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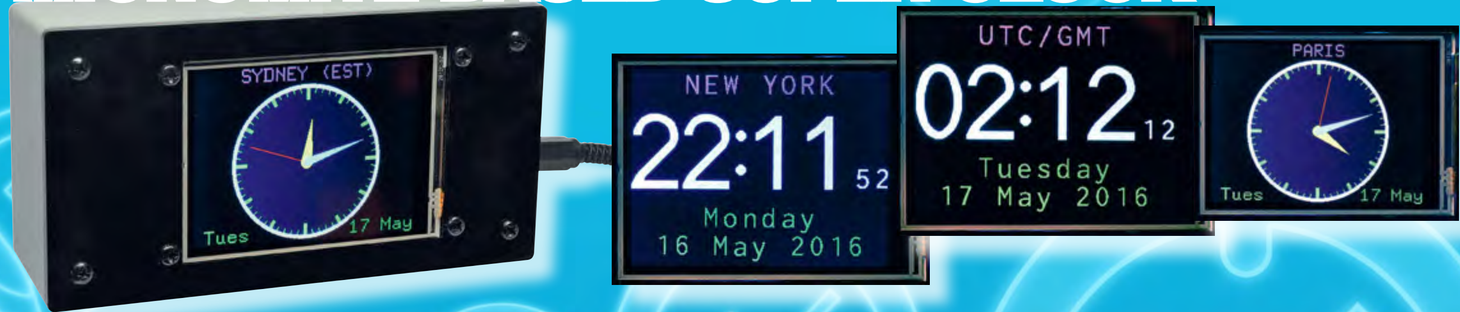


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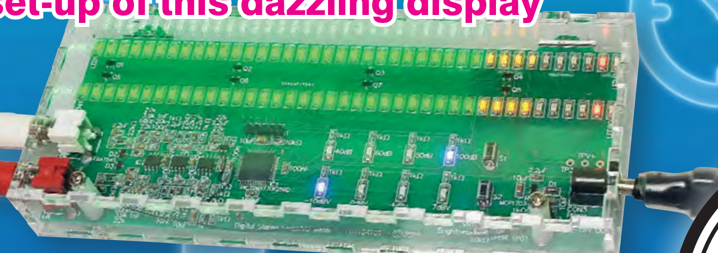

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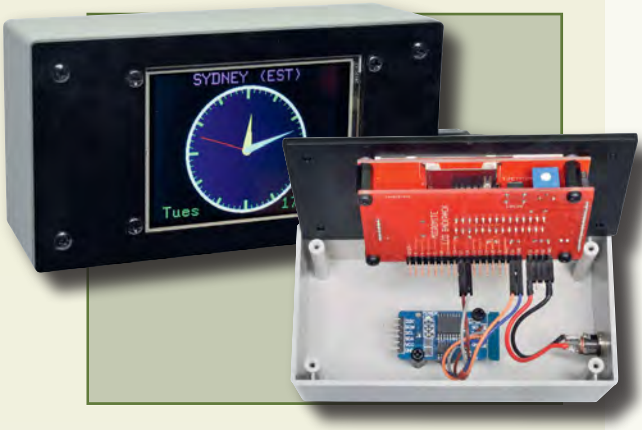


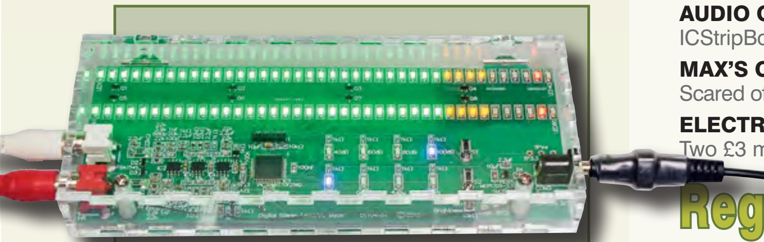


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*Our August 2017 issue will be published on Thursday 6 July 2017, see page 72 for details.*

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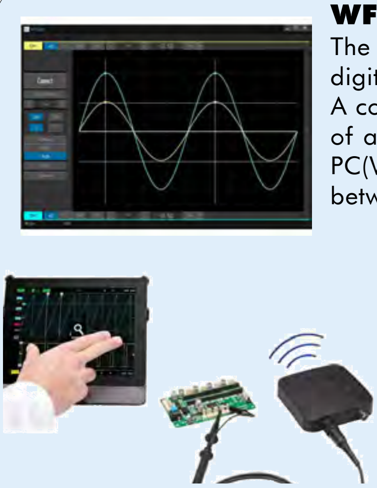

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- Signal markers / Hold function
- DVM readouts
- Li-ion rechargeable battery included (3.7V 1800mAh)
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- Timebase: 1μs to 1s/div
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- 40 Mega samples/sec in real time
- Bandwidth up to 10 MHz
- Full auto range option
- Signal markers for amplitude and time
- Memory hold function
- Direct audio power measurement
- Stylish OLED Display Quote: EPEHPS2

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0.01Hz to 2.4GHz
8 Digit LED Display
Gate Time: 100ms to 10s
2 Channel Operating mode
Power Supply: 110-220Vac 5W
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* 5 Memories
* PC Link via USB or RS232
*Output:
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0-5A

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Max Input voltage: 30Vpp
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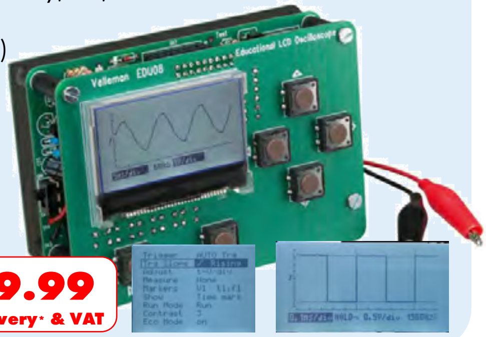
Dim: 80 x 115 x 40mm



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## Enjoying the micro:bit

We are now half-way through Mike Tooley's latest *Teach-In* series – a brief introduction to the BBC micro:bit. I must confess that with all the powerful and smart digital control options available – PICs, Raspberry Pi, Arduino and the Micromite – I had not given the micro:bit the attention it deserves. It really is a clever little device that is super easy to get up and running. That of course was part of its design brief as an educational device, and for relatively slow systems that need to be monitored and controlled it offers a perfectly good entry to microcontrollers.

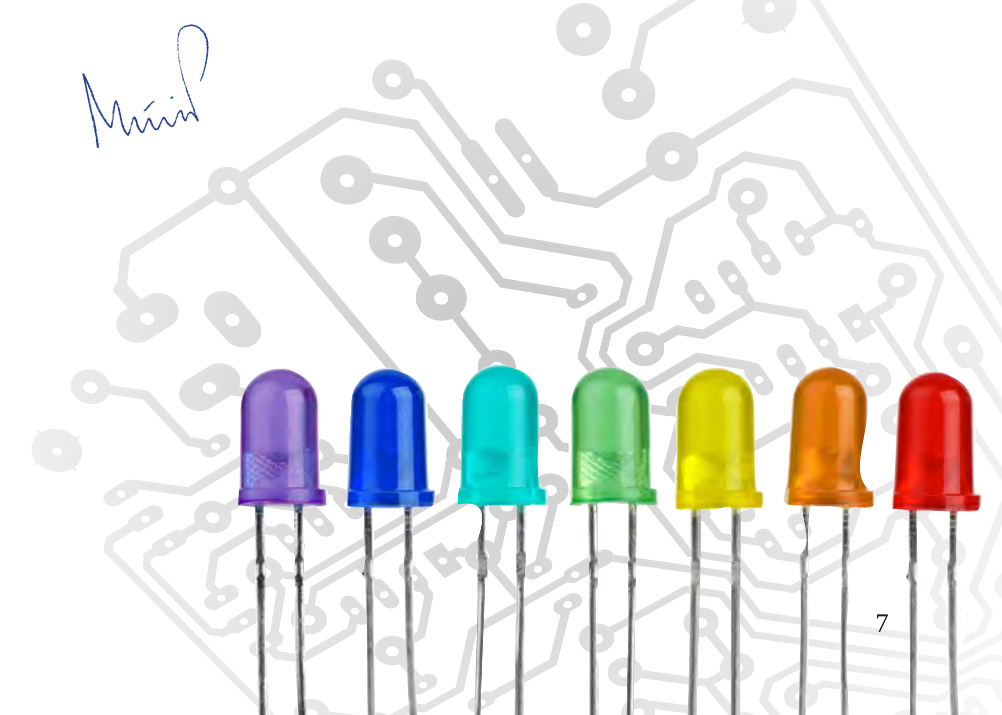
In the following two articles Mike will examine the micro:bit's analogue and communications capability, which enable the device to interface with both the 'real' world and other intelligent electronic systems. Lots to learn, look forward to and enjoy.

## VU meters

There is something pleasantly hypnotic about monitoring an audio amplifier's output on a pair of traditional moving coil VU (volume unit) meters, and I was pleased to note that in our hyper-digital world the recently revived Japanese Hi-Fi brand Technics has launched its new amplifiers with analogue not digital meters (see: **www.technics.com/uk**). Although analogue VU meters are very attractive, they do lack the flexibility of a well-designed digital meter. If you are in the market for adding some colourful bling to your latest Hi-Fi creation then we have just the project for you – a *100dB Stereo LED Audio Level/VU Meter*. The project, which started last month and concludes this month, includes some very handy features, such as adjustable dynamic range, reference level and LED brightness. Just the upgrade your amplifier undoubtedly deserves!

## Stay safe

Last, but definitely not least, the recent (as I write) ransomware attacks that struck the NHS and other large organisations worldwide are a stark reminder to be safe on the Internet. Others, especially *Net Work* author Alan Winstanley, can provide detailed authoritative advice on cybersecurity, but do remember that most of what you need to do is common sense. Keep your operating system and ant-virus software up to date; be careful not to click unthinkingly on every link that comes your way; never open email attachments that come from an unknown or suspect source; use password manager software and remember that legitimate organisations will never ask you for your passwords. Stay safe out there!



# NEWS

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

## Watching you, watching me – Berlin report *by Barry Fox*

The Museum of Photography in Berlin is currently staging an exhibition, Watching Me, Watching You, which chronicles the history of surveillance – from early religious warnings that God's eye sees all, through the installation of sound funnels in the walls of the Louvre by French queen Catherine de Medici (1519–1589) to snoop on conversations of conspirators, to the modern use of high-resolution drone cameras.

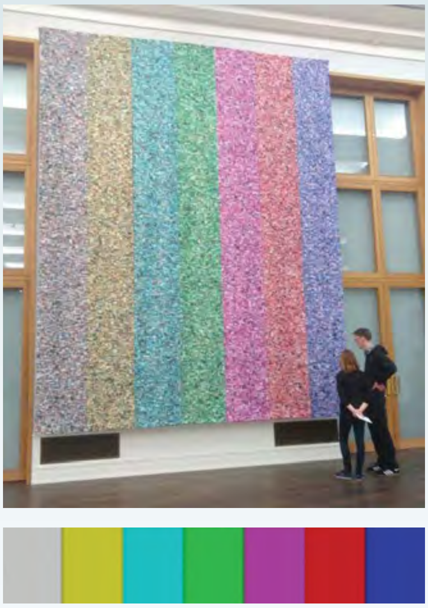
### Origins of modern snooping

Contemporary photos show how the military developed the sound funnel idea for locating planes in the pre-radar 1920s and 1930s. Systems consisted of pairs or quadrants of huge horns connected to stethoscope headphones by acoustic tubing.

The East German Stasi police took audio and photo surveillance to new heights, with a 1960 film camera so small that it could be concealed inside a cigarette lighter, and a system for automatically photographing post boxes with a telephoto lens to identify anyone who had posted a subversive letter. The Stasi also invested heavily in Polaroid cameras so that agents could take detailed photos of a home before searching it; so an untidy drawer or unmade bed looked exactly as it did before it had been gone through with a fine toothed comb.

The availability of digital cameras has made this technique far easier to employ. Until stopped under the Obama administration, the New York Police Department's Demographic/Zone Assessment Unit was monitoring the movement of Muslims living and working in the city.

One of the most most striking exhibits comes from Hasan Elahi, a mixed-race American who was wrongly suspected by the FBI of terrorist activities and placed under surveillance. Elahi responded by taking digital photograph of every movement he made, in the street, around the house, in bathrooms and bedrooms, at home or when travelling, along with date, time and place metadata. Every week for the last 12 years he has sent the FBI many hundreds of these images. The total currently stands at 70,000 pictures.



*(Top) Hasan Elahi's 30,000 pictures that document his movements over 12 year arranged in stripes to conform to the colour bars of the standard SMPTE TV test pattern (bottom).*

For the Berlin exhibition he has collated 32,000 of these images, to construct a mural which groups the images in vertical stripes based on their predominant colour. The stripes conform to the colour bars of the standard SMPTE TV test pattern.

When I took a photo, I was told by a museum guard that no pictures of the surveillance exhibition were permitted – the irony escaped him.

### World War II bunkers

Across the city an organisation called the Berlin Underworld is now offering tours of recently discovered World War II underground bunkers and above-ground forts. Highlights include rabbit warrens of hidden rooms at some of the city's underground train stations. Air-lock doors, supposedly to protect against gas attack, were actually only cosmetic. For breathable air, the sealed shelters relied on shafts down to the underground train tracks, with the trains acting as piston pumps. If there had been a gas attack, the poison would have mixed with the air; but during raids the trains stopped running, so no air was pumped – but breathed-out carbon dioxide rose to poison levels.

In the pre-fax 1920s a pneumatic post system could send written messages across Berlin in minutes. This became a key comms system in WWII and was still being used in the city until the 1970s.

One of the underground shelter walls was painted with glow-in-the-dark phosphorescent paint. So the unfortunates packed inside during an air raid could still find their way to an Exit if the power was cut.

The original glow paint, applied in the 1940s, still retains some of its ability to store energy when illuminated and release it as light for up to 15 minutes in the subterranean darkness. Although this energy-efficient emergency lighting technique could appeal to modern architects, it cannot now be used in residential buildings because the world is more aware of the health risks in using chemicals such as zinc sulphide on walls that people may touch before eating with their fingers. In the war years this was a very secondary consideration.

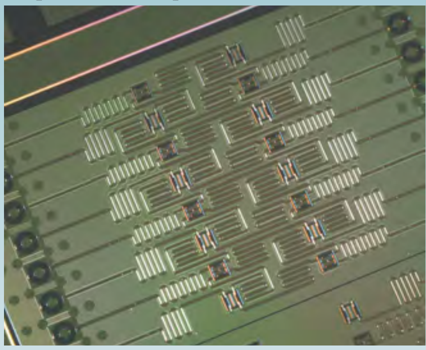
## IBM's most powerful universal quantum processors

IBM has announced two new powerful universal quantum computing processors. The first will be available for use by developers, researchers, and programmers to explore quantum computing using a real quantum processor – at no cost – via the IBM Cloud. The second is a new prototype of a commercial processor, which will be the core of the first IBM Q early-access commercial systems. IBM Q is an initiative to build commercially available universal quantum computing systems for business and science applications, delivered via the IBM Cloud platform.

The two IBM's devices are a 16- and 17-qubit processor. The 16-qubit processor allows more complex experimentation than the previously available 5-qubit processor. It is freely accessible to run quantum algorithms, enable work with individual quantum bits, and to explore tutorials and simulations.

The 17-qubit device is the most powerful quantum processor created to date by IBM and has been chosen to be the basis for the IBM Q early-access commercial systems.

'The significant engineering improvements announced will allow IBM to scale future processors to include 50 or more qubits, and demonstrate computational capabilities beyond today's classical computing systems,' said Arvind Krishna, senior vice president and director of IBM



*16-qubit processor, available for use by developers, researchers, and programmers to explore quantum computing using a real quantum processor via the IBM Cloud.*

Research and Hybrid Cloud. 'These powerful upgrades to our quantum systems, delivered via the IBM Cloud, allow us to imagine new applications and new frontiers for discovery that are virtually unattainable using classical computers alone.'

Future applications of quantum computing may include:

- Business optimisation – improved solutions to problems found in supply chains, logistics, financial data modelling and risk analysis
- Materials and chemistry – untangling the complexity of molecular and chemical interactions to discover new materials and medicines
- Artificial intelligence – making facets of AI such as machine learning much more powerful
- Cloud security – using quantum physics to enhance the security of private data in the cloud.

## Google uses Raspberry Pi for DIY AI

Google has launched 'AIY Projects', describing it as a route for constructors to do-it-yourself artificial intelligence or (artificial intelligence yourself, hence 'AIY').

The aim is for constructors to use artificial intelligence to make human-to-machine interaction more like human-to-human interactions. Google will be releasing a series of reference kits, starting with voice recognition. The speech recognition capability could be used to:

- Replace physical buttons and digital displays on household appliances and consumer electronics – imagine a coffee machine with no buttons or screen; you just talk to it
- Replace smartphone apps to control devices on connected devices such as a connected light bulb or thermostat – just talk to them
- Add voice recognition to assistive robotics (eg, for accessibility)

The kit includes a voice 'Hardware

*Google's AIY voice recognition kit*

Accessory on Top' (HAT) that contains hardware for audio capture and playback; easy-to-use connectors for the dual mic daughter board and speaker; GPIO pins to connect low-voltage components like micro-servos and sensors; and an optional barrel connector for dedicated power supply. It was designed and tested with the Raspberry Pi 3 Model B.

The AI kit ships to subscribers of the *Raspberry Pi Magazine*, and will be on sale in the UK in WHSmith, Tesco and Sainsburys.

## IoT Power Calculator

Electronic component and equipment distributor Farnell has created an IoT Power Calculator that helps developers of IoT (Internet of Things) projects understand the expected battery life of their IoT devices, and allows them to experiment with different components and software algorithms to determine their impact on battery life.

Battery power is in increasing demand in IoT applications incorporating sensor systems that collect data and pass the information to the cloud. Unlike many larger connected systems, these relatively small devices often do not have access to mains power. This means that they must have a means of powering themselves, something that is achieved using either batteries or energy harvesting.

Although an increasing number of applications can now be developed at the ultra-low power levels required for energy harvesting, many more are not suitable for this approach, and in such cases batteries are needed.

The calculator is easy to use and very quick to produce a result. Users enter basic parameters about their hardware – including different types of microcontroller and batteries – and their software (how frequently the software wakes, and how many cycles the data capture/processing and communications operations require) and the calculator uses these inputs to work out the power consumption.

See: **http://uk.farnell.com/calculating-battery-life-in-iot-applications**

## Launch of Lorenz book

The fascinating autobiography by the late Capt Jerry Roberts has been launched at The National Museum of Computing. The book tells the story of the breaking of Hitler's most secret cipher.

The 'unbreakable' Lorenz cipher encrypted communications between Hitler and his high command. Far more complex than Enigma, Lorenz-encoded messages carried the most valuable strategic information.

Roberts' book gives an in-depth personal perspective of the breaking of the twelve-wheeled Lorenz cipher. One of the great intellectual achievements of the war, the Bletchley team assigned to crack Lorenz worked out how the machine operated without ever having seen it.

*Lorenz: Breaking Hitler's Top Secret code at Bletchley Park* by Jerry Roberts, The History Press, £20 (hardback), ISBN-13: 978-0750978859

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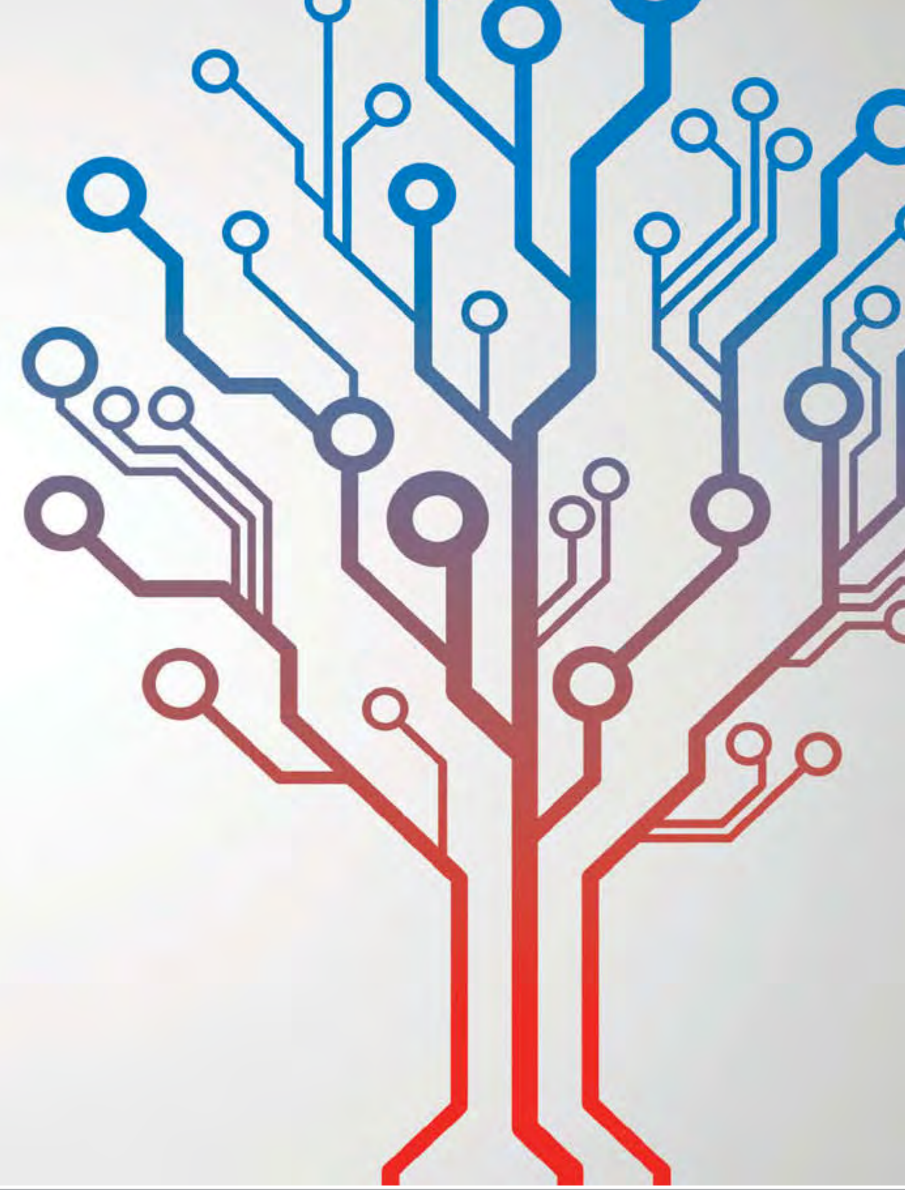

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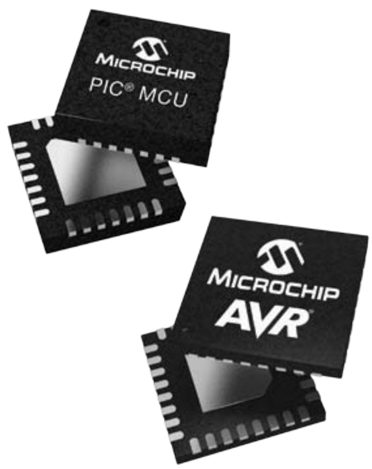


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# Your home – smart or vulnerable?

TechnoTalk

Mark Nelson

**Don't worry, there's nothing smart about my home. It's as scruffy as any man-cave can get, and there's minimal intelligence to be found in it. But I read so much about smart homes now that I really must wise up to modern living and the trend towards greater automation and the Internet of Things (IoT). If you too are lagging on the trailing edge of domestic electronics, then here's your roundup of what's bubbling away on your street.**

**FIRST OF ALL WE NEED TO** clarify what exactly makes a home 'smart'. According to one definition, the term refers to a residence equipped with computing and information technology devices that anticipate and respond to the needs of the people living there by enhancing their comfort, convenience, security and entertainment. Products that support smart homes include heating/ventilation and air conditioning (HVAC) control; security and access control; entertainment systems; lighting control and home health systems.

Factors driving the smart homes market are energy and cost saving, reduced carbon emissions, coping with an ageing population, government initiatives and more. There are, however, restraints holding back this potential paradise, such as the current lack of standardisation, high initial costs and the current economic slowdown – not to mention uncertainty over the post-Brexit situation. The IoT is of course a key enabler for the smart homes concept, as are (potentially) power line communication and smart grids, although the last two remain a little nebulous at this moment.

