs of converter chips tends to be a bit confusing. Instead of the usual D0 to D7, the data terminals are often marked Bit 1 to Bit 8, as in this example. This method of identification is perhaps a bit topsy-turvy, as it is bit 1 that is the most significant bit (D7) and Bit 8 that is the least significant bit (D0). This is the opposite of what one would probably expect. The data inputs of the chip are driven from the eight input/output lines on the even numbered row of the GPIO connector. Pin 8 provides the least significant bit (D0 or Bit 8), running through to pin 26, which handles the most significant bit (D7 or Bit 1).

The AD557JN requires a normal 5V logic supply and consumes a maximum of 25mA (typically 15mA). The 5V supply output of the GPIO port should be able to handle this with ease. The AD557JN has control inputs that enable it to interface to the buses of some microprocessors. These inputs are the Chip Enable (CE) and Chip Select (CS) inputs at pins 9 and 10 respectively, but these are of no use in the current context. They are simply connected to ground so that the chip is permanently enabled and selected.

The output section of the AD557JN has an operational amplifier and three feedback resistors. Normally, pins 14 to 16 are connected together so that all three resistors are used in the negative feedback loop. This gives an output voltage range of 0V to 2.55V, or 10mV per least significant bit. The output potential in millivolts is then equal to ten times the value written to the converter. Alternatively, dividing the value written to the converter by one hundred gives the output potential in volts. The output voltage can be trimmed using a discrete variable resistor, but this is usually unnecessary. Some external amplification and processing will normally be needed in

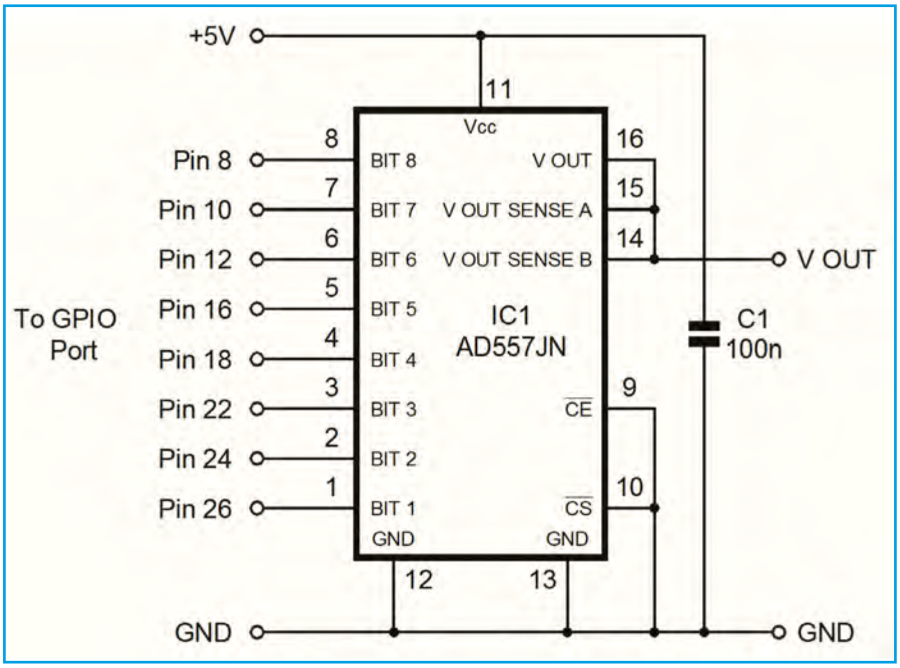

Fig.2. A basic 8-bit digital-to-analogue converter circuit for use with the GPIO port of a Raspberry Pi. The output voltage range is 0 to 2.55V

order to provide the required output voltage range.

The AD557JN has a built-in precision 1.2V band-gap reference source. The full-scale accuracy of the chip is plus or minus 2.5 LSB at 25°C, but can be as large as plus or minus 4.5 LSB at extreme temperatures. In practical applications this error would normally be trimmed out by the signal processing stages. The relative accuracy is of greater importance, and is typically plus or minus 0.5 LSB, with a maximum error of plus or minus 1 LSB. This will be adequate in most real-world applications. The settling time is typically 0.8µs, but the maximum figure is 1.5µs.

Software

There is a slight problem when outputting bytes of data to the GPIO port, which is simply that it has a number of individual input/output lines, and there seems to be no built-in support for combining eight of them to provide a byte output. This means that a number such as 237 has to be converted to binary and then written to the eight output lines one at a time. There are probably several ways of doing this, but the bitwise AND approach provides a very simply way of handling things.

Listing 1 demonstrates how it can be achieved using Python, and the basic action of the program is to take a number input at the keyboard by the user, and then output the appropriate binary pattern on the appropriate eight pins of the GPIO port. The first section of the program imports the GPIO software support, sets the BOARD mode, and sets the appropriate pins of the port as outputs.

The next section reads the keyboard using an input instruction and places the result in a variable called 'mybyte'. In a real-world application it is necessary to use some error checking to ensure that the data input by the user is valid, and that crashes due to invalid input are avoided. For this simple example no error checking is used, and it is up to the user to ensure that an acceptable value is entered at the keyboard. In this case, it must be an integer (whole number) in the range 0 to 255, after which the Return key is pressed in order to enter the number into the program. The input instruction effectively has a built-in print instruction, and this is used to put an appropriate prompt on the screen. Note that the input instruction is not available in this form prior to Python 3, so Python 3 is needed to run this program.

It is important to realise that when data is input at the keyboard and placed in a variable, that variable is a string type. In other words, it contains one or more text characters, and not a numeric value. For example, if the user inputs '237', the variable contains the ASCII characters '2', '3' and '7', and not the numeric value 237. This is an important distinction, because it is not possible to perform mathematical or bitwise operations on a string variable. It would be a bit like asking the computer to multiply 'hello' by ten, and would halt the program with an error message!

There is an easy way around the problem, which is to use the int() function to convert the character string stored in 'mybyte' into an equivalent integer value. In this example, the converted string is placed in a new variable called 'mybyte2'. The next line takes the value stored in 'mybyte2', multiplies it by ten and prints the new value on the screen. This is not an essential part of the program, and it is included simply to demonstrate that the data input by the user is now available as an integer stored in 'mybyte2'.

With a value to output, the program then uses bitwise AND operations to determine the right value to write to each of the eight output lines, starting with the least significant bit and working through to the most significant bit. However, the relevant output is set low prior to each AND operation. This ensures that the previous state of each output is irrelevant, and any existing data on the outputs is overwritten. New data is written to the outputs via a series of 'if' instructions, with each bit having its own if instruction. An output is set high only if the result of its AND operation returns a value of 1. It is otherwise left at logic 0, giving the required transfer of the 8-bit binary value.

Latching

While it will not always be of importance, it should be borne in mind that this method of writing bytes to an output port is not quite the same as writ-

Listing 1

```
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setwarnings(False)
GPIO.setup(8, GPIO.OUT)
GPIO.setup(10, GPIO.OUT)
GPIO.setup(12, GPIO.OUT)
GPIO.setup(16, GPIO.OUT)
GPIO.setup(18, GPIO.OUT)
GPIO.setup(22, GPIO.OUT)
GPIO.setup(24, GPIO.OUT)
GPIO.setup(26, GPIO.OUT)

mybyte = input('Enter byte value ')
mybyte2 = int(mybyte)
print (mybyte2 * 10)
GPIO.output(8, 0)
if mybyte2 & 1:
    GPIO.output(8, 1)
GPIO.output(10, 0)
if mybyte2 & 2:
    GPIO.output(10, 1)
GPIO.output (12, 0)
if mybyte2 & 4:
    GPIO.output(12, 1)
GPIO.output(16, 0)
if mybyte2 & 8:
    GPIO.output(16, 1)
GPIO.output(18, 0)
if mybyte2 & 16:
    GPIO.output(18, 1)
GPIO.output(22, 0)
if mybyte2 & 32:
    GPIO.output(22, 1)
GPIO.output(24, 0)
if mybyte2 & 64:
    GPIO.output(24, 1)
GPIO.output(26, 0)
if mybyte2 & 128:
    GPIO.output(26, 1)
print ("Finished")
```

ing a byte of data to a port using a single instruction. On the software side of things it is relatively slow, since data is being written to the GPIO port one bit at a time. In this respect, it is much the same as using a serial converter. Of course, if the software runs fast enough it is still the hardware that is the limiting factor.

Perhaps of more significance, the data on the output lines switches cleanly and almost instantly from one value to the next when a single instruction is used. It is not possible to achieve this when setting one output line at a time, because it takes a relatively long time to complete the writing of each byte. It is inevitable that there will briefly be invalid data on the output lines while a byte of data is being output to the port bit-by-bit, and the outputs are changed one at a time.

There is a hardware solution to this problem in the form of a device called an 8-bit data latch. This has eight inputs that are fed from the output port. Each input of the latch has a corresponding output, but the outputs normally ignore the states on the inputs. Data is transferred to the outputs by applying a pulse to an additional input of the data latch. In the current context, the eight data outputs of the GPIO port would be fed to the data inputs of the latch, and an additional output of the GPIO port would be used to drive the latch's control input. A byte of fresh data would be written from the GPIO port in the normal way, and then a pulse would be generated on the additional output so as to transfer this byte to the output of the latch and lock it there. Computer chips such as digital-to-analogue converters often have built-in data latches or other facilities that enable glitches to be avoided. In other cases there will be filtering in the analogue signal processing stages that will remove any glitches. Consequently, it will not always be necessary to use some extra hardware in order to implement this system of outputting bytes. This will all be considered in the next *Interface* article.

READOUT

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

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

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

★ LETTER OF THE MONTH ★

Storing electricity

Dear editor
Some time ago you wrote about capacitive storage of electricity. It would be interesting if you could print more about this. What is available, possible and how much does it cost?

Solar panels make 'free' electricity but it needs storing. My pocket calculator thinks about 100,000 farads of capacitance would be suitable for domestic supply if charged to 1000V and discharged down to 250V. This is just my estimate, but what is the most efficient voltage to store the most kWh per cubic yard. Are capacitors a feasible technology for powering a car?

Last, I've read that the US Martian rover is thermo-electrically-powered heated using atomic power. In general, how good are thermo-electric devices.

T Scrase, Finchampstead, Berkshire

Matt Pulzer replies:

Interesting questions Mr Scrase. Ofgem, the government gas and electricity body reckons a typical household uses about 3300kWh of electricity a year, which is:

$E = 3300 \times 1000 \times 3600 = 11.8GJ = 1.18 \times 10^{10}J$ of electrical energy

A 100,000F capacitor charged to 1000V would store:

$E = \frac{1}{2}CV^2 = \frac{1}{2} \times 100{,}000 \times (1000)^2 = 50GJ = 5 \times 10^{10}J$ of electrical energy

So your proposed capacitor would be able to run a typical UK house for several years – not a PCB item I suspect! I don't think such a device is really feasible at the moment, but you wouldn't really need to store all that energy. Solar panel installations for the UK are rated for typical sunny/cloudy conditions and often lighting, heating and running computers, TVs and other semi-constant loads, use their output immediately. I suspect a more cost-effective solution would be to have capacitors that store a day or two of energy demand, maybe 100F. That is still a pretty big device. One further point, it is often better to export/sell excess energy to the grid and buy it back when you need power, rather than trying to store it.

High-storage capacitor technology has leapt forward in recent years, thanks in main to the demands of electric cars. So-called 'supercapacitors' and 'ultracapacitors' make use of graphene and nanotechnology to massively increase the equivalent area of capacitor plates. These are likely to be part of the future of energy storage, but they are currently very expensive.

Last, 'Curiosity', the current NASA Martian rover is powered by a radioisotope thermoelectric generator. The decay of plutonium produces heat, which is converted to electricity with thermocouples. Approximately 125W of electrical power is developed from 2kW of thermal power. This is used to charge lithium-ion batteries, which in turn drive the rover and all its instrumentation and computers. It's a clever system, with a life expectancy of 14 years, but really only cost-effective for ultra-high-price projects like Curiosity.

Mastermind mystery

Dear editor
I am trying to find on the Internet a copy of the Mastermind project by PF Turney described in *Practical Electronics*, Aug 1977 to Dec 1977. I can only find a basic description, but no details.

It might be that I have it in my huge pile of old electronics magazines, but I thought the Internet might be quicker. I remember being fascinated by the project in 1977, but never actually built it.

If I remember correctly it used rotary switches to enter the codes and two analogue meters to indicate the scores. (I was 16 in 1977).

Any ideas or advice please?

Kevin Dixon, by email

Alan Winstanley replies:

I vaguely remember that project. My archives for PE are quite sketchy, so I can't refer to the originals. There is no archive of PE magazines available online, so the only way would be to ask in our forum at **www.chatzones.co.uk** *and see if a reader can help. Some regular readers have very long memories and may be able to scan copies for you, for a small cost. Unfortunately, we can't offer that service ourselves, but we usually don't mind if readers help each other out by exchanging scans of very old projects on a strictly individual basis.*

It's likely that some parts may not be available, and these days the whole lot would be replaced by a PIC microcontroller, so I'm not sure how rewarding a constructional project it would be. Do check that all parts are available before commencing construction.

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

editorial@wimborne.co.uk

Mastering rotary encoders – Part 3

THIS month, we conclude our series of three articles on rotary encoders, which was in response to discussion on the topic on the *EPE Chat Zone*. ***Lincoln*** asked about a budget (65p from Alps) three-terminal rotary encoder to advance or retard counters in a PIC circuit. In his circuit, one of the encoder outputs interrupts the program and the interrupt then reads the other pin to see if the encoder has been turned forwards or backwards, which in turn raises an appropriate flag. He found that the counting was not always working the way he wanted; he tried software debouncing and adding capacitors, but felt that these solutions were not ideal. ***Lincoln*** also asked about the advantages of more expensive rotary encoders and if he needed to raise the clock speed of his PIC. A little later, ***atferrari*** asked if Schmitt triggers are required between an optical encoder and a microcontroller such as a PIC.

After a quick summary of what we covered previously we will look at some approaches to dealing with the non-ideal signals produced by rotary encoders, particularly as a result of switch bounce and electrical noise. In the first article we looked mainly at the encoders themselves. They convert angular mechanical position or movement into a digital code or sequence. They have a wide range of applications from industrial machinery and robotics to the low cost encoders which are frequency found in consumer equipment user interfaces. There are two types of rotary encoder – absolute and incremental. Absolute encoders output a specific digital code for a specific rotational position. Incremental encoders just indicate the direction and amount of movement. The cheap encoders are typically incremental encoders.