## Early adopters

That's enough scene-setting; what kind of opportunities will smart homes offer to *EPE* readers? Plenty, I guess. The UK was the first country in Europe to embrace home computing and it will come as little surprise that we British are already mass adopters of products sold under brand names such as Belkin, Hive, Motorola and Philips. Many of these devices can be controlled (locally or remotely) from a smartphone. It will be big business too. Trade association Intellect UK claims the British market, by next year, could be worth £3bn annually, while a report by Technavio forecasts we will spend £5.5bn on smart home products in 2019. And globally, technology manufacturer Ericsson estimates the number of connected devices will reach 29bn by 2022, 18bn of which will employ IoT connectivity.

## Flies in the ointment

Early adopters often pay a price, however, and the name of that price is incompatibility. Potential customers are confused by different types of cabling, interfaces and standards. Although the former worldwide Digital Living Network Alliance (DLNA) aimed to ensure devices can communicate with each other, the complaint is made that consumers can buy two pieces of DNLA-certified equipment that do not interoperate. People may also find it hard to obtain unbiased and accurate advice on all the services on offer. 'If you leave it to market forces, eventually the market will shake out the weak links and a dominant standard emerges,' reassures one industry commentator.

## Gift to hackers

More negative news – the way some IoT devices communicate leaves users vulnerable to identity theft and worse, as Simeon Coney, chief strategy officer of mobile security provider AdaptiveMobile told trade journal *Mobile News*. 'Inherently, IoT devices are manufactured at the lowest price point possible and go to market with an excellent price, so inevitably there will be security risks due to cheaper construction,' he asserts. Another vulnerability occurs where cellular or other mobile radio operators assign part of their networks to IoT manufacturers to enable their IoT devices to communicate. This technique is called network slicing, effectively creating a fenced-off zone of the operator's network that operates as the IoT firm's own private network. But Coney asks, 'Who is then securing the IoT device?'.

Even products as innocent-looking as smart mains sockets can leave you wide open to hacker exploits, such as reading your emails. As ZDNet Security revealed last year, IoT-based smart mains outlets (intended for monitoring energy use or controlling security cameras, smart TVs and coffee makers) can also give other people access to your emails. This is because the socket can be configured to send you an email notification each time it performs an action — which naturally requires you to provide your account credentials.

## Weak protection

The security firm Bitdefender discovered that a popular smart socket on the market not only had poor security protection, but also was susceptible to malicious firmware updates. In other words, it allowed attackers to control devices remotely and gain an entry point into your home network. If they discovered the MAC address of the device and its default credentials, they could gain control of the device, plundering all of the user information stored within (including the user's email credentials if the alert feature is enabled), stated Bitdefender. New passwords could then be set to override the root password and send commands to stop, start, and schedule the device, as well as execute malicious code. The attackers could also use the smart socket to interfere with other devices connected to the same local network.

Of course this smart socket is not the only product out there with lax security. Last year, *Wired* magazine reported how Samsung's SmartThings platform, a networked home system used in hundreds of thousands of homes, had flaws that allowed anyone with a PC or smartphone to 'pull off disturbing tricks over the Internet, from triggering a smoke detector at will to planting a backdoor PIN code in a digital lock that offers silent access to your home'.

## Words to the wise

To quote Prof Atul Prakash from the University of Michigan, 'These software platforms are relatively new. Using them as a hobby is one thing, but... as a homeowner thinking of deploying them, you should consider the worst case scenario... and see if those risks are acceptable.'

So how long will it be before we see projects for smart home gizmos in the pages of *EPE*? Probably not long – I just hope they are buttoned up tight and do not provide a new vector for identity theft and other fraudulent exploits!


# Micromite-Based Super Clock

By Geoff Graham

**Yes, we can guess what you are thinking... not another clock project! But this one is special because it can show the time using either an analogue or digital display. It can also track the time in up to 20 different locations, adjust each location for daylight saving and keep precise time using either a temperature-compensated real-time clock (RTC) module or a GPS module.**

AS WITH a number of recent projects, our new clock is based on the *Micromite LCD BackPack* (May 2017). We have teamed it with an accurate real-time clock (RTC) module (or a GPS module) for basic timekeeping.

As before, it relies on the touchscreen interface of the LCD panel in order to configure and operate the unit – there are no switches or knobs. This makes it easy to build and it should take no more than an hour or so to assemble.

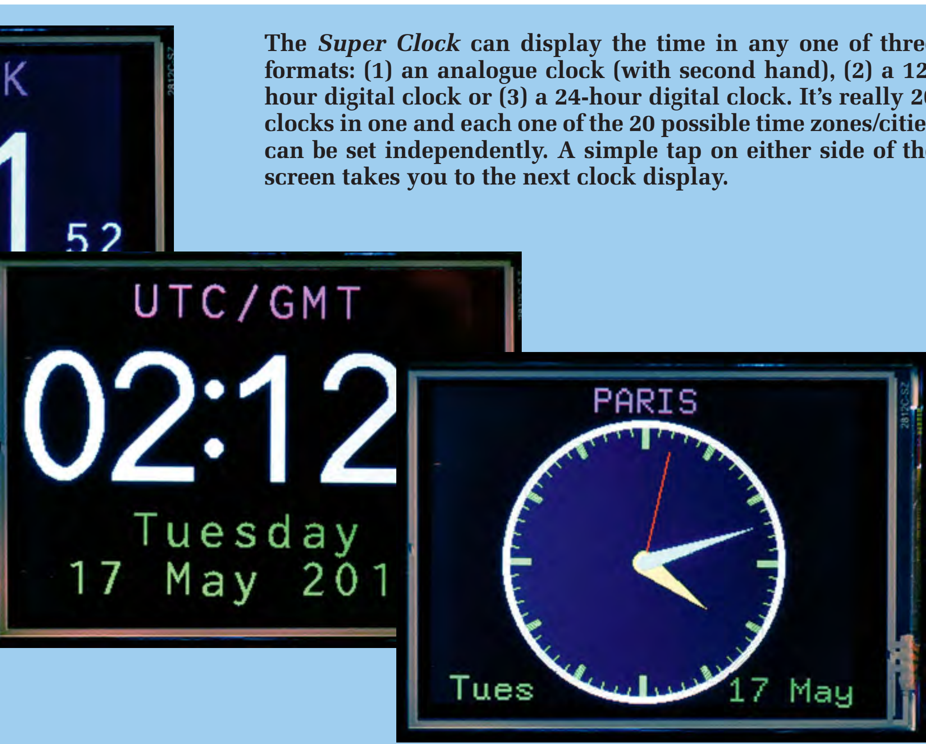
This is more than just a single clock; instead, it's really 20 separate clocks in one. When it's displaying the time, a simple tap on either the righthand or lefthand side of the screen switches the display forwards or backwards to the next clock.

Each clock can be configured to display the time as either an analogue clock (with hour, minute and second hands), a 12-hour digital clock (with AM and PM indicators) or a 24-hour digital clock. As already indicated, each clock can be configured for the daylight saving rules applying to its particular time zone. In addition, it can be given a unique title, so that you know which location each clock refers to.

All these characteristics are independently set for each clock. So, you could have one clock showing UTC, another set for home time, a third set for San Francisco, and so on. You could also have two of the clocks set to a single location, with one showing an analogue display and the other a digital display, so that you could quickly flip between whatever style takes your fancy. Naturally, it also shows the day and date beneath the time display.

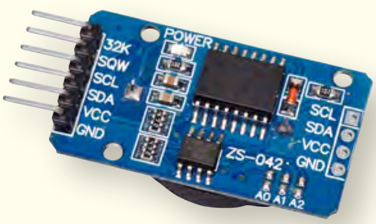
If you have relatives in different parts of the world that you telephone regularly, this clock will be a boon. With just a prod of your finger, you can quickly see what the exact time is 'over there'.

As with all Micromite-based projects, the software is written using BASIC and is stored as plain text. This means that you can 'get in there' and modify it to do whenever you want, if you feel so inclined. To do that though, you will need to make up a cable with a USB-to-serial converter, as described in the May 2017 issue.




**The *Super Clock* can display the time in any one of three formats: (1) an analogue clock (with second hand), (2) a 12-hour digital clock or (3) a 24-hour digital clock. It's really 20 clocks in one and each one of the 20 possible time zones/cities can be set independently. A simple tap on either side of the screen takes you to the next clock display.**

## Circuit uses either an RTC or a GPS module for accurate timekeeping




**This is the RTC (real-time clock) module that's recommended for use in the *Micromite Super Clock*. It employs a Maxim/Dallas DS3231 chip which can keep time to ±5s per month (or better) over a 0-40°C temperature range, while its battery back-up facility retains the time during power outages.**


**If you have a good GPS signal indoors, you can use a GPS module as the time source instead of an RTC. Its advantages are that you never have to set the time and it is always spot on. This VK-2828U7G5LF GPS module and the RTC module at left are available from eBay.**

### Timekeeping

The *Micromite Super Clock* will work with any one of three time sources: (1) an accurate real-time clock (RTC) module based on the Maxim/Dallas DS3231 chip; (2) a GPS module; or (3) the internal Micromite clock which uses a simple RC oscillator. You can use whichever source you wish but we recommend the DS3231 RTC module, shown in the photo above. It can be purchased on eBay for a few pounds.

The *Super Clock* will also work with any other RTC that's supported by the Micromite (see the *Micromite User Manual* for details). However, we recommend that you use a module based on the DS3231 for this project.

The DS3231 RTC is quite advanced and contains all the necessary timekeeping electronics, including a crystal and its associated oscillator. Every 64 seconds, the chip reads the output of its on-chip temperature sensor and then uses a look-up table to determine the amount of trimming capacitance needed to compensate and bring the crystal's frequency back into line. This is automatically done without any user intervention.

The result is a specified accuracy of ±2ppm over the temperature range of 0-40°C. This is a phenomenal result and equates to about five seconds per month. And that's just the maximum error; most times the DS3231 will achieve a precision much better than that.

The DS3231 also includes what the manufacturer calls an 'ageing offset register', which can be used to further trim the clock's accuracy. Our *Super Clock* gives you access to this register, so if you are very particular and have the patience, you can tweak the clock to give even better accuracy than the standard (highly-accurate) temperature-compensated crystal timebase.

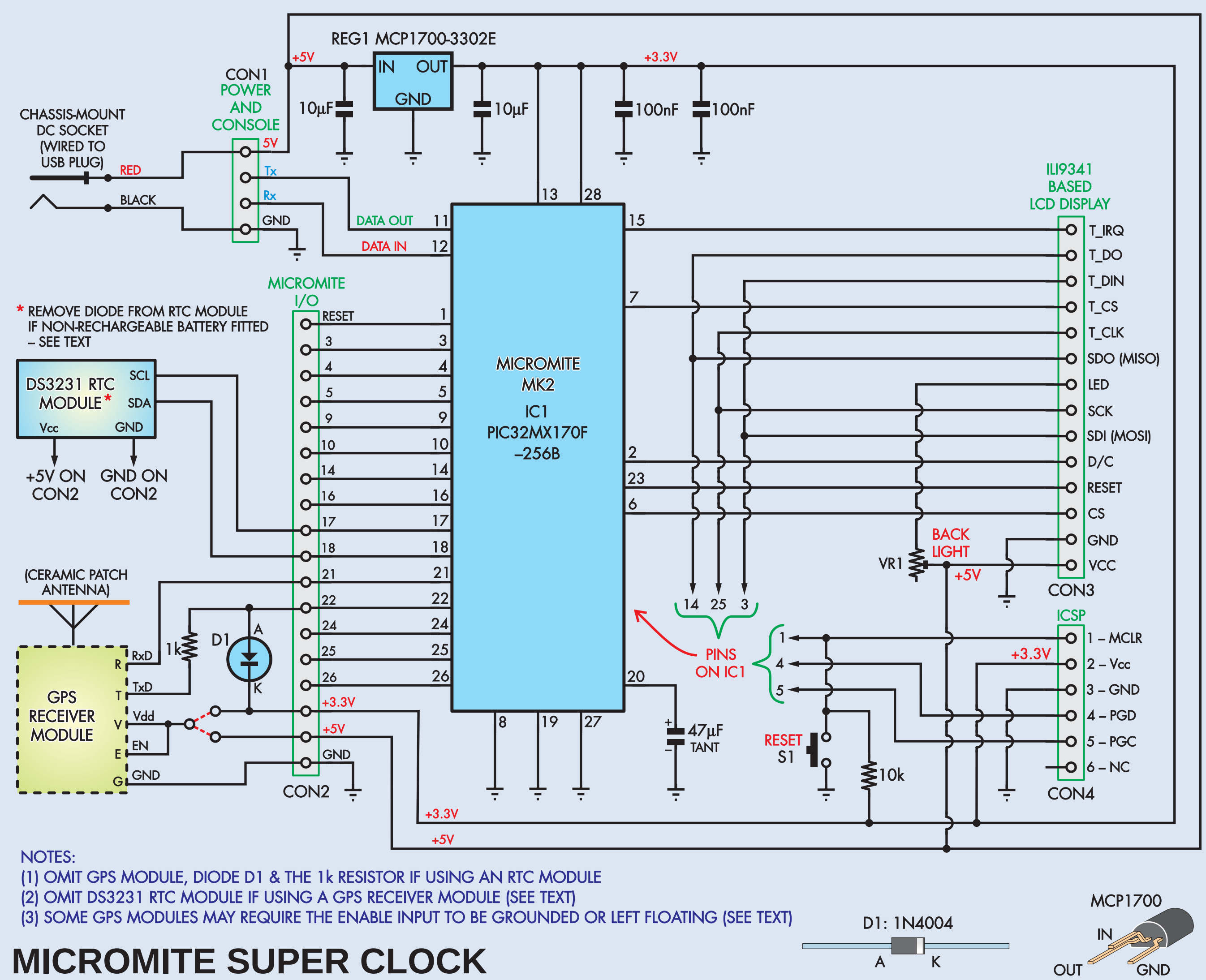
By contrast, a GPS module will be even more accurate as a time source but they are often not reliable indoors. A metal roof, rain or other factors can cause a GPS module to lose its signal. On the other hand, an RTC using the DS3231 will never drop out and with its on-board battery back-up, it will continue to keep accurate time regardless of power outages.

### GPS time source

GPS modules are now quite cheap and if you are sure that you have a good GPS signal indoors (or wherever the clock is to be used), one of these would make an excellent time source. The big advantage of using a GPS module instead of an RTC is that you never have to set the time. What's more, the time is always spot on since it is derived from the GPS satellites.

When power is applied, the *Super Clock* will first check for an RTC (such as the DS3231) and if one isn't found it will then search for a GPS module. The BASIC program in the Micromite will automatically adapt to most GPS modules on the market. This includes selecting a baud rate between 4800 and 56,300 and automatically switching between TTL and RS-232 signal levels.

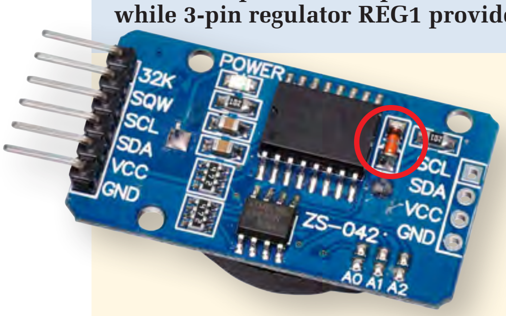
If the program cannot find either an RTC or a GPS module, it will pop up a dialog box warning that neither could be found. When you touch the OK button on the screen, the clock will then go on to use the Micromite's internal timekeeping facility. This source is not very accurate and the time will be lost whenever the power is cycled. However, it's useful if you do not have an RTC or GPS and just want to experiment with the software.




NOTES:
(1) OMIT GPS MODULE, DIODE D1 & THE 1k RESISTOR IF USING AN RTC MODULE
(2) OMIT DS3231 RTC MODULE IF USING A GPS RECEIVER MODULE (SEE TEXT)
(3) SOME GPS MODULES MAY REQUIRE THE ENABLE INPUT TO BE GROUNDED OR LEFT FLOATING (SEE TEXT)

## MICROMITE SUPER CLOCK

**Fig.1: most of the work in the *Micromite Super Clock* is done by IC1 which receives time signals from either an RTC (real-time clock) module or a GPS module (but not both) and drives a touch-screen colour LCD connected to CON3. The RTC module will generally be the one to use since the clock will be used indoors, but a GPS module can be substituted if GPS reception isn't a problem. Power comes from a 5V DC USB plugpack charger and this directly powers the LCD, while 3-pin regulator REG1 provides 3.3V to power IC1.**




**The diode circled in red must be removed if a non-rechargeable CR2032 back-up battery is used in the real-time clock (RTC). This diode is part of the charging circuit and removing it prevents the module from recharging the battery. Alternatively, you can leave the diode in place if a rechargeable LIR2032 battery is used – see text.**

### Circuit details

Refer now to Fig.1 for the circuit details of the *Micromite Super Clock*. This shows the connections for both a DS3231 RTC and a GPS module, but in practice only one of these is used. Omit the GPS module, diode D1 and 1kΩ resistor if using an RTC. Alternatively, omit the RTC if using a GPS module.

The DS3231 RTC module runs off 5V and uses $I^2C$ to communicate, so it connects to pins 18 and 17 on the Micromite (IC1) which are the $I^2C$ data and clock pins respectively. The $I^2C$ protocol requires pull-up resistors on the signal lines and these are provided by the module, which makes it easy for us.

The alternative GPS module uses a serial interface and so it connects to pins 22 and 21, which handle the COM1 receive and transmit signals (from the Micromite's perspective). As shown, the Tx (transmit) line from the module goes to the Rx (receive) pin on the Micromite via a series 1kΩ resistor and has a clamping diode (D1) to 3.3V. These are there to protect the Micromite if the module uses RS-232 signal levels, which can swing ±12V.

Alternatively, if you are sure that your module uses TTL signal levels, you can dispense with the diode and replace the resistor with a wire link (although leaving these parts in circuit won't do any harm).

Some GPS modules use a 3.3V supply, while others use 5V. As shown on Fig.1, you can connect the module to either supply pin on the *Micromite LCD Backpack*.

### DS3231 RTC module

As previously mentioned, the DS3231 module can be purchased on eBay. Just search for 'DS3231' and you will get hundreds of hits. The module that we purchased, as shown in the photos, is the most common. Make sure that the module that you purchase matches ours because we have tested this variant and it works well.

The RTC module is normally supplied without a back-up battery due to air-freight concerns. The battery specified is an LIR2032 which is a rechargeable lithium-ion type. However, this battery type can be difficult to find.

In our application though, we don't need a rechargeable battery because the clock will spend most of its time connected to a plugpack supply. This means that the RTC will not be running off its back-up battery except during the odd power outage. However, these events are infrequent and the current drawn by the DS3231 chip is so low that a non-rechargeable battery can be used instead of the LIR2032.

For this reason, if your module isn't supplied with a battery, we recommend modifying it to take a standard CR2032 battery. This type of battery is available everywhere and will last even longer than the rechargeable version (upwards of 20 years).

**Modifying the RTC module to take a CR2032 battery simply involves removing a diode, as shown in the photo on the facing page. This diode is part of the charging circuit and once it's gone, the module cannot charge the battery (which could be disastrous if a non-rechargeable battery is used).**

Note that the DS3231 module shown in the photos is also equipped with a 32K bit EEPROM memory chip, which is not used by the *Super Clock*.

### GPS modules

The *Super Clock* will work with almost any GPS module, so there are quite a few units to choose from. The basic specifications required are 3.3V or 5V power, a serial interface with TTL or RS-232 signal levels and a baud rate of 4800 to 38,400. Suitable GPS modules include the Fastrax UP501, USGlobalSat EM-408, Ublox NEO-7M-C, Ublox NEO-6M, Skylab MT3329/SKM53, V.KEL VK16HX, V.KEL VK16E and Ublox VK2828U7G5LF.

## Parts List

### Micromite LCD BackPack Unit

1 double-sided PCB, available from the *EPE PCB Service*, coded 07102122, 86 × 50mm (for 2.8-inch LCD)
1 2.8-inch ILI9341-based touch-screen LCD, 320 × 240 pixels
1 UB3 ABS box, 130 × 67 × 43mm
1 laser-cut black or clear acrylic lid to suit UB3 box
1 4-pin tactile switch, through-hole hole (S1)
1 100Ω vertical-mount side adjust trimpot (VR1)
1 28-pin DIL low-profile IC socket
1 4-pin 0.1-inch male header (CON1)
1 18-pin 0.1-inch male header (CON2)
1 14-pin 0.1-inch female header socket (CON3)
1 6-pin 0.1-inch right-angle male header (CON4)
1 2.1mm or 2.5mm panel-mount DC socket
4 M3 × 12mm tapped spacers
4 M3 × 10mm black machine screws
4 M3 × 6mm machine screws
4 M3 × 1mm (6mm OD) Nylon washers

**Semiconductors**
1 PIC32MX170F256B-50I/SP microcontroller programmed with SuperClockFull.hex (IC1). Note: a PIC32MX170F256B-I/SP can also be used
1 Microchip MCP1700-3302E/TO voltage regulator (REG1)

**Capacitors**
1 47µF 16V tantalum or SMD ceramic (3216/1206)
2 10µF 16V tantalum or SMD ceramic (3216/1206)
2 100nF monolithic ceramic

**Resistors (0.25W 5%)**
1 10kΩ

### RTC version

1 RTC module using the Maxim/Dallas DS3231
1 LIR2032 or CR2032 battery (see text)
4 single-pin female headers for the interconnecting leads
2 M2 × 10mm tapped Nylon spacers
4 M2 × 6mm Nylon screws

### GPS module version

1 3.3V or 5V GPS module with connecting cable
1 1N4004 silicon diode (see text)
1 1kΩ resistor (0.25W, 5%) (see text)
4 single-pin (DuPont) female headers (for interconnecting leads)

### Cable parts

1 USB cable with a male type A connector (length to suit)
1 2.1mm or 2.5mm DC plug to suit DC socket
1 4-pin 0.1-inch female header
Red and black hook-up wire

### Where to buy parts

A kit for the *Micromite LCD BackPack* is available from the SILICON CHIP Online Shop. This includes a 2.8-inch touch-screen LCD panel, the BackPack PCB, a PIC32 microcontroller programmed with **SuperClockFull.hex**, all the on-board parts and a laser-cut black or clear acrylic lid with a cut-out to suit the LCD and mounting holes to suit a UB3 box (the black lid has a gloss finish on one side and a matt finish on the other). (The *Micromite LCD BackPack* is also available from: **http://micromite.org**)

Note that the kit does not include the box, mounting hardware, power supply, DC socket, off-board headers or any connectors or cable parts.

A programmed microcontroller is also available separately.

### RTC and GPS modules

The SILICON CHIP Online Shop also has the RTC module (back-up battery not included) plus two M2 x 10mm nylon spacers and four M2 x 6mm nylon screws for mounting. In addition, two different GPS modules with internal battery back-up are available and these are each supplied with a connecting cable.

Finally, suitable USB-to-serial converters are on offer and these are each supplied with a short DuPont cable to connect to the Micromite.

Browse to the SILICON CHIP Online Shop for pricing and ordering details.