In the second article we looked in depth at incremental encoders and how to interpret the signals they produce. A typical system is shown in Fig.1; the encoder's outputs are conditioned to remove noise and switch bounce, and the 'pure' outputs are decoded to drive an up/down counter. The count value represents the current position of the encoder relative to the point when measurement started. Incremental encoders have two outputs which, due to the mechanical positioning of the switches or sensors driving them cannot change at the same time. If the encoder moves continuously and steadily in one direction the outputs are two square waves with a 90° phase shift (known as a quadrature signal, see Fig.2). Continuous movement in the reverse direction causes the square waves to be offset by 90° the other way.

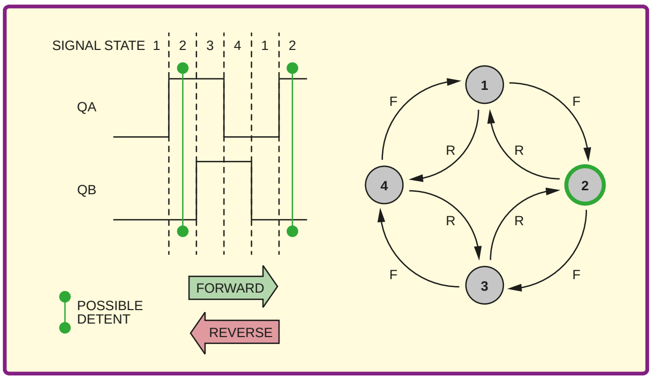

Fig.2. Quadrature signal states and the possible changes between them for forward/clockwise (F) and reverse/anticlockwise (R) movement of the encoder. There is a possible detent on the encoder corresponding with signal state 2n

Decoding

Decoding the quadrature signal can be approached in a couple of ways; either check the state of the other input when an input changes, or remember the previous two input values and compare these with the new values. We can label the four possible input values as states 1 to 4 and depict the possible changes on a diagram, (Fig.2). Each input state is shown as a circle and the possible changes indicated by arrows labelled F (forward) and R (reverse). The counter (in Fig.1) is incremented or decremented by the quadrature decoder when one of these state changes occurs.

As we saw last month, we can have different count resolutions so that for continuous movement in, say, the forward direction the counter increments by 1, 2 or 4 (referred to as ×1, ×2 and ×4 counting). This corresponds to counting on 2, 4 or all of the 8 transitions shown in Fig.2. In an ideal world the encoder would move smoothly with each movement corresponding to one or more complete loops around all four input states. To some extent, this is possible to arrange mechanically by using detents to force the encoder to rest at one input state only (state 2 as an example in Fig.2). Where this cannot be achieved, is not appropriate, or is not perfectly implemented we may get situations where the encoder comes to rest at the transition point of one of the sensors or switches. Any small mechanical vibration may trigger multiple switching resulting in a continuous pulse train, while the other input remains static.

Last month, we saw that this vibration scenario could lead to incorrect counting – continuous pulses on just one input cause continuous up or down counting, rather than a sequence of up, down, up down,... It is possible that Lincoln's software was implemented in this way, and that was at least part of the problem he experienced. The solution is for the quadrature decoder to remember the direction last moved so that the state it uses to interpret movement has 8 possible values (the four in Fig.2 for both forward and reverse directions).

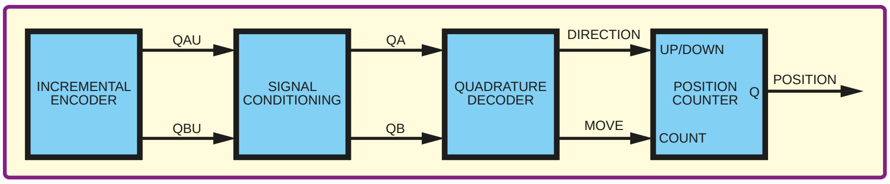

Fig.1. Simplified diagram showing signal flow in an incremental encoder position measurement system

Switch bounce

As we have mentioned several times, encoders using mechanical switches (rather than optical or other sensors) may be subject to switch bounce.

Most mechanical switches suffer from contact bounce (also called chatter) unless they have been designed to eliminate it. Mercury wetted contacts can be used for this, but the toxicity of mercury makes this undesirable. Switch bounce is exactly as the name suggests; when the contacts come together as the switch closes they bounce apart, just like a dropped ball bounces off the floor. The contact may bounce once, or several times. For most switches the bouncing lasts for a period in the order of several milliseconds. If, for example, we are just switching a light on and off the switch bounce will be unimportant – it will be too fast for us to notice. However, milliseconds is a relatively long time in terms of digital electronics, so any such circuits connected to a mechanical switch will definitely 'see' the bouncing.

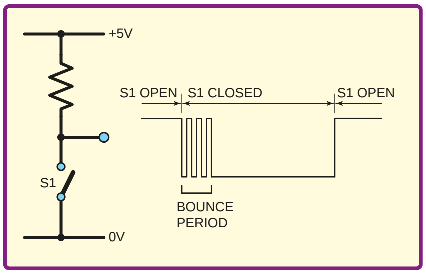

Fig.3. Signal from a bouncing switch

Figure 3 shows a typical signal from a bouncing switch and pull-up resistor – the type of switch arrangement that we might use when connecting a switch to a digital circuit. Whether or not the bounce matters depends on how the circuit responds to the bounce. If, for example, we connect the circuit in Fig.3 directly to the clock input of a counter it will count each bounce rather than each switch press.

In the case of a rotary encoder, switch bounce will look similar to the vibration condition we discussed last month. There will be a series of pulses on one input, while the other input remains static. As we explained then, an incompletely implemented quadrature decoding may cause an incorrect multiple of counts up or down, with inputs of this form. This could happen, for example, if the decoding relies on detents to ensure movement causes a complete input state. Even with full decoding the count value may go up and down several times as a result of key bounce, and this may cause undesirable system behaviour.

The classic circuit to overcome switch bounce (to 'debounce' the switch) is shown in Fig.4. This uses a changeover (or SPDT) switch and an RS flip-flop. When the switch is thrown, the first make on either contact sets or resets the RS flip-flop. The flip-flop holds its state while the switch bounces. Multiple applications of set or reset due to the switch bouncing do not change the flip-flop output. The switch has to be switched back to the other contact to achieve this (the switch does not bounce all the way between contacts, just on an off each contact).

The RS debounce circuit requires a changeover switch. Unfortunately, the switches used in rotary encoders are single pole, so this approach cannot be used. For a single-pole switch, as shown in Fig.3, the signal due to a bouncing switch is a series of pulses and is logically no different from a legitimate series of pulses. The only way to distinguish between them is in terms of their timing. Switch bounces typically last from units to tens of milliseconds (the bounce period in Fig.3), but the time varies depending on the type of switch, so manufacturer's data should be consulted when it is of concern. For human-actuated switches, including those inside rotary encoders, intervals between real switching will be much longer than bounce pulses and hence possible to distinguish.

Debouncing encoders

For the rotary encoders used in user interfaces the bounce time is typically around 3 to 5ms, but again manufacturer's data should be consulted when implementing debounce. The period implies a limit to the rotational speed. For example, if the bounce is 5ms, on an encoder with 24 pulses (per channel) per 360°, the rotation speed must be less than about two revolutions per second (120rpm). Each pulse on a channel occurs once per the state cycle shown in Fig.2. During this cycle, there are four switch actions and for correct operation we can assume the bounce must finish before the next switch activates. This argument implies a minimum time of 5ms × 4 × 24= 0.48s per revolution, but this is a limit and actual speed must be a bit slower than this. Typical speed specifications of user interface rotary encoders are in the 60 to 120rpm range.

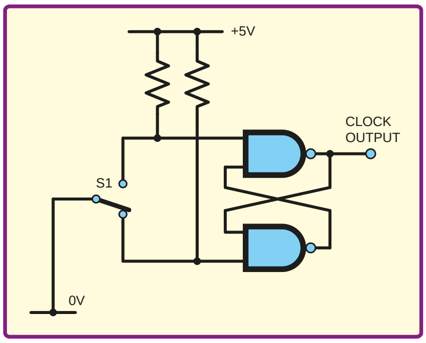

Fig.4. Classic RS flip-flop debounce circuit

Although the circuit in Fig.4 is of no use to us here, there are several other ways to solve the bounce problem, using analogue, digital or software approaches. The analogue method is simply to add a capacitor across the switch, with a series resistor if required, to create an RC filter to suppress the bounce pulses. The much slower genuine pulses will be much longer than the RC time constant, allowing full transition of the switched voltage to occur. We can illustrate this with an LTSpice simulation.

Fig.5 shows the LTSpice schematic in which we have two switches S1

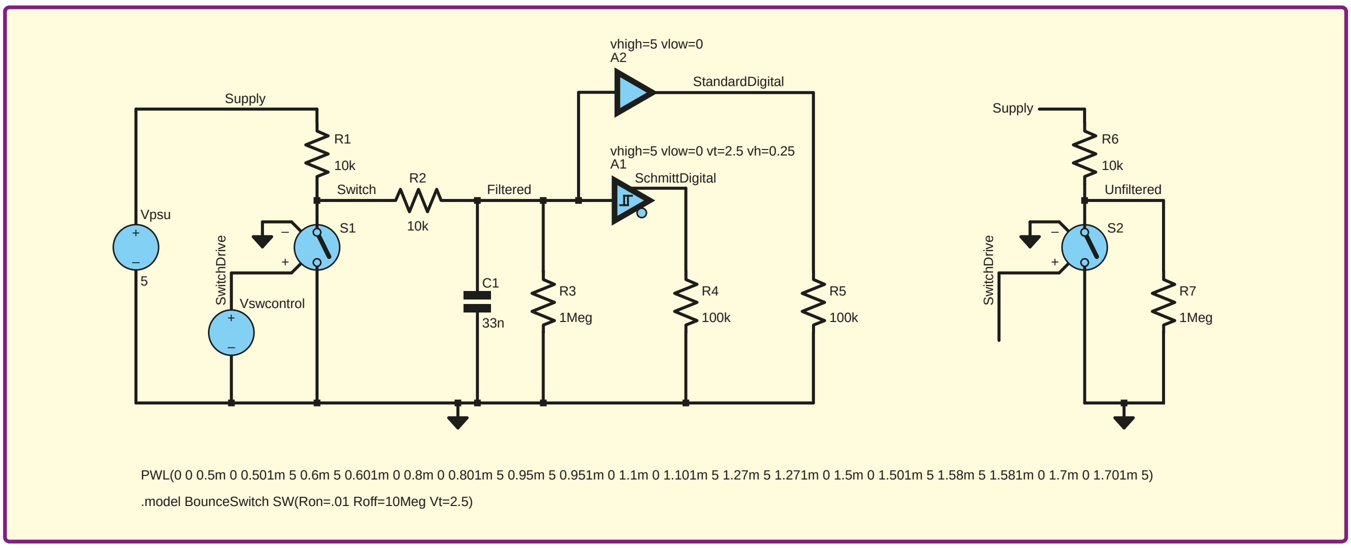

Fig.5. LTSpice simulation schematic for investigating analogue filtering of switch bounce

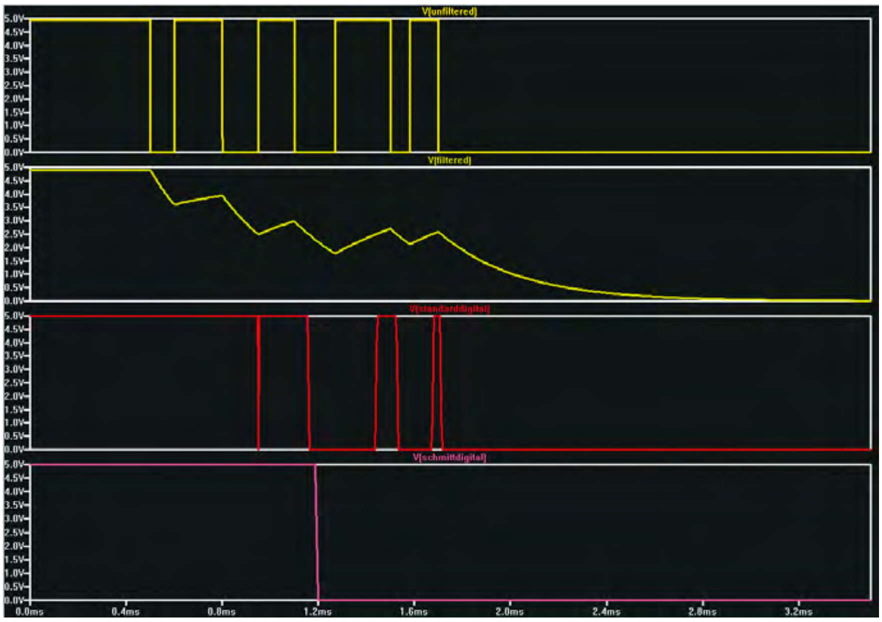

Fig.6. Waveforms obtained from simulation schematic shown in Fig.5

and S2 implemented using voltage controlled switch elements. The signal from S1 is filtered by C1 and R2 to remove bounce, but S2 is unfiltered and is basically the same as Fig.3. The points at which switching occurs are controlled using a pulse voltage source, Vswcontrol, for which the pulses are defined using a piecewise linear waveform definition. Waveforms from the simulation are shown in Fig.6.

The top trace (yellow) shows the unfiltered switching. S2 starts in the off position, so the signal is pulled high (5V) by the pull-up resistor. The switch is switched on at around 0.5ms, at which point it starts bouncing. It bounces off four times. The bouncing lasts for about 1.2ms and so the output signal finally settles to 0V at around 1.7ms. The switch with the filter (S1) is switched and bounces in exactly the same way as S2. The filter produces the waveform shown on the second trace (green). The voltage follows a general downwards trend, but rises again at each bounce point. This waveform is not a good one to put directly into a digital circuit. This is illustrated by the third trace (red), which shows the result of putting the filtered signal into a 'standard' logic gate. The reversals of direction of the filtered signal cause the logic gate to switch several times – the bounce still affects its output, in spite of the filtering.