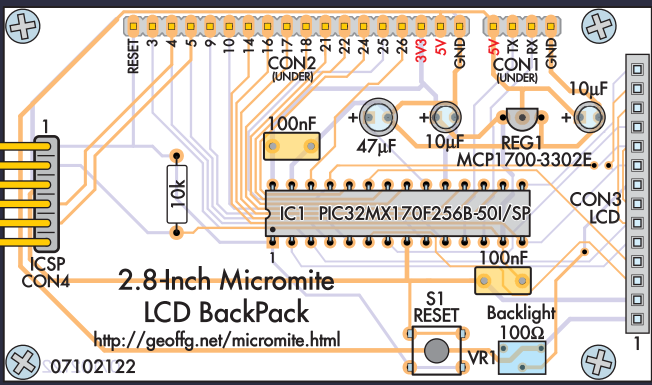
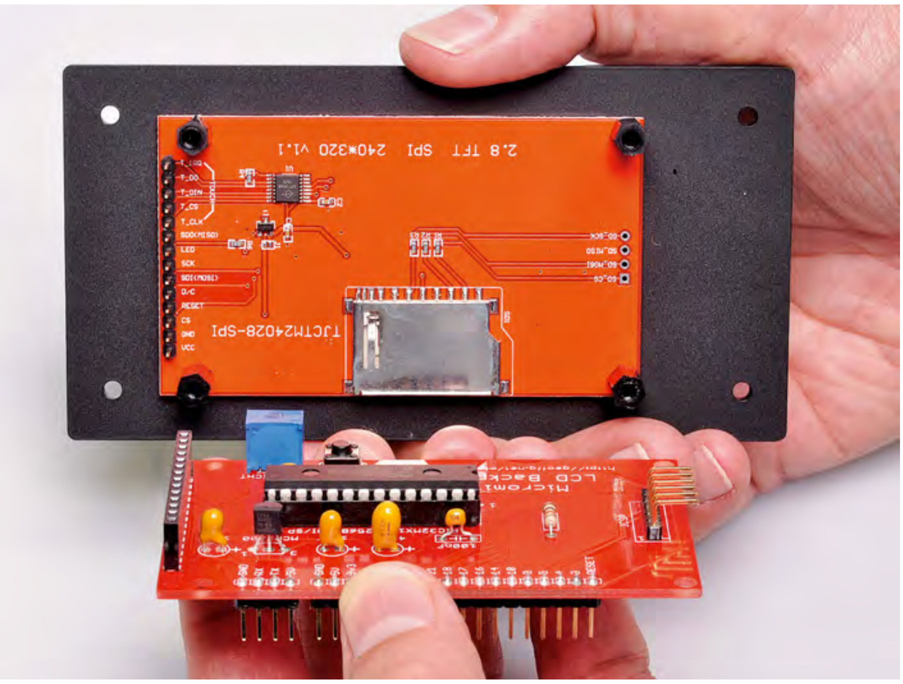



**Fig.2: repeated from the May 2017 issue, this parts layout diagram shows how to build the *BackPack* PCB for the 2.8-inch LCD. Note that pin headers CON1 and CON2 are mounted on the rear of the PCB, while CON3 and CON4 are mounted on the top (see photos).**



**The colour LCD is mounted on the laser-cut acrylic lid before being plugged into the *BackPack* PCB. Be sure to fit the LCD to the lid with the correct orientation, so that the display is centred.**

All of the above GPS modules use TTL levels, so the resistor and diode shown in Fig.1 are not required (ie, delete the diode and replace the 1kΩ resistor with a link). You should also check the data sheet for the module to determine if it has any special requirements. The most common is that if it has an enable input, then this must usually be connected to the positive supply rail for the module to work.

Alternatively, some modules require the enable input to be connected to ground or even left floating, so check the data sheet carefully.

**The Ublox VK2828U7G5LF GPS modules shown earlier must have its enable input connected to the positive supply rail and can run off either a 3.3V or 5V supply rail. It also has an inbuilt back-up battery (which some modules lack).**

### Construction

Construction mostly involves assembly of the *Micromite LCD BackPack* PCB (the 2.8-inch version is the one to use) and this should take no more than half an hour. It uses less than a dozen components and the PCB is silk-screened with the component layout and values, so it's simply a case of populating the board and plugging it into an ILI9341 LCD touch-screen panel.

The parts layout diagram for the *LCD BackPack* was originally published in the May 2017 issue of *EPE*. We're also reproducing the diagram in this issue – see Fig.2. Use a socket for IC1, take care with component orientation and note that pin headers CON1 and CON2 are mounted on the rear of the PCB (see photo at left).

A complete kit for the *LCD BackPack* is available from the **http://micromite.org** (see parts list). This kit is supplied with SMD ceramic capacitors (2 × 10µF and 1 × 47µF), as these are more reliable than tantalums (the PCB can accept either type). The SMD capacitors are non-polarised and can be installed either way around.

### Loading the firmware

The easiest method of loading the firmware is to program the PIC32 chip with the file **SuperClockFull.hex**. This single firmware file contains everything that you need, including the MMBasic interpreter configured for the display and the BASIC program for the *Super Clock*. The file can be downloaded to a PC from the *EPE* website and to load it into the Micromite, you will need a PIC32 programmer such as the PICkit 3.

Once the chip has been programmed, it's just a matter of plugging it into its socket and you are ready to go.

The only issue that you need to be aware of is that the touch calibration in the above firmware was done with a reasonably standard LCD panel. However, yours might require recalibration if it is significantly different from the 'standard' that we used.

This can be done by connecting a USB-to-serial converter to the console, halting the program with `CTRL-C` and re-running the calibration routine as described in the *Micromite User Manual* (which can be downloaded from the author's website: **http://geoffg.net**). The touch calibration procedure was also described in detail in the May 2017 issue of *EPE*.

The alternative to programming the chip with the combined firmware is to load each software component separately, as listed below:

- Program the chip with **Micromite_V5.2.hex** (the BASIC interpreter), then configure the interpreter for the display panel and touch.
- Using `AUTOSAVE` or `XMODEM`, load **SuperClockFonts.bas** into MMBasic and then save it to the library with the command `LIBRARY SAVE`.

- Using AUTOSAVE or XMODEM, load the file **SuperClock.bas** into MMBasic and issue the command RUN.

A detailed explanation of how to do this is also included in the *Micromite User Manual*.

USB-to-serial converters suitable for use with the Micromite are available and were described in the May 2017 *LCD BackPack* article.

### Pre-programmed chip

Don't want the hassle of programming the PIC32 microcontroller yourself? In that case, you can simply purchase a fully programmed microcontroller from the Silicon Chip Online Shop. As before, you may have to go through the touch calibration procedure if your LCD panel is significantly different from the standard (although in most cases, it will be fine).

### Enclosure

The *Micromite LCD Backpack* fits neatly into a standard UB3 enclosure. A laser-cut acrylic front panel (black) replaces the standard lid supplied with the box and this results in a neat assembly.

This panel is designed to suit the 2.8-inch touch-screen LCD panel and has the mounting holes pre drilled, along with a precision cut-out for the LCD. It can be purchased from the Silicon Chip Online Shop.

The first stage of assembly is to attach the LCD panel to the acrylic lid using an M3 × 10mm machine screw, 1mm-thick M3 nylon washer and an M3 × 12mm tapped spacer at each corner – see Fig.3. This arrangement ensures that the surface of the LCD sits flush with the acrylic lid. The *BackPack* PCB is then plugged into the LCD and fastened to the spacers by M3 × 6mm machine screws.

Note that the self-tapping screws supplied with the UB3 box to attach the lid may have to be replaced with No.4 x 10mm self-tapping screws. This could be necessary because the acrylic panel is thicker than the lid supplied with the box.

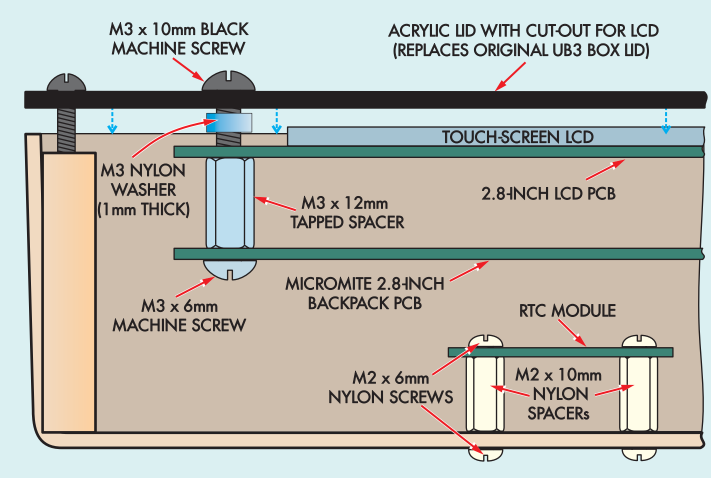



**Fig.3: here's how to attach the LCD and *Micromite BackPack* PCB to the acrylic lid. The LCD goes through a cut-out in the lid and sits flush with its top surface.**

### Power supply

The unit requires a 5V power supply rated at 300mA or more. That means you can use a 5V plugpack or a USB charger. If a USB charger is used, a suitable power cable needs to be made by cutting one end off a standard USB cable (retaining the Type A socket at the other end) and soldering the free end to a suitable DC power plug. The red wire in the USB cable (+5V) should go to the centre pin of the plug and the black to the sleeve. The other two wires (the signal wires) can be cut short, as they are not used (see Fig.4).

A matching DC power socket for the incoming power is mounted on the side of the UB3 box. This should be mounted near the base of the case, so that it doesn't foul the *BackPack* PCB. Once it's in place, two flying leads are run from this socket and soldered to a 4-pin header socket which is then plugged into the *BackPack's* CON1 connector.

Be very careful here as CON1 is not polarised, so make sure that the centre pin of the power socket (+5V) connects to the pin marked with the 5V symbol on the *BackPack's* PCB. We speak from experience here as we accidentally connected the cable the wrong way during development. The Micromite and the LCD survived, but we don't recommend the practice.

### RTC or GPS unit mounting

The DS3231 RTC module (if used) is mounted on the base of the UB3 box using four nylon M2 × 6mm screws, two M2 × 10mm nylon spacers and nylon nuts. It must be positioned towards the bottom edge of the case (see photo overleaf) to avoid fouling CON1 and CON2 on the underside of the *BackPack* PCB, as these connectors extend close to the base.

Note that nylon mounting hardware must be used due to the close proximity of the holes to the solder pads and tracks on the RTC's PCB.

Before actually fastening the RTC into position, connect four 100mm-long flying leads to its SCL, SDA, VCC and GND terminals. The RTC has solder pads for these terminals at one end and a pin header incorporating these terminals at the other; you can use either set for the connections.

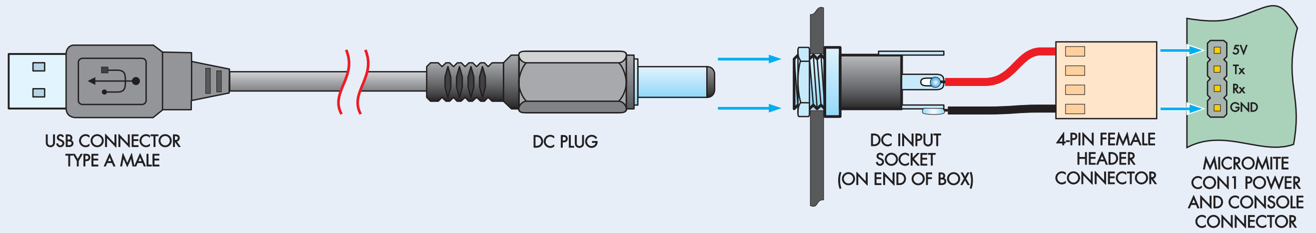
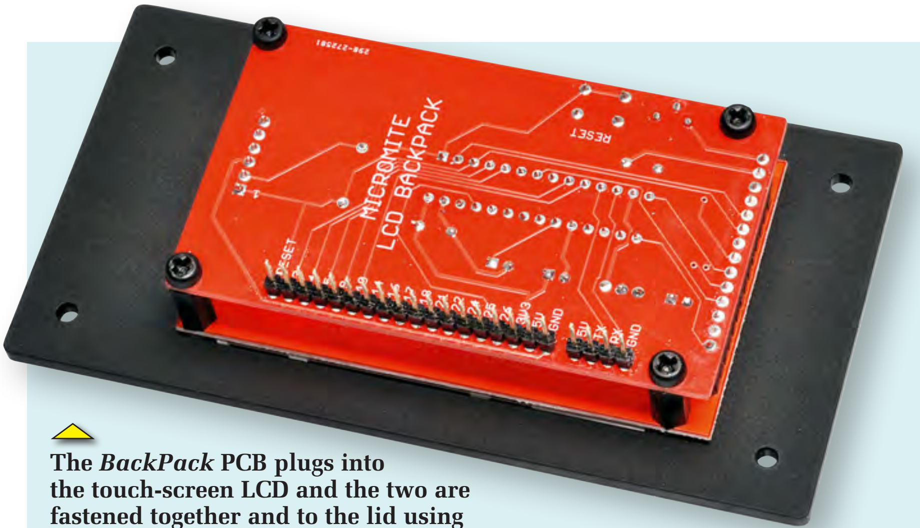
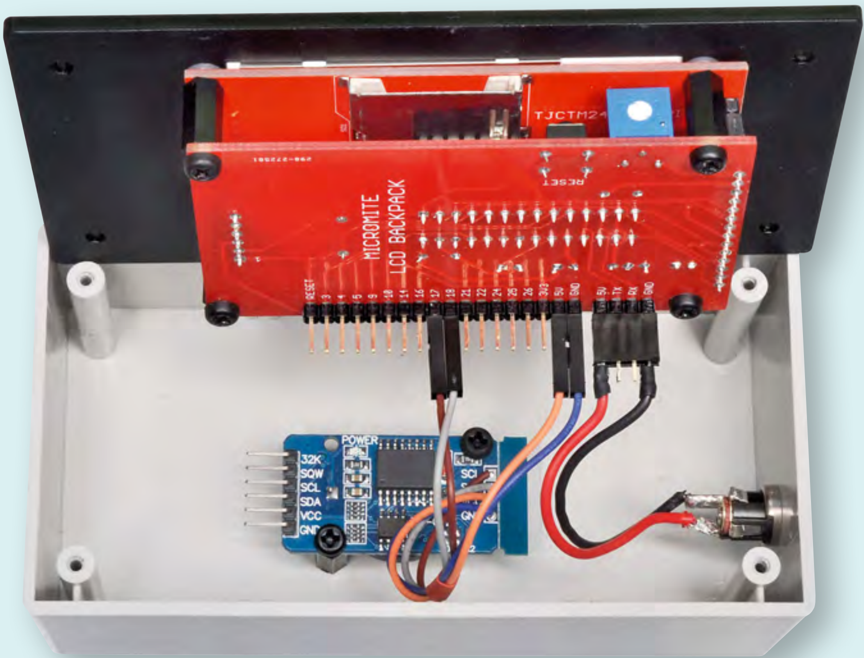



**Fig.4: the *Micromite Super Clock* is powered from a standard USB plugpack charger. To make a suitable power cable, cut one end off a USB cable (retaining the type A male connector at the other end) and solder the red wire to the centre terminal pin of a DC plug and the black wire to the outside pin. The matching DC socket is mounted on the side of the UB3 box and is connected to a 4-pin female header which then plugs into CON1 on the *BackPack* PCB.**




The *BackPack* PCB plugs into the touch-screen LCD and the two are fastened together and to the lid using spacers and machine screws – see Fig.3.




**The RTC is mounted on the base of the box towards the bottom edge so that it doesn't foul CON1 and CON2 on the *BackPack* PCB. Similarly, the DC socket should be mounted close to the base so that it doesn't foul the edge of the *BackPack* PCB or CON3's soldered pin connections.**

The other ends of the flying leads are terminated in single-pin 'DuPont' sockets to connect to CON2 on the *BackPack* PCB. Alternatively, you can solder the leads direct to CON2's terminals or you could use a multi-pin (10-way) header socket for the connection.

If you are using a GPS module instead of the RTC, the mounting arrangement will depend on the module. The important factor is that the antenna (the ceramic object on the top of the module) should be horizontal and pointing to the sky when the assembly is fitted to the case. The best solution is to attach it to the inside of the top of the enclosure (eg, using a thin smear of neutral-cure silicone), with flying leads running to the appropriate pins on CON2.

## Using the clock

When the clock is powered up, it will first check for a connected RTC. This only takes a few milliseconds and if it is found, the clock will display the time and begin normal operation.

If an RTC is not found, the clock will display a message stating that it is checking for a GPS module. This can take up to 10 seconds as the program scans through the various baud rates and TTL/RS232 combinations that are available.

If the GPS module cannot be found, the software will report this fact and you will need to sort out why it is 'silent'. The most likely cause is that the transmit and receive signals have been swapped. Alternatively, the GPS module may require an enable signal, as described above.

When the GPS module has been detected, the display will show the message 'Searching for Satellites', which means that the module is trying to locate enough satellites to get a fix. Initially, this can take up to an hour, so place the module outdoors where it has a clear view of the sky and leave it running. When a lock has been achieved, the clock will switch to showing the time.

If neither an RTC nor GPS module is found, the software will report this fact in a dialog box with an OK button. Touching this button then lets the clock function by using the Micromite's internal clock.

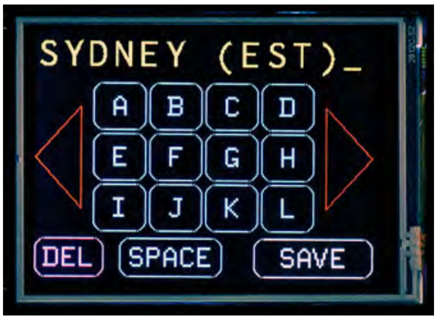
When the time is displayed, you can then step forward through the configured clocks by repeatedly touching the righthand side of the LCD, or step back by touching the lefthand side. Initially, there are five clocks configured and these are for UTC, Perth, Sydney, New York and Paris. By default, UTC is shown as a 24-hour clock, Perth and Sydney use an analogue clock and the rest use a 12-hour digital clock. In addition, the correct time zone and daylight saving rules are set for each location.

Of course, these are only offered as examples and you can jump right in and change them to suit yourself. That's done by touching the centre of the LCD which will take you to the configuration screen, as shown in Screen 1. This screen allows you to change the type of clock (Hidden, Analogue, Digital 12h or Digital 24h), the time and settings for that particular clock, and more. All these settings are stored in non-volatile memory and automatically recalled on power-up.

At the bottom of the configuration screen are buttons marked PREV and NEXT. Using these, you can step through all 20 clocks. Note that some clocks initially have their type set to 'Hidden' (clocks 6-20). This means that when you are changing the displayed clock by tapping on the screen, the BASIC program will skip over hidden clocks and wrap around at the end of the list. If you want to make a clock visible, set its type (at the top of the


**Screen 1: tapping the centre of the LCD brings up the main configuration screen. This allows you to change the type of clock (Hidden, Analogue, 12-Hour Digital or 24-Hour Digital) and to set the date and time. Note that if you build the GPS version, the SET DATE and SET TIME buttons will not be visible; instead, the status of the GPS module will be reported in this screen space.**


**Screen 2: this screen allows you to configure a particular clock (the *Micromite Super Clock* supports 20 different clocks). You can change the title and configure the time zone and daylight saving parameters.**




**Screen 3: it's easy to assign a title to a clock by pressing the SET button at the top of Screen 2 and then using this keypad.**


**Screen 4: setting both the time and date for the RTC version is straightforward using this keypad. When you set the time you are setting the local time and all the other clocks will then be automatically updated according to their time zone.**

configuration screen) to Analogue or Digital and conversely to hide a clock, set its type to Hidden.

Underneath the clock's type is the CONFIGURE CLOCK button, which allows you to set the time zone and daylight saving rules for that particular clock. The display below this button will differ depending on the time source that you are using (either an RTC or GPS module).

## Set date and time

If you are using an RTC module (or the internal oscillator), this bottom section of the screen will show two buttons designated SET DATE and SET TIME. These are used to initially set the time for the RTC.

Note that when you are setting the time, you are setting the local time. For example, if the clock is showing Sydney time, you should enter the date and time for Sydney. All the other currently programmed clocks will then automatically update based on their respective time zone – so you only need to set the time once.

Alternatively, if you are using a GPS module, the SET DATE and SET TIME buttons will not be present because the GPS module itself supplies the exact date and time. Instead, this section of the screen will show a message reporting the status of the GPS module. Most of the time it will show 'GPS Time Synchronised', which means that the GPS has a lock on sufficient satellites to get a precise time.

From time to time, the GPS could lose this lock, especially when the clock is located indoors. Rather than display an error message, the *Super Clock* will switch to using a timebase supplied by the crystal-controlled clock within the GPS module, which is accurate to within a few seconds per day. The clock will keep using this time source for up to 24 hours without a satellite fix, and this should be enough to carry it through even the most extended glitch in GPS signal reception.

If the clock is running in this mode (ie, using the GPS module's crystal-based clock), the message on the configuration screen will show 'No sync

## Trimming The DS3231's ageing offset register

If you use a DS3231 RTC module, the SET TIME button in the configuration screen has an additional feature; hold it down for five or more seconds and you will be taken to the DS3231's Ageing Offset setting. This can be used to trim the DS3231's crystal oscillator to achieve an even greater accuracy than normal.

By default, the ageing offset value is set to zero but you can plug in whatever number you wish from +127 to –127. Typically, a change of ±1 will change the clock's timing by 0.1 parts per million; about a quarter of a second over a month. Incrementing the number slows down the clock and decrementing it speeds the clock up.

If you want to experiment with this setting, the best method would be to set the time exactly against some standard (eg, an Internet time server) and then recheck the displayed time three months later. Simple arithmetic will then tell you the amount of trim required. You can then experiment with that value and recheck the accuracy a further three months later.

Provided you have the patience, you could get the clock's accuracy to close to spot on within a year or two!


**Screen 6: an ageing offset of +1 will slow the clock by about 0.1ppm while –1 will speed it up by the same amount. You can enter –127 to +127.**


**Screen 5: setting daylight saving rules is simple. The clock always increments or decrements the time by one hour at 2am (non-daylight saving time) on the start or ending day specified. The only exception is the UK (time zone zero), where the time switch occurs at 1am.**

**for n.nn hrs**'. This indicates that the GPS module has lost its lock on the satellites and has not been able to regain it for the past n.nn hours.

After 24 hours of no satellite lock, the BASIC program will restart the Micromite, which forces it to go through the full power-up sequence, including finding the initial GPS fix. So, if you initially had the clock running successfully but then find that it is sitting there with the message 'Searching for Satellites', it means that it has run for over 24 hours without a lock and you should move it nearer to a window (or install a DS3231 RTC module instead).

### Daylight saving settings

The Configure Clock menu for a particular clock or location allows you to change the name allocated to that location, the time zone and the daylight saving settings – see Screen 2.

The daylight saving settings have been designed to suit most countries, although there are some that are just too complicated (for example Iran). For both the start and end of daylight saving, the setting is displayed as something like '1st Sun in Oct'. By touching the SET button, you will be taken to a further screen where you can change the month of the daylight saving change, the day of the week and the position of that day in the month (1st, 2nd, 3rd or last day in the month).

The clock will always increment or decrement the time by exactly one hour at 2am (non-daylight saving time) on the start or end day specified. The one notable exception to the 2am change is the UK where the time switch occurs at 1am. The clock accommodates this special case by checking the time zone and if it is zero, it will assume that the country is the UK and the time switch will be made at 1am.

That's it, your *Micromite Super Clock* is complete. In practice, you will find that the menus are all simple to navigate and set-up and it will only take you a few minutes to familiarise yourself with their operation.

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# Win a Microchip PICDEM Lab II Development Platform

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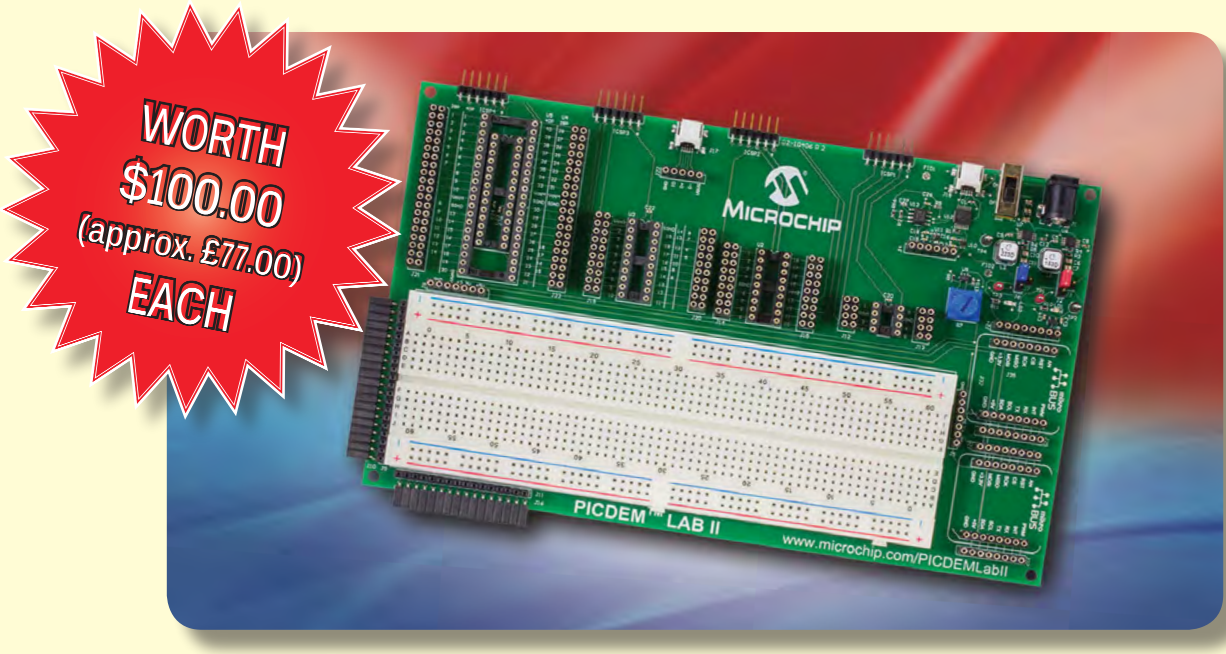
The original PICDEM Lab Development Board has remained one of the most popular development tools for PIC MCUs since its introduction. Microchip has taken this concept and expanded it for 21st century embedded development. The PICDEM Lab II Development Board supports any 8-bit PIC microcontroller (6-, 8-, 14-, 18-, 20-, 28- and 40-pin footprints), and provides an expansive array of connections for programming, I/O, analogue and communications interfaces. The PICDEM Lab II Development Board will be a valuable resource to engineers across a broad spectrum of specialties, from analogue designers looking to explore the power and flexibility of MCU-based systems to engineering professors seeking a flexible and relevant teaching tool that they can add to their curricula.