Schmitt trigger debouncing

The solution is to use a Schmitt trigger gate, as illustrated in the fourth trace (magenta). A Schmitt trigger has two switching thresholds; when one threshold is crossed, the output changes *and* the threshold changes too. This means that the input has to move back by more than just the original threshold to reverse the gate's output state. As the filtered waveform decreases, it eventually crosses the Schmitt trigger's lower threshold and its output changes. The small increase in voltage caused by the next bounce pulse is, however, not sufficient to take the input over the higher upper threshold which is requited to make the output switch back. The filtered waveform in the second trace is converted to a clean digital signal by the Schmitt trigger.

This simulation uses very simple models for the digital gates and somewhat arbitrary bounce characteristics and component values, but it illustrates the process of bounce filtering and use of a Schmitt trigger to produce a clean digital signal.

In the *Chat Zone* discussion ***atferrari*** asked if Schmitt triggers are required with optical encoders. The answer is probably not. Optical encoders do not bounce, so filtering for this is not required. However, if the signals change more slowly than standard digital signals, or if they are noisy, then Schmitt triggers may be useful. Some microcontrollers (including some PICs) have Schmitt trigger inputs, so external devices may not be needed.

A digital approach to bounce elimination is shown in Fig.7. This is the circuitry used in each channel of the MC14490 hex contact bounce eliminator from On Semiconductor (**www.onsemi.com**). The pin-out is shown in Fig.8. The MC14490 is able to eliminate bounce from a single pole switch, such as that shown in Fig.3 and is suitable for use with rotary encoders. The circuit works by ingnoring input changes until the change has been sustained consistently for at least four of its clock cycles. First consider a bounce-free input to the circuit in Fig.7. Assume the input has been 1 for a long time (switch open). All the bits in the shift register will but 1, as will be the output. Since both the output and input are 1, the two inputs to the XOR gate are equal, so it outputs a zero. Thus the shift register executes a parallel load of the output value (1) and consequently stays at 1.

If the switch is closed and does not bounce the input will change to 0 and stay there. Initially, the output will still be 1 at this by virtual of the memory of the shift register and delay circuit. The inputs to the XOR gate are now different, so it will output a 1, causing the shift register to shift. Thus zeros will start to shift through the register. After four shift register clocks and the additional delay the zero will reach the output, and the input and output will be equal again. The XOR output will return to 1 and the shift register will start parallel loading zeros.

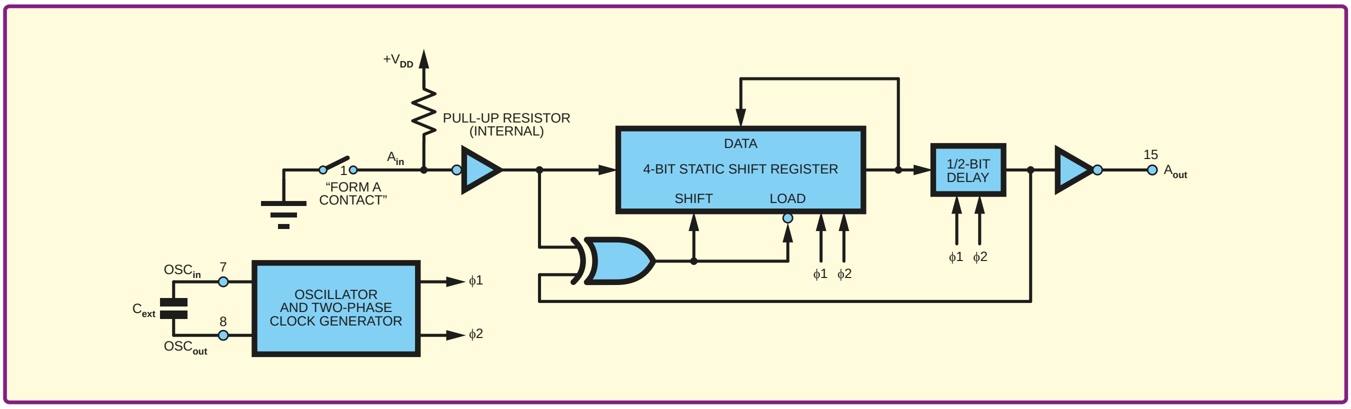

Fig.7. Bounce elimination circuit using the MC14490 from On Semiconductor (**www.onsemi.com**)

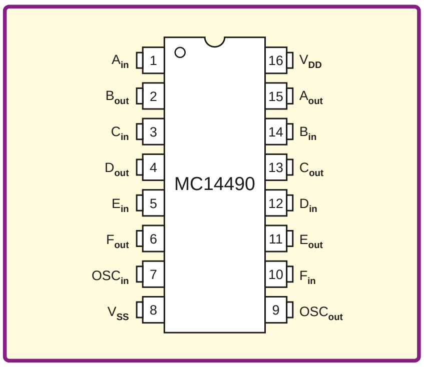

Fig.8. MC14490 pin out

Now consider a switch to zero with bounce. This will cause an occasional 1 to occur at the input, as the switch bounces, at which point the XOR input will return to 1 before the 0 has propagated through to the output. This will switch the shift register back to load mode while its output is still 1. Thus the whole shift register will return to the all-1s state it was in while the input was sitting at one. The output will only change to 0 once the circuit has sampled four successive zeros. Thus, if the bounce time is known, the clock rate of the MC14490 can be set so that one clock period is one quarter of the bounce period. The clock rate is set by a capacitor (C_{ext}), refer to the datasheet for details.

Software implementation

Switch debounce can also be implemented in software, if, as ***Lincoln*** describes, the quadrature decoding is being performed in software on a microcontroller. Typically, changes on the quadrature inputs will be used to trigger interrupts. Assuming the software has stored the previous input state and direction it will be able to track the movement by comparing this with the new value when each interrupt occurs, interpreting the changes (for example) in terms of Fig.2, or the eight-state approach discussed last month.

A very simple way to deal with switch bounce in software is to enter a delay loop for a time slightly longer than the bounce time after each interrupt occurs. Except in a very simple system, this is not a good idea because it is very wasteful of the microcontroller's resources. This approach is an example of blocking code – activity is blocked until a condition is met. It is also not a good idea because execution should usually remain within an interrupt service routine for as little time as possible.

A better approach is as follows. When the input interrupt occurs, trigger a hardware timer set to time for the bounce period, disable the input interrupt, and leave the interrupt service routine. When the timer finishes, it causes another interrupt, at which point there is no risk of bounce. The input interrupt is enabled again ready for the next signal change and the quadrature decoding and counting can take place. While the timer is running the processor is free to continue with other tasks.

Another problem which rotary encoder systems may need to deal with is noise spikes or glitches on the input. Such problems are likely in systems containing inductive loads such as motors, but could also occur in other contexts. If these get interpreted as movement signals from the encoder, the system will not correctly track the encoder's movement. Unlike switch bounce, noise spikes will affect optical as well as mechanical encoder-based systems. The usual solution is to use a simple digital filter to remove input pulses shorter than a given duration. If the characteristics of the encoder and movement are known, the shortest duration legitimate pulse can be determined and a filter configured to reject shorter pulses. A typical filter is shown in Fig.9. This is taken from the HCTL-2xxx series of quadrature decoder/counter interface ICs from Avago Technologies (**www.avagotech.com**). Pulses have to be at least three clock cycles long to produce a 1 from one of the AND gates and change the output state held by the JK flip-flop.

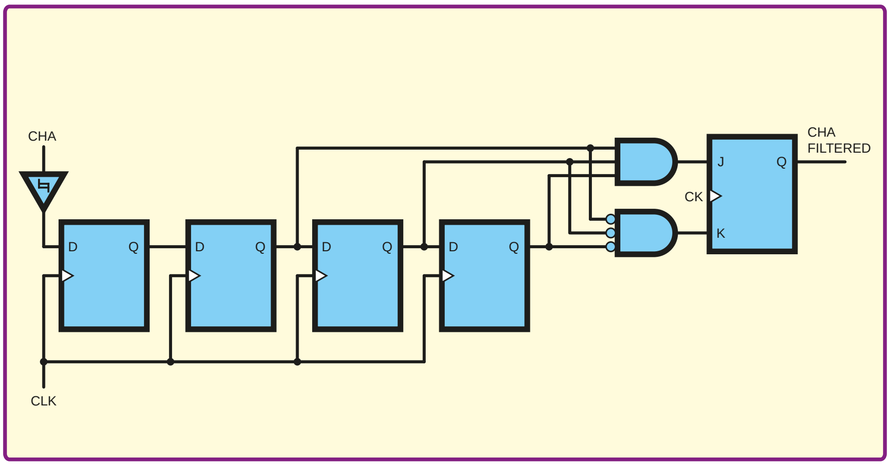

Fig.9. Digital filter for removing noise spikes from encoder signals (from HCTL-2xxx, Avago Technologies, ***www.avagotech.com****)*

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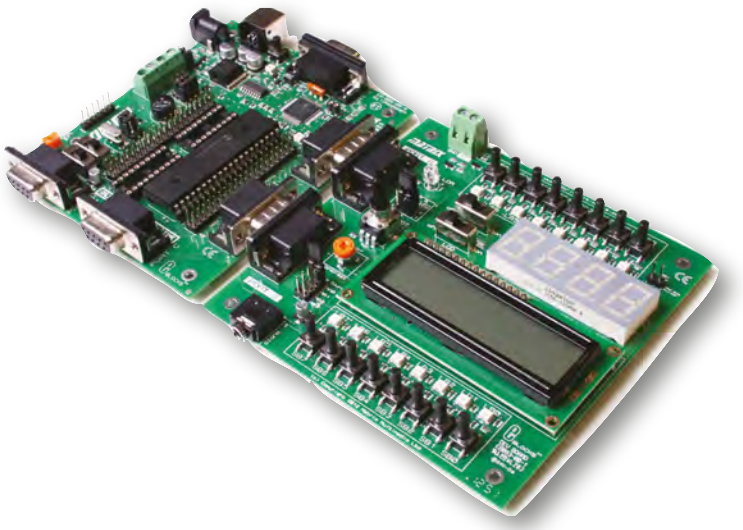

£167 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

ASSEMBLY FOR PICmicro V4

(Formerly PICtutor)

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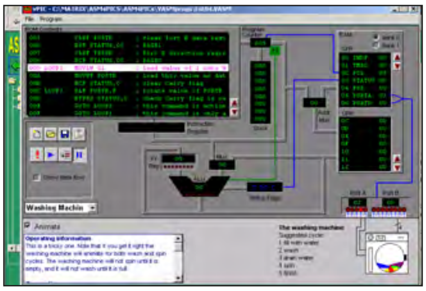
The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens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



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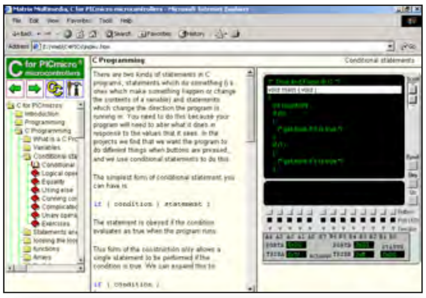

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6 (see opposite page)

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

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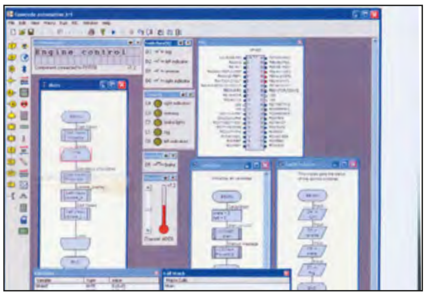

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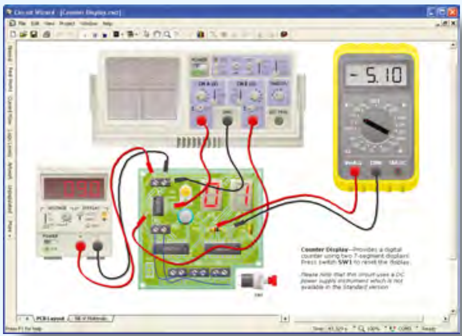

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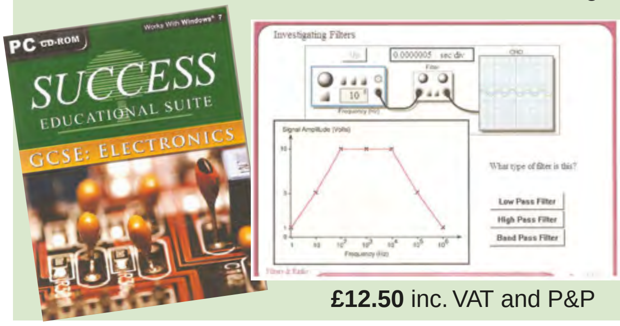

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NET WORK

by Alan Winstanley

Apped Out

MODERN smartphones are becoming more powerful all the time, and the current generation of 'featurephones' does a good job of unshackling users from their desktop or laptop computers. Last month, I looked at a typical smartphone, the HTC One which runs Google's Android operating system. In no time at all I could hook it to Wi-Fi, check email, surf the web and scan QR codes. I could pair it to my Smart TV to watch YouTube videos that were searched, selected and queued on the phone's superior YouTube app.

There is a surfeit of Android apps and many of them are free to download. The most popular games, for example, are the highly addictive *Candy Crush* which has hooked even the most die-hard cynic, and, of course, *Angry Birds*. Many such games are initially free because they carry discrete adverts, or once you're engrossed they generate sales revenue by selling 'power-ups' and add-ons. Some apps have adverts placed very close to the phone's Home key, for instance, so that you virtually cannot avoid clicking through to an advertiser accidentally at one time or another. Whether this generates further revenue is a moot point.

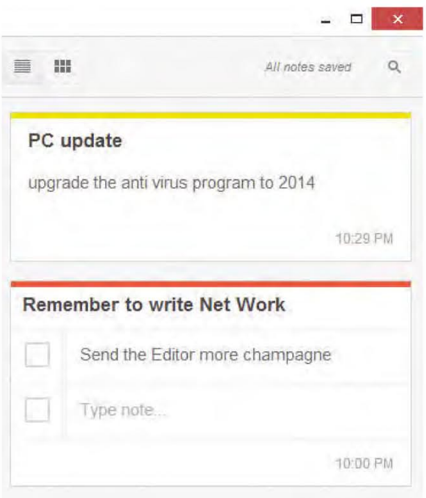
All sorts of other apps, utilities and games are available on Play Store, but most that I tried were soon uninstalled again. In due course I hope to highlight some useful Android apps, and if readers have a favourite suggestion of their own then I'll be happy to share it on this page. One such example is **IP Webcam**, which converts your Android phone into a static Wi-Fi webcam (say, for security or baby-minding purposes?). After installing it on your mobile device, simply start the server to begin video streaming; then log into a web browser at the private IP address supplied. You can toggle the camera LED to illuminate the area. You may have to experiment with different web browsers, but IP Webcam worked successfully in some trials over my LAN.