## HOW TO ENTER

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Mr Stephen Ward, who works at AIM Altitude, Bournemouth, UK

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They each won a Microchip Curiosity PIC32MX470 Development Board, valued at £23.00 each


By JIM ROWE

# Brownout Protector for Induction Motors

**Brownouts occur when the mains voltage drops to a very low level, say below 100VAC and this causes incandescent lamps to be very dim or ‘brown’. But, as well as making your lights go dim, brownouts can cause induction motors to burn out because they cannot start properly.**

**YEARS AGO, BROWNOUTS** were quite rare and generally confined to rural districts where the power lines had very long runs. A falling tree or an electrocuted animal might cause the mains voltage to drop to a low level and lights would go dim.

This has always been a hazard for the induction motors used in pumps and refrigerators.

Nowadays though, because electricity grids run much closer to total capacity, brownouts can be experienced much more commonly in the cities and suburbs.

In our own offices we have had brownouts on a number of occasions in the last few years. Each time one occurred, we made sure that the air conditioner, fridges, compressors and other machinery in the building were turned off until the full AC mains supply was restored.

Had we not done so, all the motors in that equipment were liable to burnout.

So how many motors in your home are at risk right now if a brownout were to occur?

The list can be quite long: fridge, freezer, washing machine, dishwasher, air conditioner, pool pump, spa pump and perhaps one or two garage door openers; typical of many homes. All this equipment could attempt to turn on during a brownout and the motor(s) would probably burn out.

Maybe your insurance policy covers motor burnouts, but you would need to read the fine print. The insurance company might also look askance at your claim if there was more than one motor burnout or if the appliances were more than a few years old.

The problem is that if induction motors try to start when the mains voltage is very low, they will never come up to correct speed and they will consequently draw very heavy currents. Unless they are turned off within a minute or so, they are very likely to burn out their windings.

The risk applies to all induction motors in appliances which can switch on at any time, as in refrigerators, airconditioners, water/sewer pumps on rural properties and the appliances listed above.

But you can take out your own ‘insurance’ against this possibility by building our *Brownout Protector*.

It monitors the AC mains voltage and disconnects power to the appliance when the voltage drops below a preset level, only reconnecting it when the voltage returns to its normal level.

This design includes the ability to adjust the low-voltage switching threshold (typically set to 200VAC), plus a heavy duty relay to perform the switching.

The relay contacts have a continuous current capacity of 30A and an inrush current capacity of 65A, ensuring that it is more than capable of switching loads of up to 2300W (= 10A at 230V). The circuit also has a time delay of approximately five seconds after the mains voltage drops below the threshold level, before the relay switches off power to the motor.

There is also built-in hysteresis, to make sure that the mains voltage has to rise above the threshold level by about 10V before the motor power is switched back on again. This ensures that the relay is prevented from 'chattering', or rapidly switching on and off if the mains voltage lingers at the threshold level.

## Specifications

**A low-cost brownout protector for single-phase 230VAC induction motors with power ratings up to 2300W.**

**Features include an adjustable voltage threshold, switch-on delay and indication of both normal power and brownout conditions.**

**Maximum control power: 2300W**

**Switch-on delay: 5 seconds (approx)**

**Standby power consumption: <5W with relay on**

**Brownout threshold voltage: typically set to 200V**

### Circuit operation

The full circuit is shown in Fig.1. It uses only a small number of low-cost components. These include dual op amp IC1, two BC337 transistors (Q1 and Q2), a 12V regulator (REG1) and the heavy-duty relay RLY1.

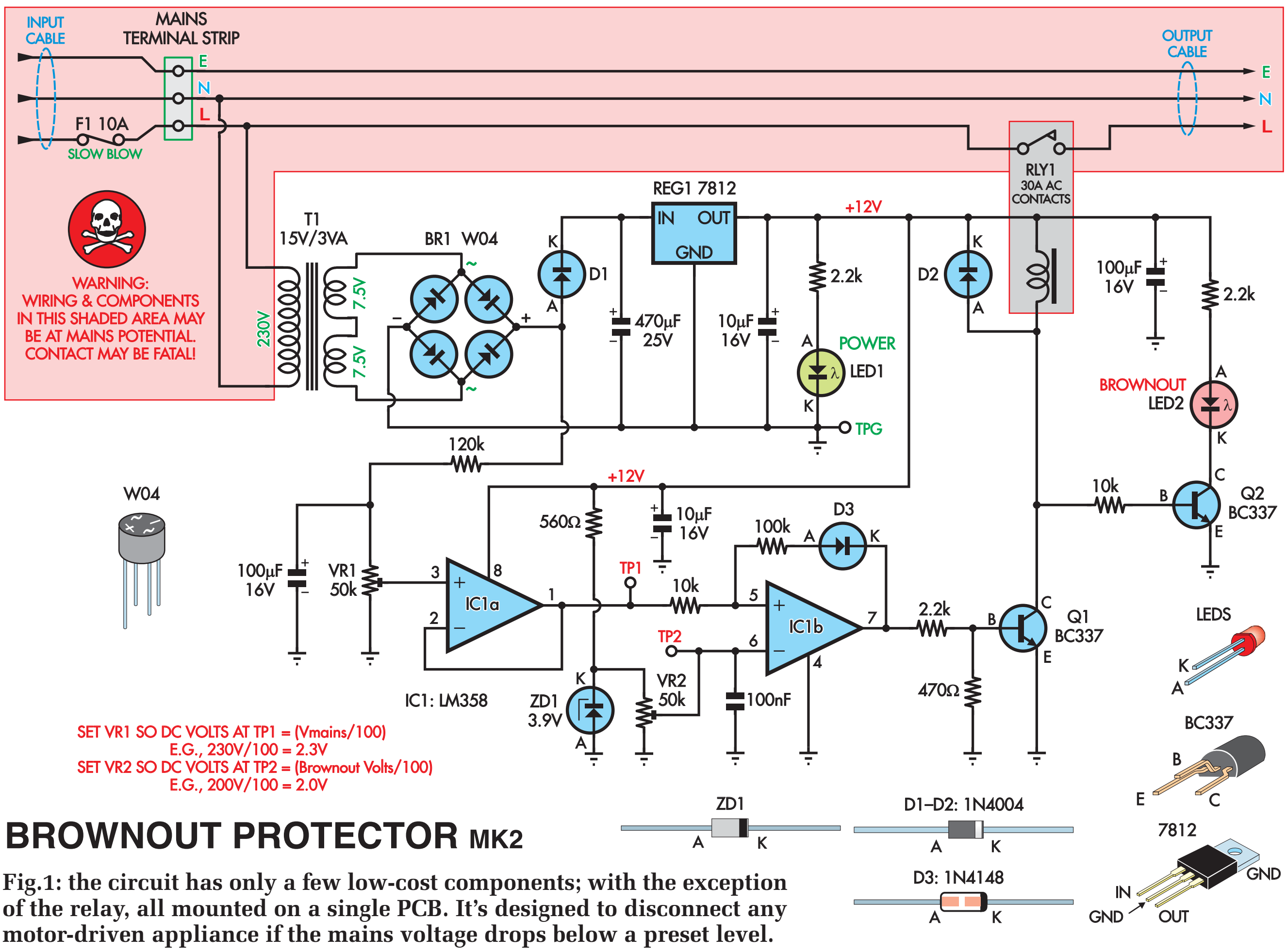
Power for the circuit is derived from the mains via a small 15VAC 3VA stepdown transformer, T1. This drives bridge rectifier BR1, with diode D1 used to couple the bridge output to the 470µF filter capacitor. The resulting nominal 19V DC is then fed to the input of regulator REG1. The output of REG1 then provides the 12V DC to power IC1, the 12V relay and both LED1 and LED2.

To detect a brownout condition, the circuit needs to monitor the AC voltage from the transformer secondary winding. Note that we don't do this directly; instead, we monitor the rectified DC waveform at the output of BR1 and the anode of D1. This is filtered using the 120kΩ resistor and the 100µF capacitor across trimpot VR1.

The resulting DC voltage across VR1 is about 3.6V. Note that this voltage does not necessarily track the 19V or so that appears across the 470µF main filter capacitor.

This is because the 470µF capacitor charges up to the peak value of the rectified 15V waveform, whereas the 120kΩ resistor, trimpot VR1 and 100µF capacitor form an averaging filter to give a lower voltage (Vp × 0.636 × 50kΩ ÷ 170kΩ = ~3.6V).

But why go to all this trouble rather than just monitoring the DC voltage across the 470µF main filter capacitor? After all, if the mains voltage varies, the voltage across the 470µF capacitor will vary in proportion, won't it?




**BROWNOUT PROTECTOR MK2**

**Fig.1: the circuit has only a few low-cost components; with the exception of the relay, all mounted on a single PCB. It's designed to disconnect any motor-driven appliance if the mains voltage drops below a preset level.**

The reason for using this averaging filter method is twofold.

First, the actual AC waveform of the mains supply is usually 'flat topped' due to the loading of gas discharge lighting (eg, fluorescents) and the capacitor-input switchmode power supplies used in most of today's computers and other electronic equipment.

Using the peak of the waveform to represent the actual mains voltage is not sufficiently accurate because the degree of 'flat topping' varies during the day, depending on whether it is a peak or off-peak period.

Second, when the relay switches on and off, it causes a considerable variation in the voltage across the 470µF main filter capacitor.

For example, we measured a voltage of 16.1V across this capacitor when the relay was energised (on), but around 18.2V when the relay was off – a variation of more than 10%.

In contrast, the measured averaged voltage across VR1 was 3.7V with the relay on and 3.8V with the relay off, a variation of just over 2.5%.

This is important because in the worst case, the brownout detector needs to respond to an actual variation in the mains voltage from 216VAC (the normal minimum mains voltage) to 200VAC (the switching threshold).

This is a variation of only 7.5% and we don't want the circuit being confused by variations in the supply waveform.

Trimpot VR1 is included so that the sample voltage fed to IC1a (which is connected as a unity-gain buffer) can be set to exactly 1/100th of the mains AC voltage value.

To give an example, if the mains voltage is 230VAC, VR1 is adjusted so that the DC voltage at the output of IC1a (ie, at TP1) is exactly 2.3V. This is part of the calibration procedure and just why we do this should become clear shortly.

The voltage at TP1 is fed to the non-inverting input (pin 5) of IC1b, which is connected as a comparator.

A nominal 3.9V reference voltage is provided by zener diode ZD1, which is fed via a 560Ω resistor from the +12V supply.

Trimpot VR2, connected across VR2 sets the switching threshold for IC1b, with its wiper connected to IC2b's inverting input (pin 6) and to TP2. This allows the voltage at pin 6 to be set to about 2.0V, representing a brownout threshold detection point of 200VAC.

So with a normal mains voltage, the voltage at pin 5 of IC1b will be 2.3V (230VAC÷100). This voltage is higher than the 2.0V at pin 6 and as a result the output of IC1b will be high (close to +12V). This switches on transistor Q1, which powers relay RLY1.

The relay contacts then supply power to the appliance connected to the *Brownout Protector's* output cable.

When IC1b's output is high, diode D3 will be reverse biased and so the 100kΩ resistor connecting back to pin 5 has no effect on circuit operation.

However, should the mains voltage drop just below 200VAC, the voltage at pin 5 of IC1b will go below the 2.0V threshold set at pin 6, and so output pin 7 will go low. This will switch off transistor Q1 and the relay, disconnecting power from the appliance connected to the output cable.

Diode D2 quenches the back-EMF from the relay coil when its magnetic field collapses, protecting Q1 from damage.

Simultaneously, transistor Q2 switches on to light the brownout indicator LED2 – connected to the +12V supply via a 2.2kΩ resistor.

## Hysteresis

When IC2b's output is low, diode D3 conducts and pulls pin 5 even lower than 2.0V due to the voltage divider action of the 100kΩ and 10kΩ resistors.

For example, if the voltage at TP1 is at slightly less than +2.0V, the output of IC1b will be very close to 0V. The anode of D3 will be at about +0.6V and so the divider action caused by the 10kΩ resistor connecting to +2.0V and the 100kΩ resistor connected to +0.6V will give a voltage at pin 5 of ((2.0-0.6V) × 100÷110) + 0.6V, or +1.87V.

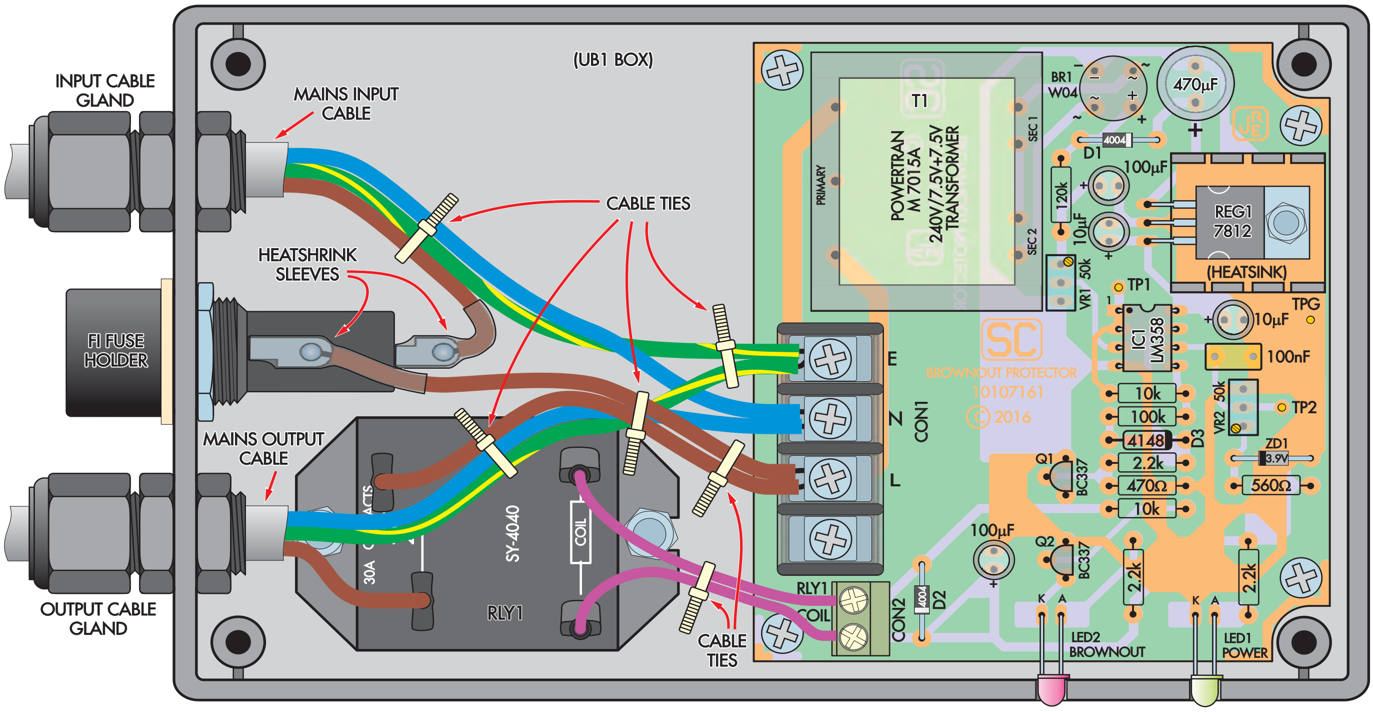


**Fig.2: same size diagram showing the component overlay on the PCB, along with the mounting of the board and various hardware in the UB1 jiffy box. Note the extensive use of cable ties to hold mains wiring securely in place.**

This is a drop in voltage of 130mV.

So instead of pin 5 now being at +2.0V, the action of the 100kΩ resistor, diode D3 and the 10kΩ resistor reduces the voltage by about 130mV, to +1.87V.

Before IC1b's output can go high again, the mains voltage would have to rise by the extra amount to make up this 130mV difference. This requires an increase in mains voltage of 13VAC, to around 213VAC.

In practice, because the average voltage at TP1 is higher when the relay is off compared to when it is on, the extra voltage required from the mains for the relay to switch back on again is around 10VAC.

This voltage difference effect is called 'hysteresis', and is included to prevent the relay from rapidly switching on and off at the brownout threshold.

Provided the mains voltage remains below the brownout threshold, the relay will remain off. In fact the relay remains off at any voltage below the threshold level, including voltages down to 0VAC (ie, a true blackout).

A power-on delay is included so that the relay only switches on about five seconds after power is applied.

This delay is due to the values of the 120kΩ and 100µF filter components that monitor the average voltage from rectifier bridge BR1.

These are sufficiently large so that it takes time for the 100µF capacitor to charge up to above the voltage provided at TP2.

This delay is also important to allow for the inevitable momentary drop in mains voltage caused by high surge currents every time an induction motor starts up.

Normally, these high currents only last a second or two, depending upon the appliance – and we want to be sure that they do not cause the *Brownout Protector* to erroneously switch off the power.

## Construction

The *Brownout Protector* is housed in a low-cost UB1 jiffy box, measuring 158 × 95 × 53mm. All of the parts except for the mains fuseholder and mains switching relay RLY1 are mounted on a small PCB, available from the *EPE PCB Service*, coded 10107161 and measuring 85 × 76mm. This mounts inside the right-hand half of the box, using four 15mm-long M3 tapped nylon spacers and eight M3 × 6mm-long screws.

Because this is a mains device, it's essential to use nylon spacers and relatively short screws to maintain insulation integrity between the inside of the box and the outside world.

Relay RLY1 mounts in the left-hand half of the box, using two M4 × 10mm-long nylon screws, flat washers, lockwashers and M4 hex nuts.

Two cable entry glands, used to secure the mains input and output cables, mount in the end of the box, with a 3AG safety fuseholder between them.

The live (brown) wire from the mains input cable solders directly to one of the fuseholder terminals while the other fuseholder terminal is connected to the *Brownout Protector's* PCB via a short (50mm) length of mains (brown) cable, cut from the input cable.

Both soldered joints are covered with heatshrink sleeves for safety.

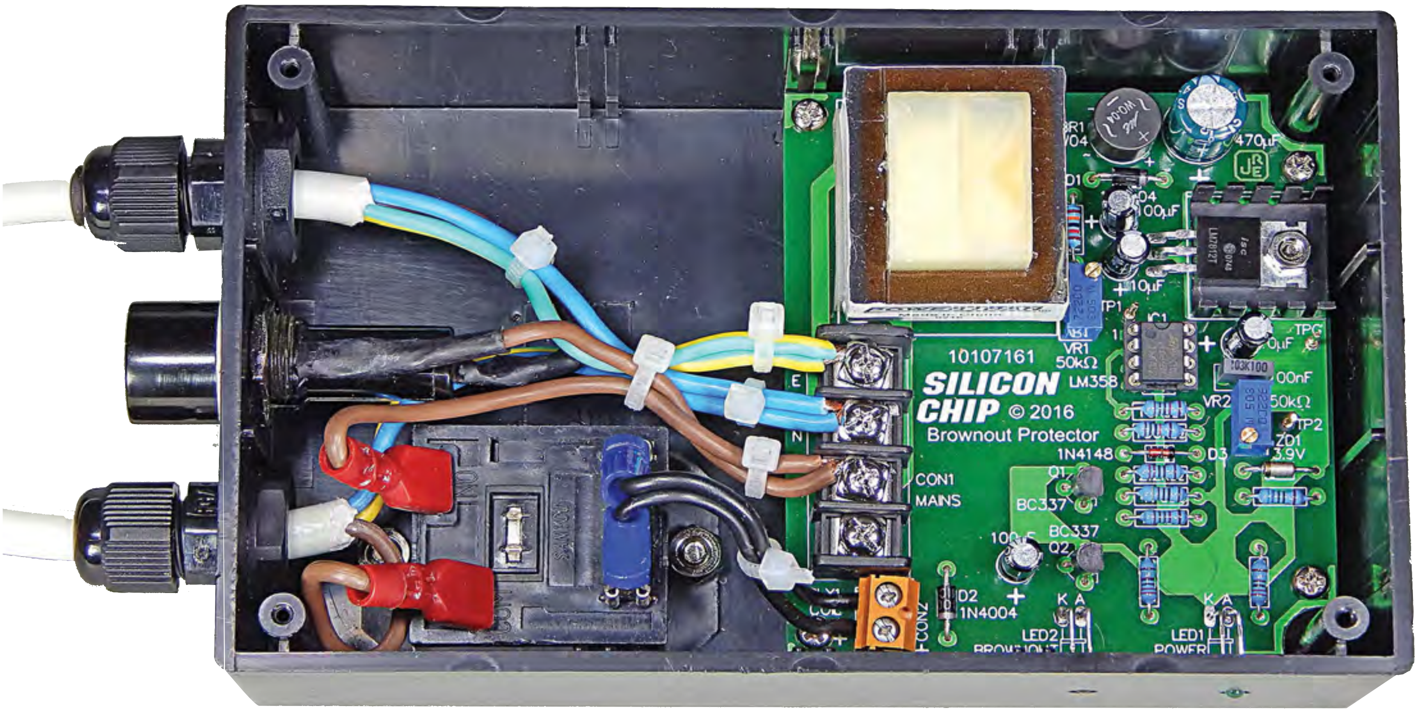
All connections between the input and output cables and the *Brownout Protector's* PCB are made via a four-way barrier terminal strip – although only three of the terminals are actually used.

The mains live connections to the contacts of RLY1 are made using 6.5mm insulated crimp connectors, which slide down over the relay contact lugs.

The connections to the coil of the relay (RLY1) are made via two short leads terminated with 4.8mm insulated crimp connectors at the relay ends, and connecting to a small two-way terminal strip (CON2) at their PCB ends.

All of these off-board wires are secured together using cable ties, as shown in both the overlay/wiring diagram of Fig.2 and the photograph alongside.

Also shown in this diagram and photo are the two indicator LEDs, which are mounted near the front edge of the PCB with their leads bent by 90° so that




**Here's a photo showing the same things as the drawing at left. All exposed mains wiring (eg, to relay, fuse) is insulated with either appropriate crimp connector shrouds or, in the case of the fuseholder, heatshrink tubing.**

the LEDs become visible via two 3mm holes drilled in the front of the box.

This overall assembly setup should all be fairly clear from the internal photos, along with the overlay/wiring diagram.

### Building it

Begin construction by fitting all of the components to the PCB in the usual order: first, the fixed resistors, followed by the non-polarised capacitor and then the polarised electrolytic capacitors – making sure the latter are fitted with the correct orientation.

After this, mount the diodes (again watching their polarity) and bridge BR1, followed by transistors Q1 and Q2 and then IC1.

Next, fit regulator REG1, which mounts horizontally on a small U-shaped heatsink with its three leads bent down by 90° at a distance of 7mm from the body of the device so they pass down through the matching holes in the PCB. A 10mm-long M3 screw and nut are used to clamp the tab of REG1 to the heatsink and also both of them to the PCB.

Now solder the two trimpots to the PCB, orienting them as shown in Fig.2. Then fit the four-way barrier terminal strip CON1, making sure all four of its connection pins are soldered securely to the pads under the PCB so the terminal strip is held firmly in place.