As you would expect with an Android phone, the phone arrives stuffed with various Google apps that offer one-click access to **Gmail**, **Google Search**, **Google+**, **Google Hangouts**, **Maps** and **Voice Search**. Not all of these apps may be familiar, so this month I'll outline some core Google apps and you can then decide whether they are worth investigating in more depth.

Google for the nonplussed

Many people use Facebook, the ubiquitous social site that connects friends with each other and allows us to publish our thoughts, photos or communicate with others (or friends of friends). While attending a conference recently I used the hotel's Wi-Fi to 'Check In' via Facebook so that close friends knew where I was; Facebook posted a Google Map of my location on my Facebook page.

Google+ is slightly different from Facebook; Google claims to know your 'interests' (things you have searched for, or websites you have looked at) and Google+ is intended to benefit 'content curators' or 'information networkers' – the web sector that farms content producers' information out to the consumers of such information. Their rationale is a bit convoluted, but Google+ defines itself not as a social network that simply joins the dots between friends like Facebook does, but as a service for sharing our 'interests' with other users who also share the same interests.



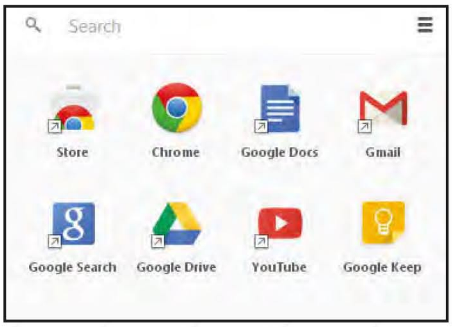
Google Keep is a task-management tool that's simple to use and stores notes in the cloud: access them from almost anywhere

In my case, Google+ suggested some contacts including the Dalai Lama, Richard Branson and scores more that I hadn't heard of; if they don't appeal to you then you can follow NASA or any number of other Google+ sites instead, and join Communities as well. Google+ helps you share interests in the first instance, and the differences and similarities between Google+ and Facebook become apparent with use.

Google Hangouts is an Android, PC and Apple group messaging and chat program that also allows video calls. Skype users who 'chat' and add emoticons to messages, or those who remember ICQ, might see some similarity. You can share a video call with up to ten friends at a time. **Hangout On Air** can be streamed publically on your YouTube channel or even your website, and you can schedule to receive forthcoming On Air broadcasts. You can also 'like' or follow those who interest you, such as a musician and see what they're saying.

If you're anything like me, your working life (and all the books and magazines that clutter it) is probably littered with blizzards of 3M Post-It Notes (including the Windows software version that I still use). The net-centric of us could use Google Keep to replace those torrents of tacky notelets dotted all around. **Google Keep** is a task management utility that is more than a sticky notes app. Its main benefit is that notes are stored in the cloud on Google Drive (**drive.google.com/keep**) and they can therefore be accessed from any suitable connected device. You can also embed photos, reminders and locations into notes. Keep has a minimalist and undemanding appearance and is simple to use, but to help organise notes you can colour-code them, and on an Android phone you can also dictate written notes which will be transcribed. Keep installs direct from the Google Play store, so give it a try.

For PC users wishing to use Google Keep, help is at hand in the form of the Google Chrome web browser, which has the capability to run extensions. (See **https://chrome.google.com/webstore/category/extensions**) Simply log into the Google Chrome Webstore with your Google account, then install the Google Keep extension for this increasingly versatile web browser. You can then type notes into Keep that will be stored in the same account. You might type a shopping list, for example, that you could then tag with a location and view it on your Android phone. A Chrome App Launcher will be installed on your PC desktop and if you have multiple Google accounts then you can swap your app user logins here.



Google Chrome App Launcher for PC offers one-click access to Google apps

May the Voice be with you

In last month's *Net Work* I mentioned how I found a city restaurant using Google search: I dictated a search term into my mobile phone and Google's voice recognition system transcribed it into searchable text and responded with a map, suggestions, locations and reviews. Desktop PC users now can experience Voice Search for themselves using Google Chrome. When Google's search webpage opens in Chrome, you might notice a discrete microphone icon in the search box (screenshot). If your PC is equipped with a microphone (my Logitech USB webcam has a built-in mic) then you can try Voice Search by clicking the mic symbol and speaking your search query. Google will transcribe your voice into text and proceed to pull in some results; not only that, but sometimes a speech engine will speak the results directly back to you!

Google Voice is a very appealing aspect of the search engine which I'm using more and more for quick searches: gone at a stroke is much onerous typing, mis-spelling and trawling of Google search phrases; instead, you just talk and see what the results are. It generally does a remarkably good job of accurately identifying the context of terms or placenames and correctly transcribing them: you can test this by speaking 'define cccp' or 'what is SQL' and the Google-bot will respond. Try it as a spellchecker too: say 'spell incorrigible' and if you're lucky the website will reply with a human-like voice (sort of). It's a listening and talking calculator, too. Much of the time, though, you'll just see a traditional Google listing of search results to trawl through. Voice Search adds another dimension to desktop search and is a valuable tool in the serious surfer's weaponry.

Other Google apps that may have slipped into an Android phone unnoticed include Play Books, Play Music, Play Magazines and Play Movies & TV. To learn more about them, simply ask Voice Search and direct web links will be shown instantly in your Chrome browser. Also on the horizon is Google Helpouts, offering personal support via live video in real time, for a fee. It's early days yet but you can check **https://helpouts.google.com/welcome** in the meantime.

The Google Chrome web browser has voice search – click the mic icon and speak a search query into your microphone

Most Google services require a login, but having accumulated a variety of Google logins and Gmail addresses for Adsense, Adwords, Chrome webstore, Webmaster tools etc, over time it can become confusing when trying to log into an increasing number of Google apps, so it's best to keep life simple in that respect and streamline your logins as much as possible.

A modern Android phone can also utilise your home network's storage drive. My Synology NAS drive hosts data backups as well as music and digital TV, and the media server can be accessed via the phone's Music player app. The phone could stream music from the NAS to a Smart TV, and any available music CD cover artwork can also be displayed on-screen. To get the most out of playing music over a home network, it's best to organise your music collection data so that music tracks, albums and artists appear consistently in the player.

This NAS consumes under 20W, which is less than a lightbulb, and 8W in hibernation, so it's economical to run (to prove the power of Google Voice Search I spoke 'power consumption of a Synology network attached server' into Chrome, and after being correctly transcribed, the relevant web page appeared instantly).

Video can also be streamed from the NAS direct to a Smart TV and a wide range of archived video and documentaries in MPEG format is always on tap; a current specification personal video recorder (PVR) such as the Humax HDR Fox-T2 is network ready and can access network storage as well.