Install the smaller two-way terminal block CON2 for the relay coil connections, along with the pair of wires connecting this and the relay coil. While this connection is low voltage, the wire is in an area with lots of mains connections, so its insulation should be rated at 250V.

This is followed by the largest component of all: power transformer T1. Take care again to solder all seven of its connection pins to the pads under the PCB, so the transformer will be held firmly in place.

The final items to be fitted to the PCB are the two LEDs, which should each have both their leads bent down by 90° at a distance of 9mm away from the body. These are then soldered to the appropriate pads on the PCB with the axis of the LEDs and their leads as close as possible to 7.5mm above the PCB. This is to allow them to protrude slightly through the matching holes in the box after final assembly.

When you are bending the LED leads before soldering them to the PCB, you need to make sure that they're being bent the correct way – so the longer anode lead of each LED will be able to pass through the right-most hole in the PCB.

Your PCB assembly can be placed aside while you prepare the box for final assembly of the project as a whole.

There are only 11 holes to be drilled in the main part of the box. You'll find full details of all of the holes in the drilling diagram, which you can download from the *EPE* website.

We suggest you drill all the holes first with a 3mm drill, then enlarge holes D with a 3.5mm drill and holes E with a 4mm drill. You can also enlarge holes B and hole C at the same time, and then use an 8mm drill to enlarge them further. Then holes B and C can be enlarged to their final sizes of 12.5mm and 15mm using either a 'stepped' drill bit or a tapered reamer.

When all holes have been drilled, remove any swarf on both sides of each hole using a countersink bit or a small rat-tail file.

Although there are no holes to be drilled in the box lid, you might like to attach to it a small dress panel like the one in our photos. The artwork for this is shown in Fig.3, or it too can be downloaded and printed in colour from the *EPE* website.

We printed this out on plain paper, hot laminated it and then cut it out to size using sharp scissors. Then it was attached to the box lid using thin double-sided adhesive tape (spray adhesive also works well).

### Final assembly

The final assembly should not give you any problems if you do the steps in the following order.

First, mount relay RLY1 in the bottom of the box on the left, with its larger staggered mains connection lugs towards the left, as shown in Fig.2. Secure it in position using two M4 × 10mm nylon machine screws with flat washers, lockwashers and nuts above each of the relay's mounting flanges. Make sure you tighten both screws up firmly using a screwdriver and nut driver or spanner.

Now fit the four M3 tapped 15mm-long nylon spacers to the bottom of the box on the right, using M3 × 6mm screws passing up through holes A from underneath. Do not tighten these screws up too firmly at this stage though, because the spacers may need to be nudged slightly during the next step, which is to lower the PCB assembly down into that side of the box until it's sitting on the spacers.

Make sure you don't damage the two LEDs or bend their leads too much when you're lowering the board into place. It should now be possible to line up the LED bodies with the holes in the front of the box and just poke them through so they can be seen from outside the box.

You should now be able to fit the four remaining M3 × 6mm screws near the corners of the PCB, to mesh with the holes in the tops of the four spacers, thus fastening the PCB assembly in position. Complete the tightening of the lower screws as well, to ensure that the PCB assembly is firmly locked in place.

Now fit the two cable glands into holes B in the left-hand end of the box, fastening them in position using a pair of small spanners – one to hold the hex nut moulded into the body of the gland, and the other to turn the actual mounting nut on the inside.

Now you can fit the safety 3AG fuseholder into the 15mm diameter hole in the centre of the left-hand end of the box, tightening up its mounting nut with a small spanner while holding the fuseholder's outer barrel with your hand so it doesn't rotate far enough to make its connection lugs too difficult to access for soldering the active wires.

Next, take the 3m-long 230V/10A extension cord and cut it in to two equal lengths. The half with the 3-pin plug on the end will be used for the *Brownout Protector's* input cable, while the other half (with the 3-pin socket) will be used for the output cable.

Cut off a length of around 150mm from the cut end of the input cable, which will be used to provide the two short lengths of brown (live) mains lead for making the connections between the fuseholder, barrier terminal strip and one of the relay contact lugs.

Now remove about 90-100mm of the outer sheath from the cut ends of both


**An extension cord is cut to form the mains input and out leads.**

the input and output cables, freeing the three internal wires. Remove 10-15mm of insulation from these six wires.

Then remove the outer clamping 'nuts' from the two cable glands, and slip each nut onto one of the cut ends of the cables (outer end first).

After this, you need to push the end of each cable into and through its corresponding cable gland, until about 10mm of the cable's outer sheath is protruding through the gland into the interior of the box.

Then bring the outer clamping nut for that gland back up the cable and thread it back onto the gland's outer thread, tightening it up to make sure the cable is being clamped securely in that position and can't be pulled out. This should all be repeated for the second (output) cable.

(If you want to prevent any possibility of the gland becoming loose and not providing proper cord anchorage, you can put a drop of super glue on the thread before tightening the nut.

But don't do this until you have made sure the project is fully working because it will make the nut impossible to remove.)

Next, cut off about 40mm from the input cable's brown (live) lead and strip off about 6mm of the insulation from the end of the remainder.

This will allow it to be soldered to the rear lug of the fuseholder – but first, slip a short length (say 20mm) of 5mm-diameter heatshrink sleeving over the lead and slide it up to the end near the cable's outer sheath. This is to avoid it shrinking prematurely.

Solder the end of the lead to the fuseholder lug, and after the solder joint has cooled down you should be able to slide the heatshrink sleeve back up the lead until it has covered both the joint and the metal lug. Then apply heat to the sleeve using the side of your soldering iron's tip (without touching it), so that it shrinks securely in position.

A similar job needs to be done on the brown (live) lead of the output cable, only in this case it needs to be shortened by about 50mm, again with 6mm of the insulation stripped from the remainder, and then fitted with a 6.5mm insulated crimp connector to attach to one of the relay contact lugs.

The blue (neutral) and green/yellow (earth) are all left at their full length of 90-100mm, but with about 12mm of insulation stripped from the end of each one.

The bared wires of the two earth leads should then be twisted tightly together. The same needs to be done with the two neutral leads.

They should then be fitted under the clamping plates of the matching terminals on the barrier strip, after the screws have been loosened. The Earth leads need to be fitted under the rearmost 'E' terminal screw, of course, while the neutral leads go under the next 'N' screw.

Make sure you retighten each screw firmly after the wires are in place under the screw's clamping plate.

The next step is to remove the brown (live) lead from the 150mm length of cable you cut from the 'input' cable earlier, and cut it into two 75mm lengths. One of these will be used to make the lead connecting from the side lug of the fuseholder to the live (L) terminal of the barrier strip, while the other will be used to make the lead connecting the same barrier strip terminal to the second contact lug of RLY1.

It's probably easiest to strip 6mm of insulation from one end of each lead, and 12mm from their other ends.

The shorter bared end of one lead will then be soldered to the side lug of the fuseholder, with another 20mm length of 5mm heatshrink sleeving slipped over the joint and lug once they have cooled down, then heated once more to shrink over them securely.

The bared end of the other short brown lead should then be fitted with a 6.5mm insulated crimp connector, to attach to the second contact lug of the relay.

Finally the wires on the 12mm bared ends of these two short live leads should be twisted tightly together and then clamped under the 'L' terminal screw of the barrier strip.

Finally, cut two 60mm lengths of insulated hookup wire, strip off about 6mm of insulation from both ends, and then fit one end of each wire with a 4.8mm insulated crimp connector to mate with the coil lugs of RLY1.

The other end of each wire should be clamped under one of the two screw terminals on the smaller terminal strip (CON2) at the left front of the PCB.

All of your off-board wiring will then be complete, and all that remains is to fit about six cable ties to the leads to prevent them from 'wandering' if one of the solder joints, screw terminals or crimp connectors should come adrift.

The suggested positions of these cable ties are shown in Fig.2.

Unscrew the front insert of the fuseholder and fit it with a 10A slow-blow 3AG fuse cartridge and then screw it all back together again.

Don't attach the lid to the box yet, because the two trimpots on the PCB still need to be adjusted to set up the *Brownout Protector* correctly.

### Setup procedure

There's not a great deal involved in setting up the *Brownout Protector*, but you are going to need at least one good digital multimeter (DMM) – and ideally two of them.

**As the setting up must be done with the lid left off the box, be very careful while you're doing it. Be especially careful not to touch either the live (L) or neutral (N) screw terminals on the barrier strip – this could be fatal!**

All other 'bitey bits' should of course be shrouded or covered in heatshrink.

Plug the *Brownout Protector* input cable into a convenient power outlet and switch on the power. You should see LED1 glowing to show that the circuit is powered up. Don't worry too much about whether LED2 also glows, or if you hear the relay click on instead.

But if you want to make sure that the power supply circuit is working correctly, you can use your DMM (set to measure say 20V DC) and check the voltage between test point TPG and pin 8 of IC1.

If you get a reading of +12V, this will confirm that all is well.

Next, set your DMM to measure at least 250VAC and very carefully touch the tips of its test leads to the screws of the 'L' and 'N' terminals on the main barrier strip, making sure you don't


**The two LEDs are mounted at right-angles to the PCB so they just poke through appropriate holes drilled in the side of the case. For a detailed case drilling diagram, go to the *EPE* website.**

## Parts List

- 1 Double-sided PCB 85 × 76mm, available from the *EPE PCB Service*, coded 10107161
- 1 UB1 size jiffy box, 158 × 95 × 53mm
- 1 240V-to-15V power transformer, 3VA, PCB mounting
- 1 SPST relay with 12V coil and 30A/230V contacts
- 2 M4 × 10mm machine screws, nuts, flat washers and lockwashers
- 2 6.5mm spade connectors (for relay contacts)
- 2 4.8mm spade connectors (for relay coil)
- 1 Panel-mounting 3AG fuseholder, 'very safe' type
- 1 10A slow-blow 3AG fuse cartridge
- 2 Panel-mounting cable glands for 3-6.5mm diameter cable
- 2 20mm lengths of 5mm heatshrink sleeving
- 6 Nylon cable ties, 100-150mm long
- 1 3m long 230V 10A extension cord *(cut in half to use for the Protector's input and output cables)*
- 4 15mm M3 tapped nylon spacers
- 2 10mm M3 nylon machine screws
- 8 6mm M3 machine screws
- 1 10mm M3 machine screw
- 3 M3 hex nut
- 1 U-shaped TO-220 heatsink, 19 × 19 × 9.5mm
- 1 4-way PCB-mounting barrier terminal strip
- 1 2-way PCB-mounting terminal block
- 3 1mm PCB terminal pins

**Semiconductors**
- 1 LM358 dual op amp, DIL8 (IC1)
- 1 7812 12V regulator (REG1)
- 2 BC337 NPN transistors (Q1, Q2)
- 1 3mm green LED (LED1)
- 1 3mm red LED (LED2)
- 1 W04 400V/1A bridge rectifier (BR1)
- 2 1N4004 1A diodes (D1, D2)
- 1 1N4148 signal diode (D3)
- 1 3.9V 1W zener diode (ZD1)

**Capacitors**
- 1 470µF 25V RB electrolytic
- 2 100µF 16V RB electrolytic
- 2 10µF 16V RB electrolytic
- 1 100nF MKT polyester

**Resistors** (1/4W, 1%)
- 1 120kΩ   1 100kΩ   2 10kΩ
- 3 2.2kΩ   1 560Ω   1 470Ω
- 2 50kΩ multi-turn vertical trimpots

touch these yourself in the process, or touch them together. Note the reading and then remove the test leads.

Now set the DMM to DC volts, and clip its leads to test points TPG and TP1, to measure the voltage between them. You're aiming to get a reading here of 1/100th the AC mains voltage you just measured, ie, 2.30V DC if your measured mains voltage was 230VAC.

The odds are that the reading you get will be some distance away from this correct figure, either higher or lower.

Not to worry though; all you need to do is adjust trimpot VR1 (just to the right of transformer T1) until the voltage reading rises or falls to the correct figure or as close as possible to it.

Since the mains voltage can vary somewhat at different times of the day, the above measurements of the mains voltage and the DC voltage at TP1 should ideally be done at the same time – using two different DMMs.

However, if you only have a single DMM just try to make one measurement soon after the other and perhaps re-check them both again after you believe you've found the right setting for VR1.

Just make sure you remember to reset the DMM correctly to change from high voltage AC to low voltage DC, and vice-versa!

The remaining setup adjustment is even simpler. All that's needed is to clip the DMM test leads to test points TP2 and TPG and adjust trimpot VR2 until you get a reading of 2.0V.

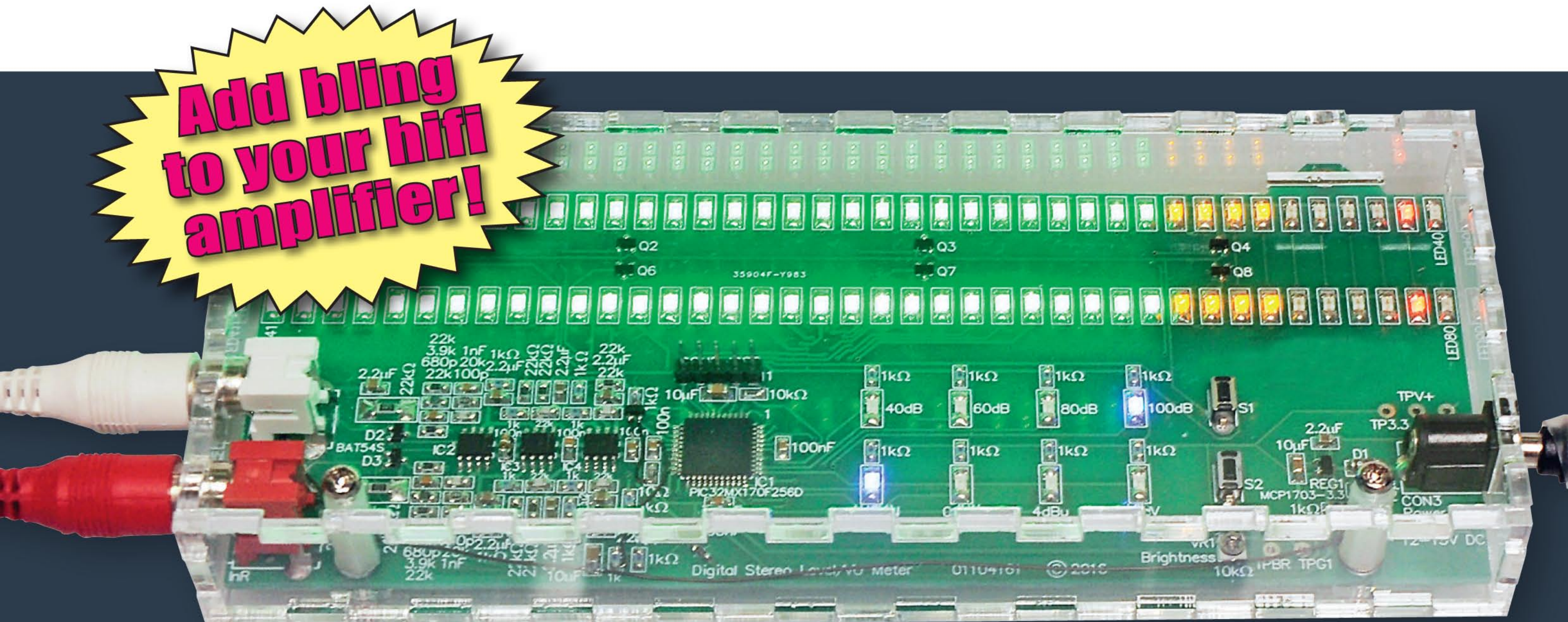
(If you want the brownout voltage threshold to be other than 200VAC, set this to 1/100th the voltage you want).

Once this second setup adjustment has been made, you can turn off the power, remove the DMM test leads and then screw the lid onto the *Brownout Protector's* box to complete assembly.

Your *Brownout Protector* is now ready to begin protecting the induction motor from damage in the event of one of those nasty power brownouts.




**Same-size 'cover all' front panel artwork for the *Brownout Protector*, to fit a standard UB1 jiffy box. If you prefer, you can cut out the inner (gray) section and centre that on the lid. (This panel, along with a hole drilling diagram, can be downloaded from the *EPE* website.**




# 100dB Stereo LED Audio Level/VU Meter

Part 2: By Nicholas Vinen

**Last month, we introduced our new *Audio Level/VU Meter* which uses 80 high-brightness SMD LEDs to give a colourful dual-bargraph display showing average and/or peak audio levels. It has a number of useful features, such as adjustable dynamic range, reference level and LED brightness. This article deals with assembling it and explains how to set it up and use it.**

AS DESCRIBED in Part 1 last month, the meter is based on a 32-bit PIC processor driving 88 bright SMD LEDs. It has an analogue front end. Processed signals are delivered to the PIC's analogue inputs, to be converted to digital format by its internal ADC so that the signals can be analysed by the software.

Having gone over the details of its operation, let's move straight on to building the PCB.

### Construction

The PCB overlay diagram is shown in Fig.4. All parts are fitted to this board, with most being surface-mount devices (SMDs). The exceptions are connectors CON1-CON4 and switches S1 and S2. All of these through-hole components can be mounted off-board (eg, chassis-mounted) and connected via shielded cables (for CON1 and CON2) or twin lead (eg, figure-8, for CON3, S1 and S2) – see below for more details. If doing this, these components are left off the PCB and PC stakes can be fitted to the test points near the DC socket for wire termination.

Start construction with the SMD components. It's best to fit IC1 first, as it has the finest lead pitch of any of the SMDs on this board, although it is not too daunting as the pins have a relatively generous 0.8mm pitch on a 10 × 10mm package.

There are various valid techniques for hand-soldering SMDs as well as other methods involving toaster ovens, frying pans and so on. Our preferred technique (as long-time readers will no doubt be aware) is to first place a small amount of solder on one pad, heat this while sliding the part into place, check its orientation and that all the pins are correctly centred over their pads, then solder the remaining pins before finally refreshing the initial joint.

Take your time doing this with IC1, and be careful to ensure that its pin 1 dot is in the location indicated on Fig.4 and that all its pins are nicely aligned before soldering more than one. Spreading a thin layer of no-clean flux paste over the pads aids in soldering. Don't worry too much about bridging the pins – in fact, it's easier if you simply place some solder on the iron and run it along the side of the IC to solder a whole bunch of pins at once.

You can then clean up the bridges by adding a little extra flux paste and then gently applying some solder wick

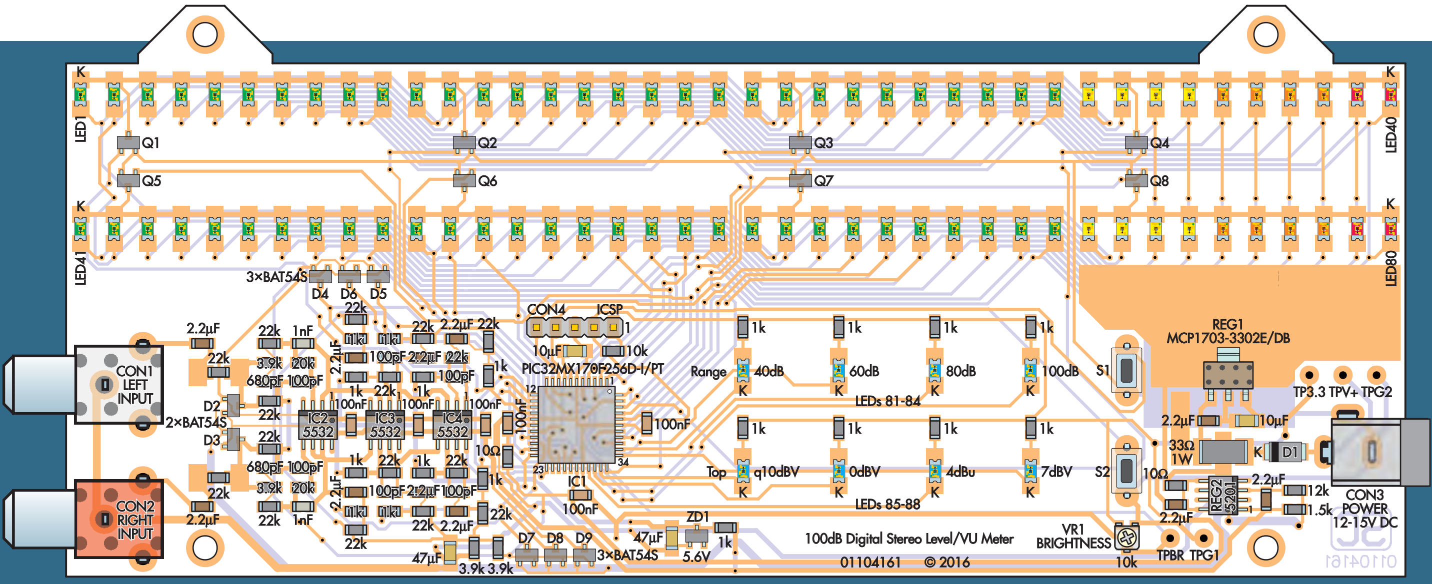



**Fig.4: follow this parts layout to build the *Stereo Level/VU Meter*. Most parts are SMDs and all are fitted to the top side of the board. Microcontroller IC1 has a 0.8mm pin pitch, while the remaining parts have wider-spaced pins. Take care when fitting the LEDs to ensure they have the correct orientation and that they are lined up neatly.**

and heating it until the excess solder flows off the IC pins and into the wick. Repeat until all the pins have been properly soldered. It's a good idea to then inspect the joints under a magnifying lamp after cleaning off any flux residue with pure alcohol or a specialised flux cleaning solution.

The remaining ICs, including REG1 and REG2, can be soldered using a similar technique, although their pins are far enough apart to be soldered individually. Note that if IC2, IC3, IC4 or REG2 lack a dot to indicate pin 1, you should be able to identify it as being on the chamfered side of the package. For REG1, it's easiest to solder the smaller pins first and then the tab, as the tab will require significant heat (and thus time) to solder. It helps to spread some solder paste on the large pad for the tab before sliding REG1 in place.

With the ICs soldered, follow with D1 and ZD1, ensuring that D1's cathode stripe goes to the left, as shown in Fig.4. You can then solder transistors Q1-Q8 and diodes D2-D9 in place, making sure you don't get them mixed up as they are in identical packages. Follow with all the capacitors and resistors, none of which are polarised. Note that the resistors will have value codes printed on top (eg, 223 = 22kΩ) while the capacitors will be unmarked.

The 10µF and 47µF capacitors may be a larger size than the others and larger pads are provided to accommodate these. Similarly, the two 22kΩ resistors in the input divider are larger than the others (in case they have to dissipate more power in a fault condition) and the 33Ω 1W resistor is larger again.

Next, fit VR1, unless you are going to mount an external brightness pot. Try to avoid getting solder on its metal body as the flat pins cover most of the pads and are quite close to the body.

### Installing the SMD LEDs

In terms of SMDs, that just leaves the LEDs. The first job to do is to check their polarity. All the LEDs we used (which are the same types as we will be supplying) have green cathode dots. However, some LEDs have green anode dots so you should confirm this. To do this, set a DMM on diode test mode and touch the probes to either side of one of the LEDs. If they make good contact and the polarity is correct, the LED will light up. In this case, the red lead is on the anode.

If nothing happens, try flipping the LED around (or reversing the leads). You should get it to light up with one polarity, although it's possible some DMMs will not have enough bias voltage to light some LEDs (eg, blue).

It's a good idea to do a reasonably neat job of soldering LEDs81-88, centring them on their pads and making sure they are not fitted crookedly, but it's absolutely critical for LEDs1-80 if you want the bargraphs to look good. The first trick to doing a neat job is to solder all the LEDs at one end and inspect them critically before soldering the other ends. This gives you the possibility of nudging any LEDs which are misaligned compared to the others.

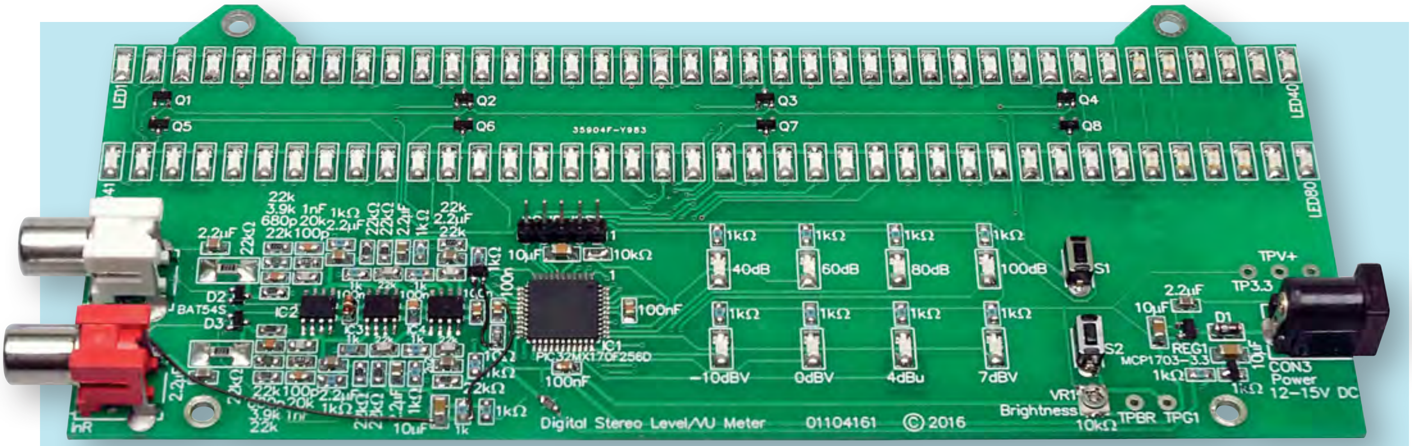
Don't forget that the cathodes for LEDs81-88 face the bottom of the PCB, while the cathodes for LEDs1-80 face the top. Reversing the polarity of LEDs en masse is possible but time consuming!

We aligned the main bargraph LEDs by hand and while close inspection reveals that a few are slightly askew, this really isn't obvious when viewing the device during operation. If you want them perfectly aligned, the best solution may be to clamp a straight edge parallel to the top of the PCB so that you can push the LEDs up against it and have them located evenly between the pads and square with them.

It would then just be a matter of sliding them until they were centred and soldering the far side. Once they're all in place, you can remove the straight edge and solder the other ends. Note that SMD LEDs are easier to solder if you've first applied a little flux paste to the pad and/or terminal. Don't overheat the plastic lenses though, they can be burnt quite easily – we strongly advise *against* using a hot air reflow tool in their vicinity.

### Through-hole parts

Assuming you are fitting them, push switches S1 and S2 down fully onto the PCB and solder their leads. Alternatively, you could fit PC stakes to their mounting pads, or simply solder wires direct to the PCB. DC connector CON3 should also be pushed down fully before soldering or, as stated earlier, connect supply leads to TPV+ and TPG2.




**This view shows the prototype PCB assembly. Take extra care when installing the LEDs and ICs to ensure they are all oriented correctly. We used green LEDs for LEDs 1-30 and 41-70, yellow for LEDs 31-34 and 71-24, amber for LEDs 35-38 and 75-78, red for LEDs 39-40 and 79-80 and blue for LEDs 81-88.**

If your microcontroller has been supplied pre-programmed you don't need to fit CON4. Otherwise, solder it in place in the usual manner. Alternatively, it can later be fitted to the rear of the PCB if necessary.

That just leaves RCA sockets CON1 and CON2. If using the RCA sockets supplied by Silicon Chip, you will need to bend the two side pins out to make them fit the pads (see photos of our prototype). We supply them in a pack of four, including white and red; unfortunately, white RCA sockets are hard to find. Alternatively, you could use different colours (eg, red and black). Regardless, make sure they are pushed down fully and properly perpendicular to the edge of the board before soldering the pins.

If you don't want to use sockets, solder the braid of a length of shielded cable to the central pin and the signal wire to the terminal closer to the top edge of the board.

### Programming the micro

If you don't have a pre-programmed micro, you will need a PICkit 3 (or equivalent) and the HEX file from the *EPE* website. The Microchip MPLAB Integrated Programming Environment is a free download from the Microchip website. Enter the chip type, connect to the programmer, then go into advanced mode and under 'Power' options, enable 'Power Target Circuit from Tool'.

You can then go back to 'Operate', click on the 'Browse' button next to 'Source' and select the HEX file. Plug the PICkit 3 into CON4 on the PCB, with the triangle on the programming tool lined up with the pin 1 indicator on the PCB. Press the 'Program' button and after 20 seconds or so it should announce that the chip was successfully programmed and verified. You can then unplug the tool.

If programming fails, check that the solder joints on IC1 are OK, along with those on the four capacitors surrounding it. Check also that you have enabled power from the PICkit 3 (at 3.3V or so) and that it has been correctly plugged into CON4 and is not offset or reversed.

### Chassis-mounting connectors and/or controls

If fitting the *VU Meter* assembly inside a power amplifier chassis, you may be able to do without connectors altogether, although they do make installation somewhat more convenient. In this case, CON1 and CON2 can be wired directly to the amplifier outputs. Similarly, CON3 can be omitted and TPV+/TPG2 wired directly to a regulated 12-15V DC supply within the amplifier.

Be careful to avoid creating a ground loop involving the signal grounds and power ground connections. Ideally, the power supply should be floating and if necessary, derived from a dedicated transformer secondary winding (or separate transformer).

We also recommend that you avoid using a DC supply that's also used to power a preamplifier. That's because the pulsed current drawn by the *VU Meter* might affect the preamp's performance. The ideal solution is a small, separate rectifier/filter/regulator based on, say, a 7812 and powered from a separate low-voltage winding on the transformer. It only needs to be able to deliver 150mA.

If you can't use a floating supply, make sure there is no difference in ground potentials between the supply for the *VU Meter* and the amplifier outputs. Also, if the amplifier outputs are bridged, do not connect the negative output to the inputs of the *VU Meter*. Instead, wire these inputs to ground and keep in mind that the input signal swing will be half of the amplifier output swing (ie, 3dB lower).

Switches S1 and S2 may be mounted off-board if desired, so that they are accessible outside the chassis, although in cases where the inputs are hard-wired to amplifier outputs, you probably won't need access to S2. In this case, the unit will normally be used with a fixed reference level of +7dBV.

VR1 can also be mounted off-board so that the brightness adjustment can be easily accessible. Any potentiometer of approximately the same value should be fine. Wire its wiper to TPBR, the bottom of the track (anti-clockwise) to TPG1 and the top of the track (clockwise) to TP3.3.

### Testing

Ideally, the unit should be powered for the first time with a current-limited power supply. If you have a bench supply, set it for 12V with a limit of 200mA. Otherwise, you could use a 15V regulated (or 12V unregulated) plugpack wired with a 47Ω 5W resistor in series. Apply power and check that LED81 (40dB) and LED86 (0dBV) are lit. A quick press of S1 and S2 should cycle the lit LEDs.

The current drain should be around 50mA. If using a series resistor, you can check this by measuring the voltage across the resistor (eg, ~2.35V across 47Ω). When LED84 (100dB) is lit, you may find some of the bottom segments of the bargraphs light up. This

| Table 1: Display modes | | | |
|---|---|---|---|
| **Mode** | **Averaging** | **Display** | **LEDs flashing** |
| 1 (default) | RMS | average bar + peak dot | LED81, LED85 |
| 2 | RMS | average bar only | LED81, LED86 |
| 3 | N/A | peak bar only | LED81, LED87 |
| 4 | VU-style | average bar + peak dot | LED82, LED85 |
| 5 | VU-style | average bar only | LED82, LED86 |

is normal as the inputs are currently unterminated.

Check the voltage between TP3.3 and TPG2. It should be between 3.28V and 3.32V; a little lower or higher is OK. You may also wish to check the voltage across the 2.2µF capacitor to the right of REG2; it should be between about 10.8V and 11.5V. If it's above 11.2V, you may wish to consider shunting the 12kΩ resistor with a 470kΩ resistor (which can be soldered on top) to reduce it, to ensure the regulator won't enter drop-out with a supply voltage very close to 12V.

If using a series resistor to limit current, this will not permit the unit to draw enough current to light up all LEDs and continue to operate normally. So short out the resistor before performing further tests.

If you switch off the unit and hold down S1 while applying power, all LEDs will light up. You can use this feature to check that they are all soldered properly and operating normally. If any do not light up, check their soldering and orientation. If you need to remove an LED (eg, if it is faulty), you can do so by alternately heating the two pads until it lifts off. Then add a little flux paste and use solder wick to remove the remaining solder from the pad(s).

Assuming all LEDs are working, release S1 to exit LED test mode, then connect a signal source to the unit. You can then check that the bar displays are working normally and respond to presses of S1 and S2 as expected (use the instructions below as a guide).

## Operating instructions

The *Stereo LED Level/VU Meter* will fire up as soon as it has power and resumes the last used mode. You only need to use the controls to switch modes or to perform calibration.

A brief press of S1 will cycle to the next meter scale. The default is 40dB. Pressing S1 will change this to 60dB, then 80dB, then 100dB, then back to 40dB. The decibel level of the top-most segment remains the same, ie, this lights when the input signal reaches the reference level which is 0dBV by default. Pressing S2 cycles through the four available reference level options.

Initially, the display shows the average level as a bar, with a dot indicating the peak level. In some cases, the peak dot may coincide with, or be just above, the top of the bar so it will not be visible. Normal program material will typically have a 5-15dB difference between the average and peak, so there will normally be a significant separation.

You can change to a different display mode by pressing both S1 and S2 simultaneously, then quickly lifting off both. Refer to Table 1 for a list of the five available modes.

To adjust the bar brightness, simply rotate VR1. Note that the specified SMD trimpot does not have an end-stop, so if you turn it too far in one direction it will 'wrap around'. Note also that the minimum brightness setting gives about 5-10% duty cycle, which may not be all that dim, given how bright modern SMD LEDs are.

Further adjustments can be made using switches S1 and S2 to access the various set-up modes described below. The method to access these modes is summarised in Table 2.

## Noise nulling

The input noise level of our prototype unit is around –100dBV, although this depends on how the inputs are terminated, the LED brightness setting and how quiet the power supply is. With the unit set to 100dB dynamic range, a 7dBV reference level and average-only display, both bars should be totally unlit. However, if the meter is set to 100dB dynamic range and you select a lower reference level or enable peak metering, some of the segments will be lit all of the time, even with no signal.

If your signal source produces some noise, and most do, it will likely increase the no-signal reading and may even light one or more segments on the less sensitive ranges if it is particularly noisy.

In either case, you can null out the noise to give a blank display with no signal by simply hooking the signal source up, switching both units on and, with no audio output, holding down S1 for a little over half a second. LED84 ('100dB') will flash and the bars should drop to zero. If they don't, try again. Now introduce a signal and verify that the meters still light up as expected.

This works by storing the average and peak level measured when S1 is held down and these readings are subtracted from future measurements. If you want to cancel it and go back to showing the raw (unadjusted) reading, simply hold down S2 for at least half a second. LED88 ('7dBV') will flash and the display will go back to how it was before.

## 0dB calibration

If you want the unit to handle signals above 2.33V RMS, you will need to change the input divider. But if you want to make a small adjustment, eg, to set a reference level other than one of the four existing options, or to compensate for resistor error (including differences between the two channels), you can do that using the software's calibration feature.

A new reference level can be set for each channel in each of the four available 'slots' corresponding to LEDs85-88. When you set a new reference level, it overrides the pre-existing level for that slot. Before you set a new reference level, use S2 to select the slot in which you want to store the new level(s).

The easiest method is to feed a signal into both channels at the level you want for full scale, then switch the unit on with S1 held down. Before releasing S1, press S2 twice. LED86 will flash a few times. The signal level for both channels will be used as the new 0dB reference level for the currently selected slot.

Alternatively, if you do not have a signal generator that can produce the appropriate levels, you can adjust the reference level for a slot incrementally, in 0.1dB steps between –20dBV and +7.3dBV. Instead of pressing S2 twice before releasing S1, press it three times. LED87 flashes instead. Now, the

**Table 2: Summary Of set-up modes**

| Setting | Action |
|---|---|
| LED test | Hold down S1 while powering on |
| Relative LED brightness adjustment | Hold down S2 while powering on |
| Set noise null levels | Hold down S1 after power on for at least 0.5s |
| Cancel noise null | Hold down S2 after power on for at least 0.5s |
| Change average/peak hold period | Hold down S1 after power on, press S2 once (LED81 flashes), release S1 |
| 0dB calibration with reference signals | Hold down S1 after power on, press S2 twice (LED82 flashes), release S1 |
| 0dB calibration without reference signals | Hold down S1 after power on, press S2 three times (LED83 flashes), release S1 |

left-channel display (top-most bar) will be shown as usual, but the right-channel display will instead show the currently selected reference level.

This is achieved by lighting up a 12-LED section of the bar which moves up and down by one LED for each 1dB change in reference level. At the minimum setting of –20.0dBV, this bar will start at the bottom-most LED, so you can figure out the whole number of decibels by counting the number of LEDs before the bar starts. At the maximum setting of +7.4dBV, the bar will stop one LED from the top.

The fractional number of decibels is indicated by switching off one LED within the bar. If the number ends in .0, the second LED will be off. If it's .1, the third LED will be off, and so on until it's .9, in which case the second-from-last LED will be off. This may sound complicated, but once you see it in action, you should find it pretty easy to figure out.

A quick press of S1 will reduce the selected reference level by 0.1dB, while a quick press of S2 will increase it by the same amount. Because the left-channel bar operates normally, you can observe the effect of changing the reference level on the display, and adjust it for a particular level for a particular signal should you wish. Hold down S1 for at least half a second in order to set the level for the other channel. You can switch back and forth, adjusting the levels as required.

When you've finished, hold down S2 for at least half a second and the changes will be saved. The unit will return to its normal display. If you want to abort changing the reference level, simply pull power from the unit.

There's one extra function available in this mode: if you press S1 and S2 simultaneously (briefly), it will copy the level setting from the other channel to the currently selected channel. This makes it easy to set both channels to the same (or a similar) reference level.

### Changing the averaging/ peak hold period

When the unit is in VU mode (modes 4 and 5 shown in Table 1), the unit performs RMS averaging on each block of 1024 samples and then uses a ballistic simulation of a moving needle to provide the required 300ms settling time to 99% and 1-1.5% overshoot for a VU meter. But in the other modes, the average value is calculated by averaging one or more of the RMS amplitude results from the 1024 sample blocks.

By changing the number of values averaged, you can change the response time. The minimum is one block, representing around 25ms of signal, and the maximum is 40 blocks, ie, around one second's worth of data. Similarly, the peak value is calculated as the maximum peak value of between one and 40 blocks worth of data. You can change both values. Changing the peak calculation period will also affect the VU-style mode if the peak is shown.

To adjust these settings, simply hold down S1 while applying power, then press S2 once. LED85 should flash and you can then release S1. The averaging window size is shown by which of LEDs1-40 is lit; LED1 indicates averaging over one sample block, LED2 over two and so on. Similarly, LEDs41-80 show the peak period.

Initially, one LED will be flashing in the top row. Press S1 to reduce the averaging window size by one sample block or S2 to increase it. Hold down S1 for at least half a second to switch to the other row, to adjust the peak calculation period, and use S1/S2 to reduce/increase it. When finished, hold down S2 to save the settings and return to normal operation. To abort the changes, simply pull power to the unit.

### LED brightness adjustment

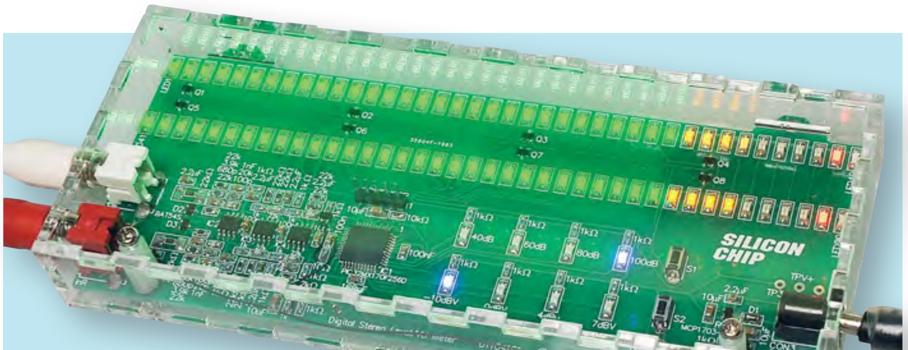
If you're using different colour LEDs which are reasonably well matched in terms of brightness, the display should look good without any further adjustment. However, if you're particularly fussy or using different LEDs which are not so well matched, you may find that some are noticeably brighter than others.

We have incorporated a feature to allow you to dim a subset of the LEDs in the display in order to match the brightness. There are a few limitations (explained below) but this method generally works quite well.

To access this setting, hold down S2 while powering the unit up, wait for at least half a second, then release it. Only LED1 and LED2 will be lit. They will be driven at maximum duty cycle, to allow you to compare the brightness of the two LEDs. Short presses of S1 and S2 change which pair of LEDs are lit, to the left and to the right respectively. Use these to light up the first pair of LEDs which have a significant difference in brightness.

You can then rotate VR1 to adjust their relative brightness until they appear to be matched. Use S1/S2 to move along until you find another pair of LEDs with mismatched brightness and adjust those too. Continue until you reach the final pair of LEDs for the left channel, LEDs39 and 40. At this point, pressing S2 will illuminate the entire top bargraph and the LED brightness will be adjusted based on the settings you have made so far.

You can now use VR1 to adjust the overall brightness of the bar. Note that if you have made more than one adjustment, because they are cumulative, you may find that the brightness matching is not perfect. You can now press S1 and make further adjustments before returning to the 'preview' mode. Continue until you are satisfied with the result, then use S2 to switch to the bottom bargraph and use the same procedure to match the brightness of its LEDs.



**The PCB assembly can be housed in a laser-cut clear acrylic case which is available from the SILICON CHIP Online Shop. The PCB, programmed microcontroller and other parts are also available from the Online Shop.**

Once you have selected a pair of LEDs and rotated VR1, the brightness offset for that pair remains adjusted. To clear this adjustment, select the pair of LEDs, then hold down S1 for at least half a second. They will be reset to their original state. Holding down S2 for at least half a second resets all LEDs to their default states and allows you to start the adjustment procedure from the beginning.

When you are satisfied with the result, press S1 and S2 together briefly and release them. The changes will be saved and the unit will return to its normal operating mode. Changes are stored in Flash memory so the unit will apply them each time it is powered on.

To make further changes to the relative LED brightness you will need to remove power and repeat the procedure. To disable this feature, re-enter the adjustment mode and hold down S2, then save the changes.

### Limitations

The limitations are as follows. First, any relative brightness adjustment will reduce the overall maximum brightness of the display. Second, the software supports up to four different brightness levels within each bank of 10 LEDs. Making adjustments that would require more than this will have undefined consequences. Also, making relative adjustments that are too extreme may result in a flickering display.

Finally, the signal-to-noise ratio of the unit and its ability to register very brief signal peaks may be slightly impacted by this feature.

### Laser-cut case

For those building the *Level/VU Meter* as a stand-alone unit, we have designed a clear acrylic case. It consists of six pieces that are glued and screwed together and is just a little bit larger than the PCB itself, giving a compact assembly.

All parts except for the lid should be glued using a specialised, solvent-type plastic adhesive. We used a tube of SciGrip 'Weld On' 16 fast-set clear, medium-bodied solvent cement.

Note that the PCB has two trapezoidal tabs at the top with mounting holes. These tabs are not required if using the laser-cut case and can be cut off using a fine-bladed hacksaw or similar tool (the sides of the tabs are squared to make this task easier).

Note that you can still get the PCB into the case with the tabs intact (as shown in our photos) but it looks a little odd and makes it much more difficult to remove the PCB later if that should be necessary.

The first step in assembling the case is to attach the PCB to the base. You can identify this as it is the large piece with two round holes and one rectangular slot. A small T-shaped piece of plastic is supplied and this is glued into the rectangular slot after removing the protective film from both pieces. This small piece forms a support for the top part of the PCB.

Two small square pieces with holes in the middle are also supplied. Remove their protective film and place them over the holes in the base. Feed a 10mm machine screw up through each pair of holes.

You can then drop the PCB down on top, with the two screws passing through the mounting holes at the bottom of the board. That done, place a pair of 3mm ID shakeproof washers on each screw shaft and then screw an M3 × 12mm tapped nylon spacer loosely onto each, holding the PCB in place. Make sure the square supports are oriented parallel to the edge of the board, then tighten the spacers up.

Now mock-assemble the case, with the protective film still on the remaining pieces, to ensure everything fits. You can temporarily fit the top panel to the two spacers using M3 x 6mm machine screws but don't do them up too tightly as they may prevent the sides from going on. Push the other four pieces into place and make sure everything fits. If it does, remove the top panel and take the protective coating off both sides, then screw it back on.

It's a good idea to keep a clean, disposable cloth on hand while gluing the case, to wipe off any excess glue quickly before it starts to set. Try to avoid getting the glue on any of the external faces of the case since it can cause hazing.

It's now basically just a matter of removing the protective film from the rear, front and lefthand (input side) pieces and gluing them in turn to the base panel and to each other. Coat all the mating surfaces with the solvent glue before pushing the panel into place and ensure it can't move until the glue hardens after 5-10 minutes. Full strength is achieved after 24 hours.

If you need to get the PCB out of the case, it will be necessary to slide it out, pulling the RCA socket barrels out of the holes in the lefthand side of the case. **To allow this, the righthand side piece should be glued not to the rest of the case but to the DC socket.** This will hold it in place but allow it to slide out with the board should you need to remove it (assuming you have cut off the top tabs). Like the rest of the pieces, its protective film should be removed before it's glued.

### Other case options

The meter could also be fitted into a case with a clear lid. In this case, you would simply need to fit tapped spacers to the four mounting holes on the PCB and either screw and seal or glue these to the base of the case. Alternatively, the PCB assembly can be fitted into an amplifier chassis, behind a clear window on the front of the unit, and attached via those same four mounting holes.

# Development Tool of the Month!

## MPLAB® ICD 3 In-Circuit Debugger


Part Number
DV164035

### Overview:

The MPLAB® ICD 3 In-Circuit Debugger System is the most cost effective high-speed hardware debugger/ programmer for Microchip's Flash Digital Signal Controller (DSC) and Microcontroller (MCU) devices. It debugs and programs PIC® MCUs and dsPIC® DSCs with the powerful, yet easy-to-use graphical user interface of MPLAB X Integrated Development Environment (IDE). The MPLAB ICD 3 supports target supply voltages from 2.0 to 5.5 volts and is powered by a USB port, so an external power adapter is not required.

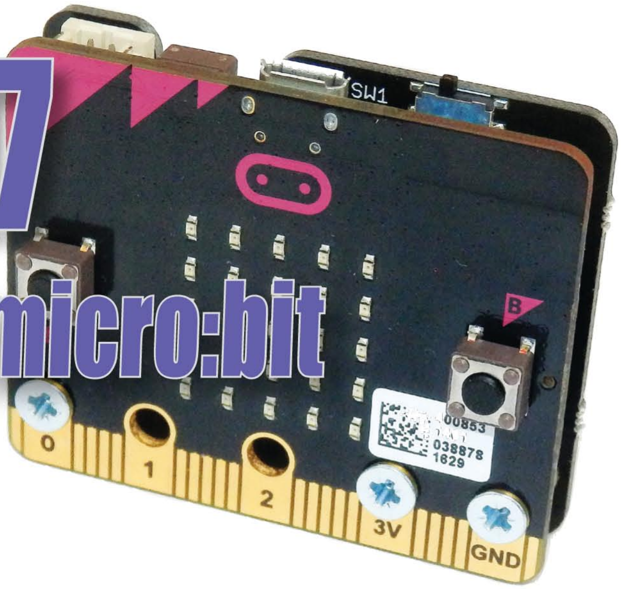
### Key Features:

- Real-time Powerful Debugging
- Ruggedized Probe Interface
- Microchip Standard Connectivity
- Portable, USB-powered and RoHS-Compliant
- High Speed Programming
- Low Voltage Emulation
- Test Interface Module

# Teach-In 2017

# Introducing the BBC micro:bit

## Part 2: micro:bit Mu editor




**by Mike Tooley**

**Welcome** to *Teach-In 2017 – Introducing the BBC micro:bit*. Following on from our popular *Teach-In 2016* series on the Arduino (and previously the Raspberry Pi), Mike Tooley has extended his investigation of low-cost microcontrollers to the recently introduced BBC micro:bit. Not just an educational resource for teaching kids coding, this tiny low-cost microcontroller provides you with yet another solution to the problem of controlling a wide range of electronic projects, ranging from simple domestic gadgets to more complex control systems such as those used for lighting, central heating and security applications.