Network blues

Not everything about the Android handset has been plain sailing however. Using Bluetooth can be a problem and pairing it with an older sat nav system that uses older-standard Bluetooth standards was not possible. In particular, trying to use the Android phone to download traffic data to feed an older TomTom sat nav was unsuccessful. Hunting around the web, the BlueDUN (dial-up networking) app was suggested as a way of emulating a modem to enable data to be transferred from a network to a Bluetooth device. Unfortunately, although the BlueDUN app looked very promising it would not run consistently with the author's HTC One and his older TomTom sat nav.

At this stage, it's worth remembering that very many low-price apps originate from small developers or individuals who offer free trials and cheerful levels of support, so don't expect blue-chip levels of service and ensure you take full advantage of any trial periods. Quite often the cost is trivial compared with the personal time that is invested in testing a cheap app, and I never cease to be amazed by those who will spend a day of their lives complaining about an app that only cost 79 pence, or those who will try to trash it with negative feedback!

A solution to the sat nav problem is, of course, to try Google Maps and a special 'Car' icon is included in the Android phone; it offers large easy-access buttons for the phone, navigation and music. An added benefit is that costly annual traffic data plans are avoided. Direct access to the Tunein Internet radio app is also included, offering the prospect of listening to Internet radio stations while on the move – if reception and your mobile data tariff will permit.

Next month, more home area network problems arise – can the HAN keep up with the traffic, and what other options apart from Wi-Fi are available? You can email the author at **alan@epemag.demon.co.uk**.

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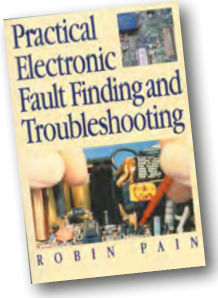

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Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. * **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevent project articles.

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
NOVEMBER '12		
Hearing Loop Level Meter	874	£9.53
RFID Security System	875	£7.75
Jump Start – Frost Alarm	876	£8.55
DECEMBER '12		
Hot Wire Cutter – Controller	877	£8.55
★ Universal USB Data Logger – Part 1 (double-sided)	878	£16.52
Jump Start – Mini Christmas Lights	879	£10.69
JANUARY '13		
Low-Capacitance Adaptor for DMMs	880	£8.55
★ 3-Input Stereo Audio Switcher – Main Board	881	
– Switch Board	882 } pair	£20.00
Stereo Compressor – Main Board	883	£12.63
Jump Start – iPod Speaker	884	£8.16
FEBRUARY '13		
10W LED Floodlight	885	£6.75
★ Crystal DAC (double-sided)	886	£18.46
Jump Start – Logic Probe	887	£6.42
MARCH '13		
Lightning Detector	888	£8.75
★ Digital Spirit Level	889	£8.75
★ SemTest – Part 2 – Main/Lower Board	890	£16.52
– Display/Upper Board	891	£15.55
Interplanetary Voice	892	£8.75
Jump Start – DC Motor Controller	893	£8.55
APRIL '13		
Six-Decade Resistance Substitution Box	894	£10.10
SoftStarter (single-sided)	895	£8.36
Jump Start – Egg Timer	896	£8.36
SemTest HV DC Crowbar	897	£13.61
MAY '13		
Electronic Stethoscope	898	£9.72
PIC/AVR Programming Adaptor Board (d'ble-sided)	899	£23.33
Jump Start – Signal Injector Probe	900	£8.16
JUNE '13		
USB Breakout Box	901	£7.97
Jump Start – Simple Radio Receiver	902	£8.94
Mix-It	903	£11.28
JULY '13		
6-Decade Capacitance Substitution Box	04106121	£18.00
6-Decade Capacitance Substitution Box Panel/Lid	04106122	£18.00
SoftStarter For Power Tools	10107121	£9.00
High-Current Adaptor For Scopes And DMMs	04108121	£18.00
Jump Start – Temperature Alarm	904	£7.97

PROJECT TITLE	ORDER CODE	COST
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Driveway Sentry	03107121	£18.00
Build A Vox	01207111	£22.00
Milliohm Meter Adaptor For DMMs	04102101	£18.00
SEPTEMBER '13		
MiniReg Adjustable Regulator	18112111	£6.00
USB Stereo Recording Interface	07106111	£18.00
Digital Sound Effects Module	09109121	£9.00
OCTOBER '13		
High-Temperature Thermometer/Thermostat	21105121	£22.00
LED Musicolour	16110121	£22.00
NOVEMBER '13		
Mains Timer For Fans Or Lights	10108121	£9.10
CLASSiC-D Amplifier (inc. 3 Rockby Capacitors)	01108121	£26.50
– Speaker Protector	01108122	£9.10
DECEMBER '13		
CLASSiC-D Amplifier – Power Supply	01109111	£16.66
USB Instrument Interface	24109121	£26.38
– Front Panel	24109122	£28.54

*** See NOTE above left regarding PCBs with eight digit codes ***

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**

PCB MASTERS

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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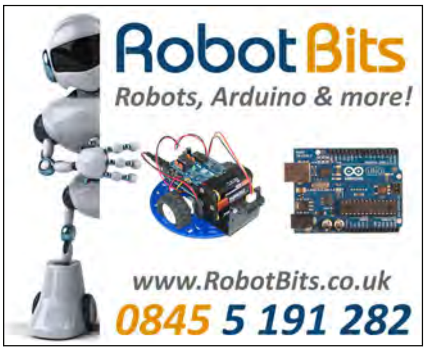

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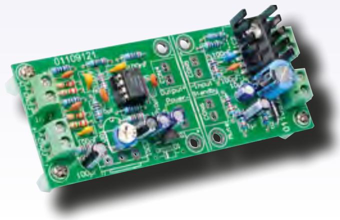
For editorial address and phone numbers see page 7

Next Month

Content may be subject to change

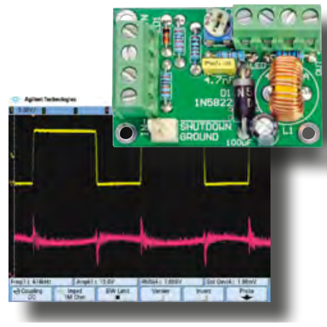
2.5GHz 12-digit frequency counter with add-on GPS accuracy

We are rightly proud of this high-resolution frequency counter. It covers a range from below 10Hz to over 2.5GHz and not only has an internal timebase, but also features an external timebase input which can accept 1Hz pulses from a GPS receiver. This means it achieves measurement accuracy approaching that of an atomic clock – and it doesn't cost a mint to build!



The Champion mini amp

Here's a superb new compact amplifier module that's easy and cheap to build. We've dubbed it the *Champion* because its performance is outstanding. In fact, our 'champ' can deliver up to 7W of peak power with a quality that will truly impress you.



Simple 1.5A Switching Regulator

This tiny regulator board outputs 1.2-20V from a higher voltage DC supply at currents up to 1.5A. It's small, efficient and cheap to build, with many handy features such as a very low drop-out voltage, little heat generation and electronic shut-down.

Teach-In 2014: Raspberry Pi – Part 4

Next month, *Teach-In 2014* will go analogue. Our *Pi Project* deals with the construction of a simple eight-channel analogue input board based on the Humble Pi. In *Python Quickstart* we will be taking a first look at the serial (SPI) interface with some sample code for temperature sensing and analogue data logging applications. For good measure, *Pi Class* will be introducing a variety of must-have software applications for the Raspberry Pi.

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