To get you up and running quickly, each *Teach-In 2017* concludes with a simple but useful practical project. In this second part, Mike introduces the Mu editor, delves into some of the complexities of the MicroPython language and takes a detailed look at the micro:bit's I/O capability. Our practical project takes the form of an electronic spirit level. This handy gadget requires less than a dozen lines of code. We start this month by taking a brief look at the micro:bit's architecture.

## Micro:bit architecture

The architecture of the micro:bit is shown in Fig.2.1. It might at first appear deceptively simple, but there are several important features that you need to be aware of. The first of these is the arrangement for supplying power to the processor (IC1). This is a 3V device, and in normal operation the micro:bit's designers expect it to be powered from an external DC supply (eg, two series-connected 1.5V alkaline cells).

The USB processor (IC2), on the other hand, needs to operate with a 5V DC supply derived from the same USB connection. In this case, IC2 uses its own internal voltage regulator to provide the necessary 3V supply for IC1 as well as the accelerometer and magnetometer chips. Note that the USB interface is unavailable when the micro:bit is operated from an independent 3V supply.

A simple diode switch arrangement (see Fig.2.1) is used to connect an external 3V supply, but an external battery should *not* be connected *at the same time* as a 5V USB supply. Failure to observe this precaution can result in over-dissipation in IC2 (reported by several users). Two separate 16MHz clocks are used; one for the main processor (IC1) and one for the USB processor (IC2).

The main processor (IC1) handles the on-board Bluetooth Low-Energy (BLE) interface with the only external components being a simple RF filter and antenna. Note that BLE is supported even when USB is disconnected and this makes it possible to communicate (and even to program) a micro:bit without having to use the USB interface. Other devices, such as the magnetometer and accelerometer chips are linked to IC1 via an internal data bus.

## Introducing Mu

In last month's *Teach-In 2017* we introduced code blocks and made use of the Microsoft Block Editor to develop a very simple application. The visual code block environment is ideal for beginners, but if you need to do any serious programming with the micro:bit (and particularly if you have any previous experience of using Python) you will almost certainly want to move on to a more powerful environment that can be used locally without the need for an Internet connection. Fortunately, there's a ready-made solution in the form of the handy no-frills Mu editor.

Mu is written in Python and is available for Windows, OSX and Linux. The software can be freely downloaded from **https://codewith.mu**. Mu has only the most essential features, so users are not intimidated by a baffling interface. At the same time, anyone with previous Python experience will not find the environment too limiting. Mu can be quickly and easily learned and the development cycle of coding and testing code is accomplished without having to leave the editor. This all makes Mu a very attractive environment for developing code of almost any complexity.

Mu is downloaded as an executable file. Once downloaded, you can save the executable file to a directory of your choice. Fig.2.2 shows a typical editing session with Mu. The functions of the eleven menu buttons are listed in Table 2.1.

### *Using* `Repl`

`Repl` (which stands for 'read-eval-print-loop') is a useful tool that can be accessed directly from the Mu coding environment. `Repl` provides you with a means of entering and testing lines of code without having to compile and then download them to the micro:bit. Note, however, that when you are using the `Repl` window you are interacting *directly* with the micro:bit. Anything that you enter from the keyboard will be

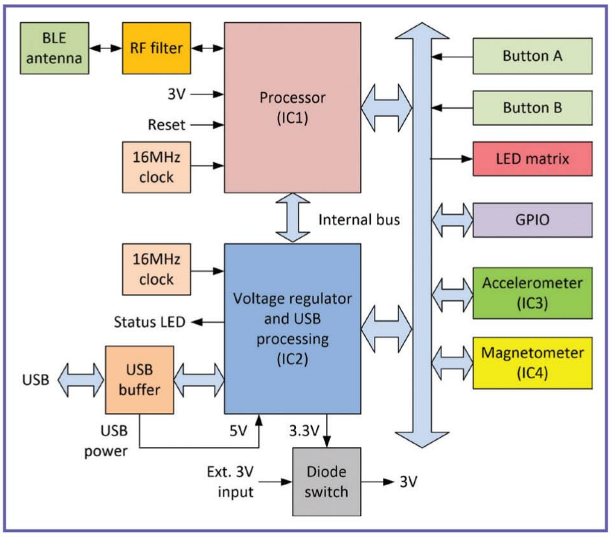



***Fig.2.1. Internal architecture of the BBC micro:bit***

interpreted by the micro:bit immediately; you are no longer one step removed from it! It is also important to be aware that `Repl` cannot be used at the same time as the file system.

When using `Repl` the control keys will provide you with a way of interacting with a running program. For example, `CTRL-C` will halt a running program, `CTRL-D` (entered on a blank line) will perform a soft reset of the micro:bit, and `CTRL-E` will enter paste mode, turning off the auto-indent function.

To list the available commands from within `Repl` you can just type `dir()`. If you need more information you can enter the name of the method as a parameter. For example, the command `dir(spi)` informs you that the following are available: `init`, `write`, `read`, and `write_readinto`.

To get an idea of how `Repl` works, try entering `running_time()` as an immediate command (if you have a program already running on the micro:bit press `CTRL-C` to halt execution). The result of entering this a few times is shown in Fig.2.3. The number displayed by the micro:bit is the number of milliseconds elapsed since the board was last reset.

**Table 2.1 Mu editor menu buttons (left to right)**

| Button | Function |
|---|---|
| `New` | Creates a new file and opens it in the editing window (rename the 'untitled' file when you first save it) |
| `Load` | Loads a previously saved file |
| `Save` | Saves a file (save your work regularly) |
| `Flash` | Transfers code to the micro:bit (the status light on the micro:bit will flash and the board will perform a reset before executing the new code) |
| `Files` | Displays a list of local Python files (.py) as well as those that might currently be present on the micro:bit |
| `Repl` | Opens an interactive window that provides you with a means of executing commands immediately (see text) |
| `Zoom in` | Zooms the editing window, increasing the text size |
| `Zoom out` | Zooms the editing window, decreasing the text size |
| `Check` | This button will check your code and underline errors you have made; worth doing before you flash your code |
| `Help` | Displays the help page |
| `Quit` | Closes the Mu editor. (Save all files that are open for editing before you click on the Quit button.) |

*Getting started with Mu*

Mu is very simple to use but it is important to be careful with indentation using spaces and tabs. It is also important to be careful to use terminating colons where appropriate. Spaces are usually the preferred method for indentation, but they need to be consistent throughout your code. Four spaces are the accepted standard, as shown in the following simple examples. Listing 2.1 checks Buttons A and B and displays appropriate characters on the LED matrix.

To make good use of its matrix LED display, the micro:bit is able to display some simple pre-defined images. For example, `Image.YES` is a large tick while `Image.NO` is a large cross. A simple quiz application could make good use of this as shown in Listing 2.2. These two simple examples will help you gain an understanding of how the Mu editor works and how easy it is to get your code working with the micro:bit.

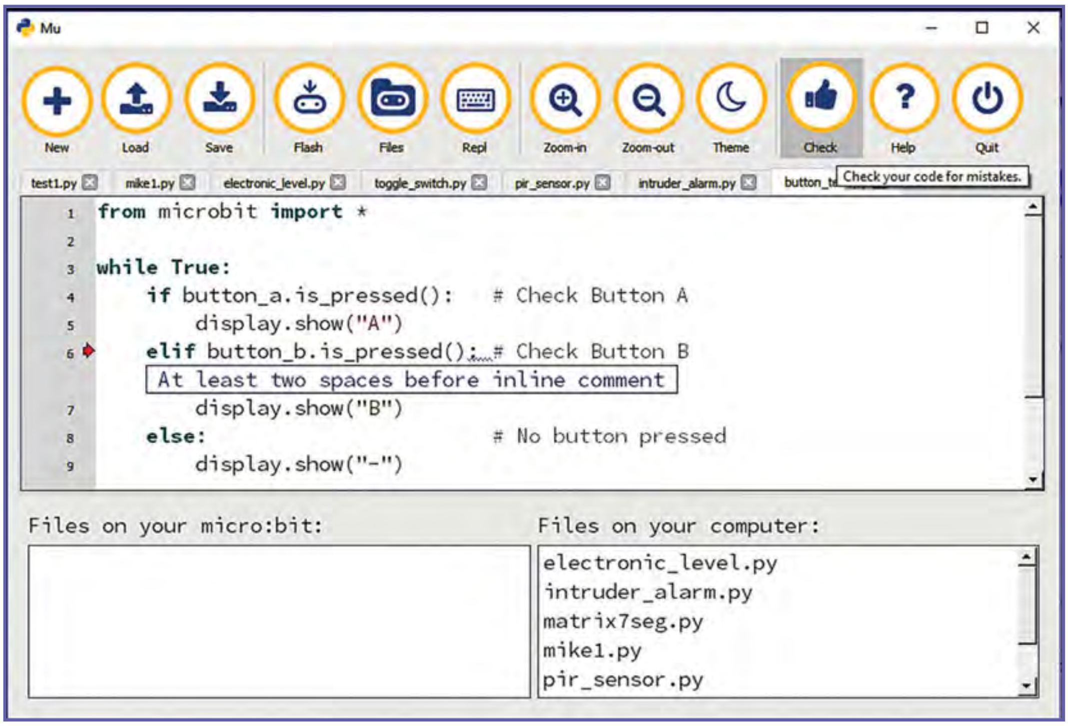


*Fig.2.2. A typical Mu editing session*

## Digital I/O

In last month's *Teach-In 2017*, I mentioned the micro:bit's edge connector provides you with a number of pins that can be configured for digital I/O. These pins make it possible to connect buttons and switches as inputs to the micro:bit, as well as LEDs, relays and audible transducers as outputs. There are, however, a few caveats that need to be observed; including the choice of pins and the maximum current that they can be reliably expected to sink or source.

*Which pins to use?*

Digital I/O is extremely straightforward on the micro:bit, but the question of which digital I/O pins to use can sometimes be a little problematic. It might at first appear that there's plenty of GPIO pins to choose, but it's important to remember that many (indeed, most) of these are taken up with specific functions, such as SPI or $I^2C$. In fact, without having to worry about the impact on other

```
MicroPython v1.7-9-gbe020eb on 2016-04-18; micro:bit with nRF51822
Type "help()" for more information.
>>> running_time()
11430
>>> running_time()
29604
>>> running_time()
50442
>>>
```

*Fig.2.3. The result of entering* `running_time()` *in the* `Repl` *window*

*Listing 2.1: Checking the state of the micro:bit's buttons*

```
from microbit import *

while True:
    if button_a.is_pressed():    # Check Button A
        display.show("A")
    elif button_b.is_pressed():  # Check Button B
        display.show("B")
    else:                        # No button pressed
        display.show("-")
```

*Listing 2.2: Displaying icons on the micro:bit's LED matrix display*

```
from microbit import *

while True:
    if button_a.is_pressed():    # Press Button A for YES
        display.show(Image.YES)
    elif button_b.is_pressed():  # Press Button B for NO
        display.show(Image.NO)
    else:                        # No button pressed
        display.show("?")
```

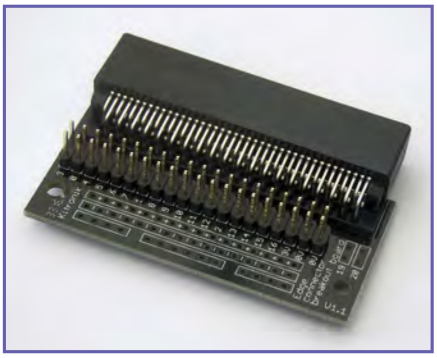


*Fig.2.4. The Kitronik edge connector*

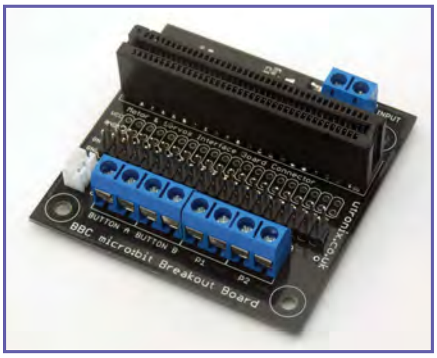


*Fig.2.5. The Utronix edge connector*

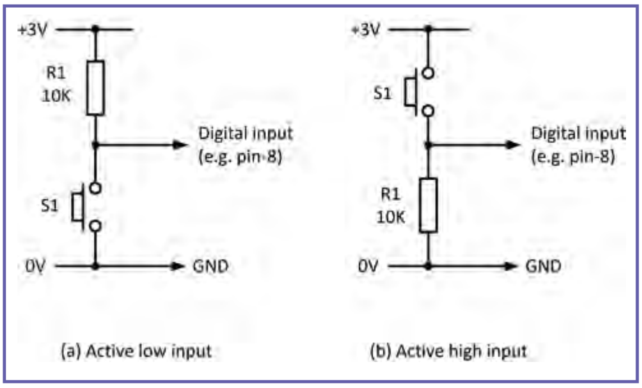



*Fig.2.6. Connecting buttons and switched to a digital input pin*

micro:bit functions, there are only five inputs available for digital I/O.

If you are prepared to sacrifice the LED display then you will have six more possibilities: pins 3, 4, 6, 7, 9, and 10. In addition, if you don't need to make use of the micro:bit's on-board buttons (Button A and Button B) two more pins become available in the shape of pins 5 and 11. The SPI bus uses GPIO pins 13, 14, and 15, while I$^2$C makes use of pins 19 and 20. So, if you plan to make use of these two bus standards, you should not use these pins.

Taking this all into account, my preferred digital I/O pins are pins 0, 1 and 2, followed closely by pins 8 and 16. The first three of these are brought out to large pads, while the remaining pair are available on the smaller pins and must be accessed by means of a ready-made edge connector such as those supplied by Kitronik and Utronix (see Figs. 2.4 and 2.5).

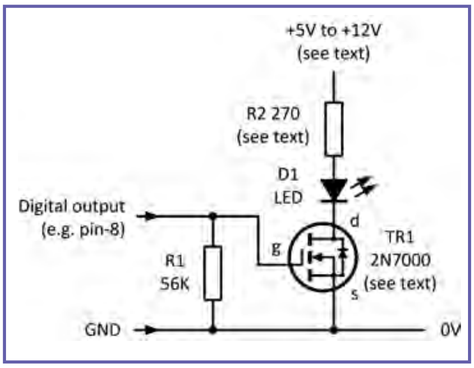



*Fig.2.7. MOSFET LED driver*

## Connecting buttons and switches

It's easy to connect an external button or a switch to the micro:bit, but it's important to remember that, when the switch is operated, the voltage change must be sufficient for it to cause a change in logic level, from a 0 (low) to a 1 (high) and vice versa. A high state is normally taken to be equivalent to a voltage of +3V (or near), while a low state is a voltage of 0V (or near).

In order to ensure that sufficient change takes place we use pull-up or pull-down resistors, like those shown in Fig.2.6. Note that the micro:bit has internal pull-up and pull-down resistors (see later) but, because we don't want to forget that they are there, we will duplicate them with external components. Thus, in the active-low input arrangement shown in (a), when the normally open contacts of S1 are closed the input state will change from a logical 1 to logical 0. Conversely, in the active-high input arrangement shown in (b), when the normally open contacts of S1 are closed the input state will change from a logical 0 to logical 1. Finally, it is important to note that you should never exceed the nominal 3V supply to these two circuits. Anything much more than 3V will damage the micro:bit.

## Pull modes

If desired, the micro:bit's internal pull-up and pull-down resistors can be configured in various ways depending upon which of the following three conditions are needed:

- Pull-down (the digital input pin is internally pulled down to 0V)
- Pull-up (the digital input pin is internally pulled up to +3.3V)
- No-pull (the digital input pin is simply left floating).

The pull mode is automatically configured when the pin changes to an input mode. Input modes are defined when you call the relevant functions (ie, `read_analog()`, `read_digital()`, and `is_touched()`) as shown in Table 2.2. Note that you can only call the `set_pull()` function in order to change the default pull mode setting when in `read_digital()` mode.

**Table 2.2 The micro:bit's pull modes**

| Pull mode | Input condition | Associated function | Default input state | Notes |
|---|---|---|---|---|
| No-pull | Input floating | `read_analog()` | Indeterminate | |
| Pull-down | Internal pull-down to +0V | `read_digital()` | Low (0) | |
| Pull-up | Internal weak pull-up to +3.3V (via 10MΩ resistor) | `is_touched()` | High (1) | Available on pins 0, 1 and 2 only |

## Connecting output devices

Typical output devices consist of LEDs, relays,

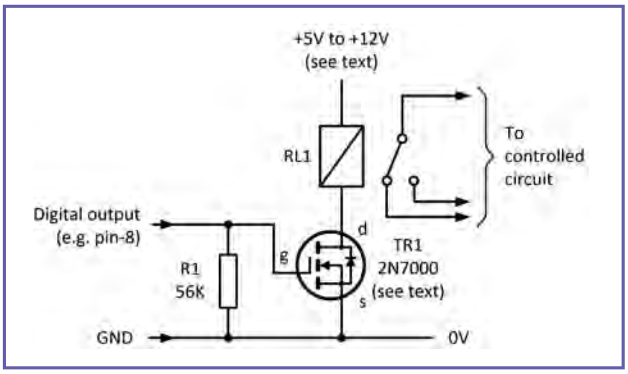



*Fig.2.8. MOSFET relay driver*

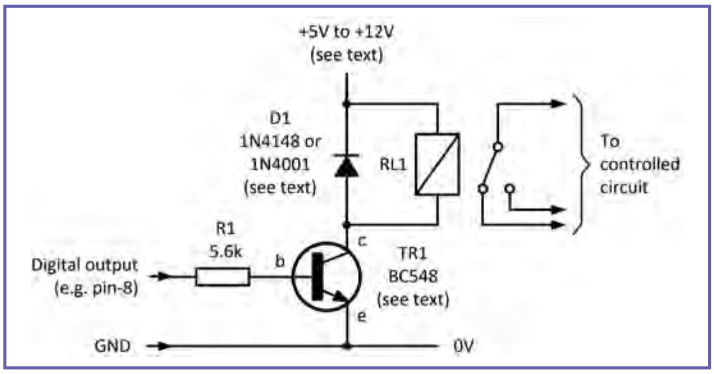



*Fig.2.9. Bipolar transistor relay driver*

motors and sounders. Unfortunately, most of these require voltages and currents that are well beyond the capability of the micro:bit so some form of interface will normally be required, along with a power source that's capable of delivering the required voltage and current.

## *Drive current limitations*

In normal low-current drive mode the current at a digital output should be limited to less than 1mA and we need to take account of this in the design of any interface circuitry. Furthermore, since the output is compatible with 3.3V logic additional precautions need to be taken in order to interface with 5V-logic-compatible devices.

## *Output driver circuits*

A typical LED driver circuit is shown in Fig.2.7. This circuit uses a MOSFET transistor operating as a switch, conducting heavily when the gate voltage goes high. The value of R2 sets the current flowing through the LED (approximately 10mA with the value shown when operating from 5V). Fig.2.8 shows a typical relay driver. The relay can be any miniature type suitable for operation from a voltage of between 5V and 12V. A typical 5V relay has a coil resistance of around 70Ω and operates with a current of about 70mA (well in excess of the micro:bit's capabilities). An alternative relay driver using a bipolar transistor is shown in Fig.2.9. Note that since all three of these driver circuits require active-high inputs for the transistors to conduct (ie, to switch 'on'), a logic 1 (high) from the micro:bit is required to turn the LED on or operate the relay.

An alternative to constructing your own relay interface is that of using a ready-made relay module. These are widely available at low cost and are often designed for use with Arduino or Raspberry Pi boards. Such boards are usually compatible with both 3V and 5V logic systems.

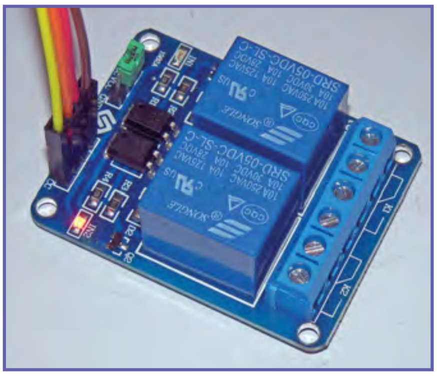


*Fig.2.10. Two-channel relay module*

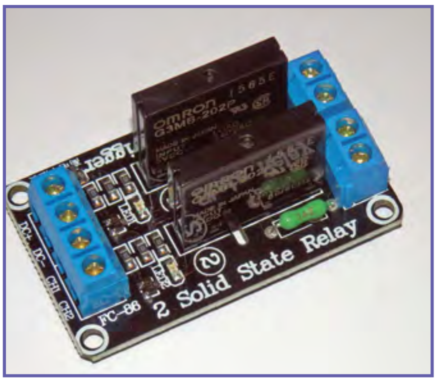



*Fig.2.11. Two-channel solid-state relay module*

Fig.2.10 shows a two-channel relay module that uses miniature changeover relays while Fig.2.11 shows a two-channel solid-state relay module that can handle mains voltage loads of up to 500W.

## *Supplying power to interface circuits*

One annoying feature of the micro:bit (at least as far as the electronic enthusiast is concerned) is the absence of a +5V pin on the board's edge connector. This isn't a problem when the micro:bit is being used with devices that are compatible with 3.3V logic, but life becomes more complicated when 5V devices and external boards need to be interfaced. Depending on what you need to do and what voltages are required, there are various possibilities for supplying power, as shown in Fig.2.12.

Fig.2.12(a) shows a very simple arrangement in which the micro:bit is being supplied from an MI:powerboard, as used in last month's project. The micro:bit derives its supply from the power board which houses a 3V button cell. Sadly, this arrangement is only suitable for simple stand-alone applications.

In Fig.2.12(b) the micro:bit is powered from a 3V battery pack comprising two AA or AAA cells. While this arrangement is able to supply limited current to interface devices such as LEDs and sounders it is unsuitable for relays, motors and other high-current/high-voltage loads.

Fig.2.12(c) shows the arrangement used during application development. The micro:bit takes its supply via the USB link to the host computer and this

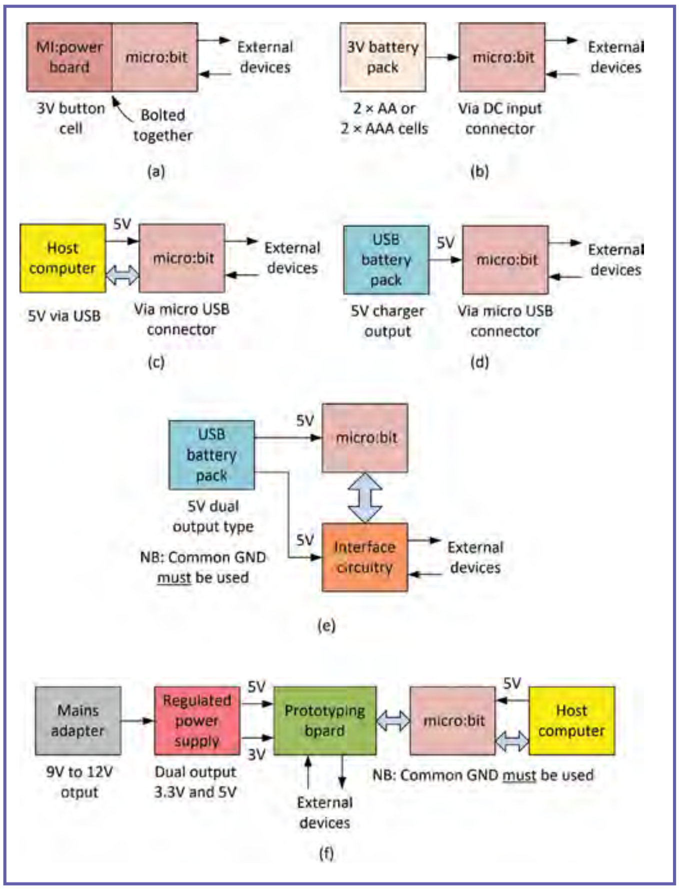



*Fig.2.12. Various power options for interface circuits*

makes it possible to use the arrangement shown in Fig.2.12(d) where the supply is derived from a mobile USB battery charger. The 5V regulated output will provide power for many hours of continuous operation. Note that some 'automatic' chargers will turn off when the current demand placed on them is small. If that's the case, it might be necessary to place an additional resistive load across the output. A 0.5W resistor of 100Ω will usually be adequate for this purpose.

In many cases you may find it necessary to make use of devices that are compatible with 5V logic or that require a 5V supply rather than the 3V supply available from the micro:bit. In such cases a USB battery with dual 5V outputs can be used, as shown in Fig.2.12(e). If that's the case it is important to ensure that the GPIO signals are at 3V logic levels and not the more usual 5V.

Finally, the arrangement shown in Fig.2.12(f) is our preferred set-up for developing micro:bit applications. This provides +3.3V and +5V for our breadboard interface circuits while the micro:bit is powered via the USB cable to the host computer. Note that with this arrangement (as well as that shown in Fig.2.12(e)), it is essential to ensure that there is a common 0V/GND connection throughout the system.

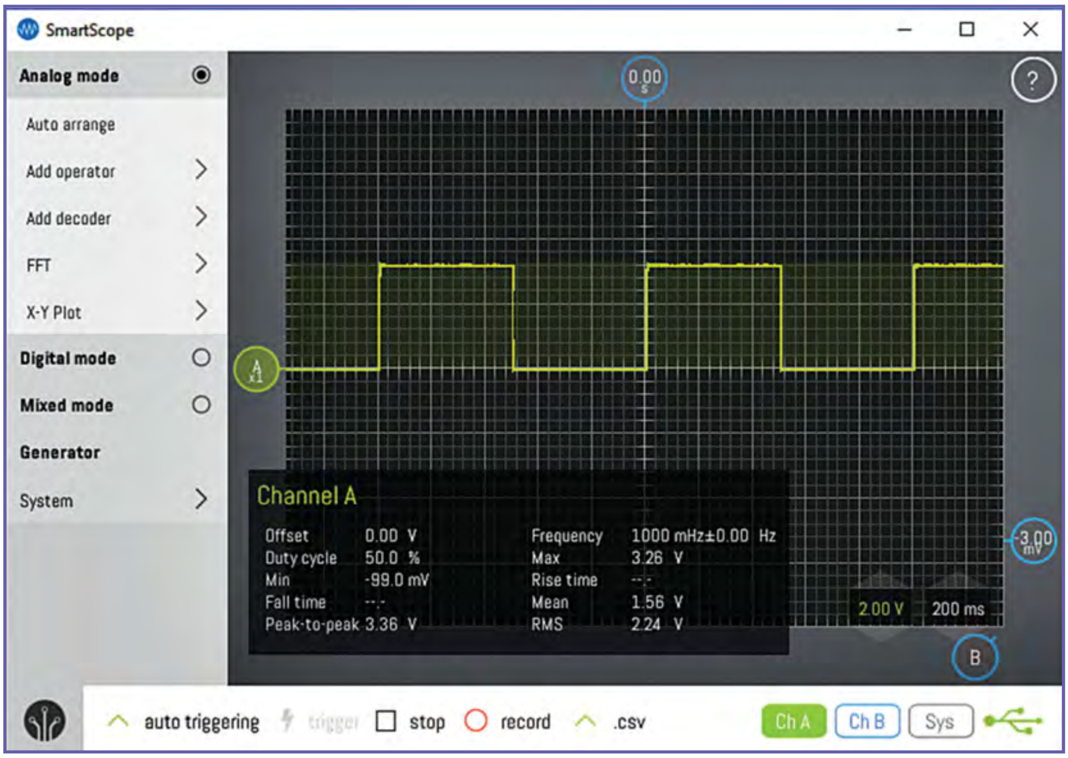



*Fig.2.13. Waveform produced by the code shown in Listing 2.3*

## *Writing to the digital outputs*

To write to a digital I/O pin you simply use `write_digital()`. For example, the following code fragment sets pin-0 'on':

```
pin0.write_digital(1)      # Pin-0 taken high
```

To set the same pin 'off' you would use:

```
pin0.write_digital(0)      # Pin-0 taken low
```

To set pin-2 'on' and pin-3 'off' you would use:

```
pin2.write_digital(1)      # Pin-2 taken high
pin3.write_digital(0)      # Pin-3 taken low
```

To read the state of a digital I/O pin you can use `read_digital()`. This will return 1 if the pin is high and 0 if it is low. For example, the following Python code reads the state of pin-0 and displays an H (high) or L (low) depending on its state:

```
while True:
     if pin0.read_digital():
           display.show("H")  # Pin-0 is high
     else:
           display.show("L")  # Pin-0 is low
```

Notice how we are using `pin0.read_digital()` to return a Boolean variable which will be used by the `if … else` construct. You can read the state of a digital I/O pin into a variable (it's a Boolean variable because it can only be one of two states, either a 0 or a 1). This is how it's done:

```
switch_state = pin0.read_digital()
```

To display the state using the matrix LED you would use something like:

```
display.show(switch_state)
```

Finally, Listing 2.3 generates a 1Hz square wave on pin-0 by repeatedly taking the output high for 500ms before taking it low for 500ms. The output waveform produced when this code is executed is shown in Fig.2.13.

***Listing 2.3 Generating a 1Hz square wave output on pin-0***

```
from microbit import *

while True:
    pin0.write_digital(1)
    sleep(500)
    pin0.write_digital(0)
    sleep(500)
```

## Project: A micro:bit electronic spirit level

Our practical projects have been designed to give you some hands-on experience of using the BBC micro:bit. In last month's practical project we used the Microsoft Block editor to produce a handy electronic compass. This month we will be describing another simple micro:bit gadget in the form of a simple electronic spirit level.

The micro:bit's accelerometer object provides you with a means of detecting movement in three axes as well as some recognised gestures such as, up, down, left and right. In this application we are only concerned with what's happening in the horizontal plane, so the only accelerometer function that we need is `accelerometer.get_x()`. The required code is shown in listing 2.4. Note that if you use an MI:power board to supply the micro:bit you will have the added bonus of an audible output to indicate the level condition

Enter your code into Mu (see Fig.2.14) and save it with an appropriate filename before compiling and downloading it to your micro:bit using Mu's Flash button (see page 39). As the file is being sent to the micro:bit you should notice the micro:bit's power LED flashing. When this stops the file transfer will be complete and the code will be running on the micro:bit.

Hold the micro:bit horizontal and the = character will indicate that the board is level. Tilting the board one way will display the > character while the opposite direction will display the < character. The sensitivity of the electronic spirit level can be adjusted by changing the values used in the comparisons (shown as 20 and –20 in the listing. Reducing the value will increase the sensitivity and vice versa.

*What does the code do?*

The `while True` statement ensures that the program continues in an infinite loop for as long as power is applied to the micro:bit. We first obtain a value from the on-board accelerometer and store it in the variable, `reading`. The first comparison, `if reading > 20`, checks to see if the current value of `reading` is greater than 20 and, if this condition is satisfied (ie, if it evaluates True), a less than character (<) is displayed on the LED matrix. Execution then continues at the top of the loop with a further reading being taken from the accelerometer.

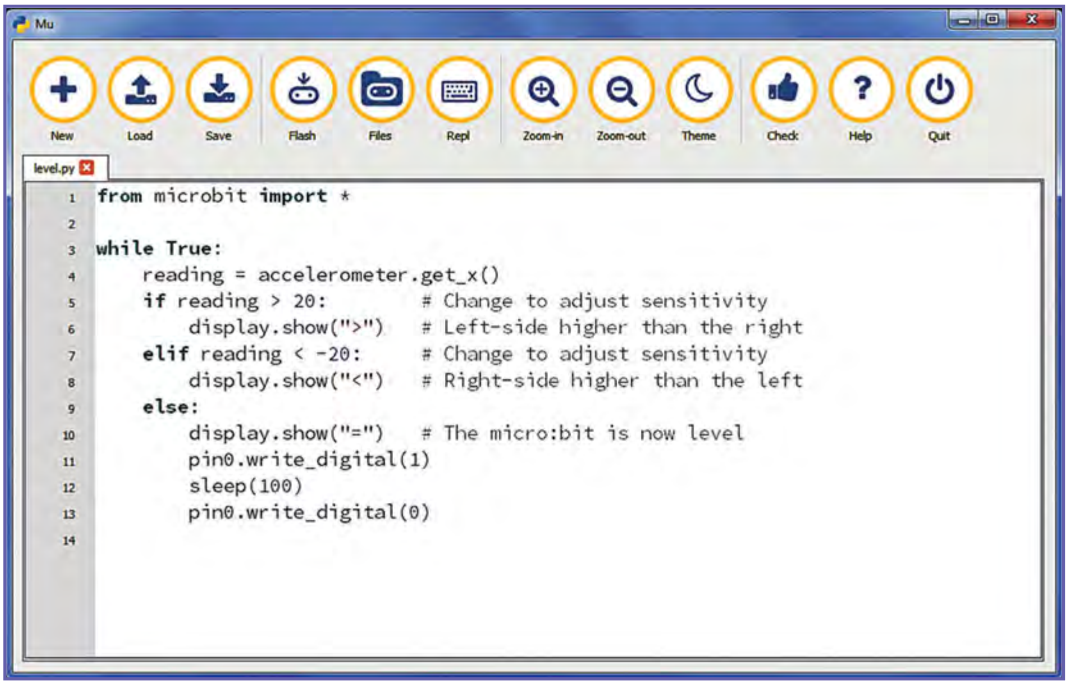



***Fig.2.14. The micro:bit electronic spirit level code as it appears when entered in Mu (notice that we've used the file name* `level.py`*)***

***Listing 2.4 Code for the electronic spirit level application***

```
from microbit import *

while True:
    reading = accelerometer.get_x()
    if reading > 20:        # Adjust sensitivity
        display.show(">")  # L-side higher
    elif reading < -20:    # Adjust sensitivity
        display.show("<")  # R-side higher
    else:
        display.show("=")  # micro:bit level
        pin0.write_digital(1)
        sleep(100)
        pin0.write_digital(0)
```

If the first comparison is not satisfied, the second comparison, `if reading < -20` is tested to see if the current value of `reading` is less than –20 and, if this condition is satisfied (ie, if it evaluates True) a greater than character (>) is displayed on the LED matrix. Execution then continues at the top of the loop with a further `reading` value taken from the accelerometer.

Finally, if neither the `if` or `elif` comparisons evaluate True, the equal character (=) will be sent to the LED matrix display and a pulse is sent to pin-0 using `pin0.write_digital()` before execution once again continues at the top of the loop with yet another `reading` value taken from the accelerometer.

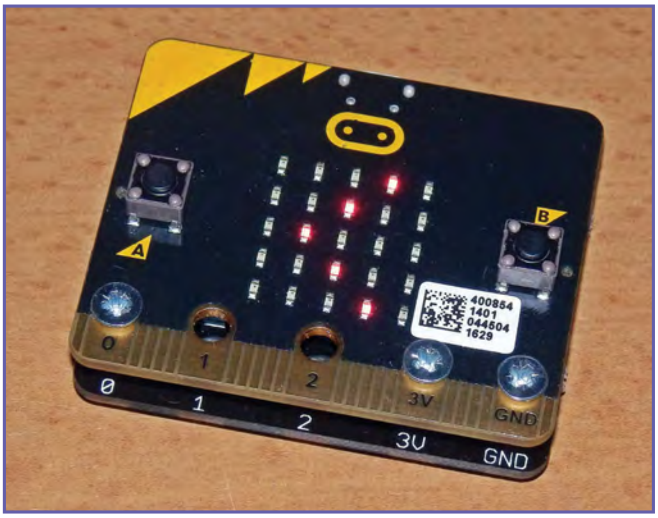


***Fig.2.15. The micro:bit electronic spirit level in use***

## Next month

In next month's *Teach-In 2017* we will be delving into analogue I/O using the micro:bit and our practical project uses an external temperature sensor and two-channel relay module as the basis of a simple thermostatic controller.

# NET WORK

by Alan Winstanley


## Phony friends

**IN LAST** month's column I mused that one's instincts can be a lot more powerful than one might think, something to bear in mind when accessing the Internet services that we often take for granted today. If something seems a bit suspicious and doesn't quite pass the 'sniff test', ask yourself whether it's all that it seems to be, and tread carefully. One can almost marvel at the lengths that fraudsters and villains now go to when dreaming up more cyber attacks, perhaps intending to steal personal credentials or blackmail victims into paying ransoms to unlock their precious data. Ransomware is even available as a 'Software As A Service' kit that allows rising numbers of unskilled actors to deploy crypto-ransomware with ease, reported Symantec.

My own instincts were put to the test a few days ago when, to my surprise, a familiar old friend suddenly popped up on Facebook, asking me to 'Friend' him. I thought it was odd because he was already a 'Friend', or so I thought, but a current photograph accompanied his request so maybe he'd had to re-install Facebook or set it all up again, I pondered. It looked genuine enough so in my half-asleep state I accepted his incoming request, swishing some buttons around on my Android tablet without a second thought.

Immediately, my supposed friend popped up on Facebook Messenger and asked, 'Hi, Alan! How's things?' I gave a typically chipper reply and my friend immediately replied: 'I am OK. Have you heard the news?' At this point my suspicions started to stir as something felt not quite right. I replied 'brb' ('Be Right Back') – 'OK Alan I will wait', replied my friend, which was another clue that something smelt a bit funny: my friend never talks that way and, come to think, he never uses Messenger, either!

Another contact phoned me at the same time saying the same thing happened to her a few moments ago and she had blocked our mutual 'friend'. I called the real 'friend' and we soon realised that a duplicate Facebook account had been set up by fraudsters using stolen photos, and they were busily trying to 're-friend' everybody in sight. Possibly they would steer people to a website to download a virus or side-load them with ransomware instead. I will never know because I quickly blocked the phony contact too, but this quite credible attempt at social engineering was unsettling nonetheless.

### Anti anti-virus

Having an up-to-date anti-virus package is the order of the day, especially when using desktop PCs or laptops to handle any Internet-based 'heavy lifting', but mobile versions of anti-virus software are becoming commonplace too. Many modern anti-virus packages offer a whole armoury of tools to safeguard your system from aggressors. Website scanning, ad-ware protection, software version scanning and updating, parental controls, pop-up protection and secure online banking – all this and more is now offered by a multitude of Internet security programs that are available free, often in the hope that you will subscribe to the paid-for upgrade.

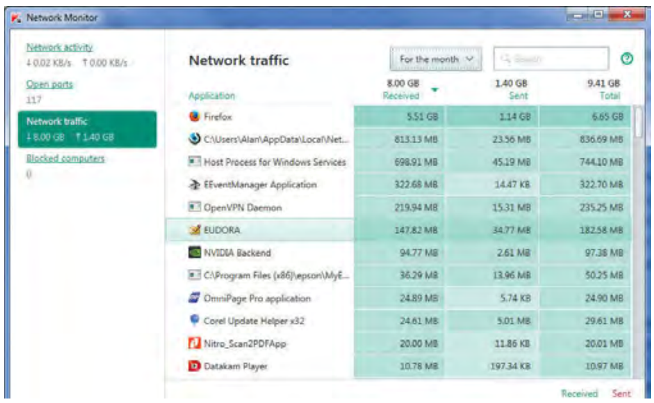
The anti-virus market is big business, and last year the once little-known Avast Software (**www.avast.com**) acquired another well-known brand, AVG (**www.avg.com**), in a $1.3 billion deal that would allow some cross-fertilisation of their technologies. (Consumer users can still choose one brand over the other, though.) For many years I have suggested Avast Anti-Virus as a reasonable 'freemium' package, though it does tend to nag users with pop-ups along the lines of 'Your passwords might not be secure! Your software is not up to date!' I have seen how this sort of nagging can affect inexperienced web users who are left thinking that some catastrophe may be about to befall them, and this kind of nuisance pestering can unsettle them. It can be hard to reassure them that despite these urgent-sounding alerts, everything is still in full working order.

On my own system, web design and graphics are handled on a PC that is hooked via a LAN to another machine responsible for uploading files onto web servers. Another local backup is taken onto a NAS drive. Avast Anti-Virus keeps watch and Adobe Dreamweaver synchronises web files between the two machines to keep everything up to date – or at least it's supposed to. With website update deadlines looming recently, Dreamweaver resolutely refused to 'sync' files over the LAN as web files were reportedly 'in use by another process'. I tried everything to no avail and gradually the escalating problem started to cause serious damage to my workflow.

### Another process

After trying every Windows dodge that I knew without success, I decided the machine was probably overdue for a rebuild so a new hard disk and Windows installation went in, keeping to the basics and building up the system methodically from the outset. Avast Anti-Virus was reinstalled and Adobe Dreamweaver followed and the network was soon up and running again – or so I thought. I still had exactly the same problem, with network traffic still blocked and my web design software was refusing to sync files between computers. It was also found that the Avast Self-Defence module was blocking a legacy graphics program from launching. Worse still, files could no longer be copied manually either, as they were 'in use by another process' (darn!) so I could not synchronise files that way even if I wanted to.

It's common to add 'exceptions' (or exclusions) in an anti-virus program which are hidden deeply in the program. These allow certain programs to run properly, or you can



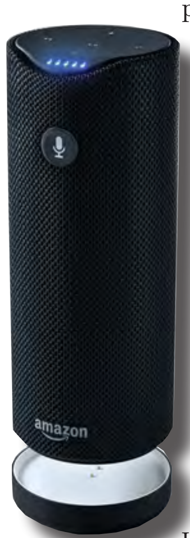

*Kaspersky Internet Security includes a Network Monitor tool showing bandwidth used by programs and network hardware* choose to avoid scanning files or folders routinely to prevent the system from slowing to a crawl. However, nothing I did in Avast would cure my networking problem: files were locked because they were in use by another process, and not even Process Explorer (download from **http://tinyurl.com/jzmfmsn**) could shed any light on it. Since everything had worked seamlessly for years, maybe a software update had affected the network. Thinking about it, the only program that could have updated itself recently was Avast Anti-Virus. After suffering ten days of grief I finally replaced it with Kaspersky Internet Security instead. It was worth a try and, lo and behold, everything was suddenly running perfectly again and I was back in business.

Kaspersky Internet Security is a clean and tightly-designed program with no less than fifteen protection modules to safeguard Internet users. Its webcam protection claims to stop hackers spying on you and a protected web browser safeguards online banking and payment pages; this threw some web pages completely so I turned it off. Should I disable Advanced Disinfection Technology? What is Kaspersky Security Network? How about its Self Defense Module? There are myriad options like these to check into so it's easiest to accept the defaults and gradually tweak them over time to improve performance. Kaspersky's very useful Network Monitor (in the Tools sub-menu) also shows the bandwidth being consumed by various programs and network hardware such as my IP camera and Wi-Fi printer. Advanced users can set various exclusions here. They say a change is as good as a rest, and after all those earlier network problems I now have some interesting-looking new software tools to try out.

## Home sweet Google Home

Amazon continues to heavily promote its mains-powered Echo smart loudspeaker with regular commercials appearing on Britain's TV screens. Its smaller sibling, the Amazon Dot, is a cheaper (£50) unit missing some of Echo's powerful speaker performance.

Yet to arrive in the UK, a smaller Amazon Tap was launched in the US last year as a slightly more compact Alexa-enabled rechargeable Bluetooth speaker. The 66mm diameter tube has dual 1.5-inch drivers and connects to Wi-Fi: you tap (hence the name) a button to activate it, though a recent software update offers a voice-activation option with reduced battery life. The brand new Amazon Echo Look (US, invitation only) is a $200 stand-alone voice-controlled camera with built-in LED lighting, designed with personal fashionwear and style photography in mind. Its pseudo depth-of-field blur introduces a little *bokeh* into snapshots to create impromptu full-length fashion images. The Look can also capture video and can supposedly 'rate' your fashion look against 'expert advice', so they say. It is free-standing or wall-mountable, with the usual Alexa voice awareness built-in. Amazon remains tight-lipped about the development of a larger device having a built-in LCD touch screen rumoured to be in the pipeline, which Bloomberg reported at the end of 2016.



*Amazon Tap is a rechargeable portable Bluetooth speaker with Alexa voice control; charger dock also shown. Carrying sling available, US only for now.*

Google has arrived late on the UK scene with its own smart speaker called Google Home. It is now on sale and will sport at least one feature that Amazon Echo currently does not: the voices of up to six different users can be recognised by Google Home, which will respond to play a user's individual playlists, To-do lists and so on. (Note this voice-recognition feature is 'coming soon' in the UK, at the time of writing.) The market is still quite young and the jury's out over which smart speaker will be better: for dedicated Internet enthusiasts, Google Home's powerful and intelligent Google Assistant,


*Google Home smart speaker is now on sale in the UK. It will feature multi-user voice recognition allowing interaction with up to six users*

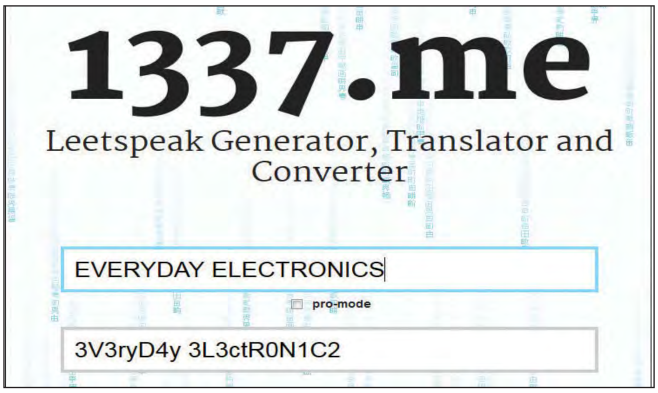
*Amazon Echo Look is a standalone voice-controlled camera with LED flash and depth of field sensing. US, invitation-only trials*

Chromecast TV and Youtube compatibility, multi-user and multi-room audio might swing things in its favour, but existing Amazon Kindle and Fire users may prefer to buy into the Echo system. You can see Google Home in action at: **https://youtu.be/nWiIWyCeZso** and it's now available from UK major stores and Maplin for £129. Preceding every spoken question by chanting 'OK Google' is still decidedly un-British, but give it time!

## Scrambled p455w0rd5

The need for strong passwords has been a mantra hummed by Internet gurus almost since the dawn of time. People are funny about passwords – they often want something that's easy to remember but difficult to guess. The most popular passwords used are 'qwerty', 'password', '123456' and 'secret'. Simple English words make for inadequate passwords as hackers could try to uncover them using a brute-force dictionary attack on a vulnerable server, so users eventually learned to include numbers and symbols in logins as well, in order to thwart such attacks. Another trick is to substitute alpha characters with similar-looking numbers to generate more obscure passwords still – like p455w0rd5, for example. This is known as 'Leetspeak' and was originally used by 'elite' hackers or forum users as a revered badge of honour. Typing 'Everyday Electronics', for example, into the Leet converter website **1337.me** produces the results seen in the screenshot. Nowadays, Leetspeak is associated more with teenagers, but it's still handy to use when generating or obfuscating passwords of your own. You could also try the Universal Leet Converter at: **www.robertecker.com/hp/research/leet-converter.php**. Incidentally, the same website has a text-to-Morse-code converter as well, and seems to create a MIDI file at the same time.

In next month's *Net Work* I'll be looking at some useful Internet tools including virtual private networks (VPNs). You can contact the writer at: **alan@epemag.net** or letters for possible inclusion in *Readout* can be sent to: **editorial@wimborne.co.uk**



**1337.me** *(Leet Me) converts text into 'Leetspeak' – useful for password obfuscation*

By Robert Penfold

# INTERFACE

## Using the I²C serial interface

**SEVERAL** previous *Interface* articles have covered the GPIO port of the Raspberry Pi computer. In these, the direct approach to interfacing has been used, with a Python program taking full control of the hardware. Where serial interfacing was used, the program generated the clock signal, read the data bits one-by-one, and so on. An alternative approach is available in the form of SPI and I²C serial interfaces. Using these interfaces is quite complex if you take the direct approach, and control everything with your own software routines.

### The simple life

Fortunately, there is a much easier way, because computers such as the Raspberry Pi have built-in support for these two types of interfacing. Some setting up is needed in order to get a Raspberry Pi operating with one of these interfaces, but matters are very straightforward once this has been done. Data can be read from or written to the peripheral device using one simple program instruction. When using the GPIO lines to read or write bytes of data, whether in serial of parallel form, a fair number of program lines are needed.

Of equal importance to the computer's built-in support, there are plenty of integrated circuits that are specifically designed for use with one or other of these interfaces. These include such things as port expanders, analogue-to-digital converters, and temperature sensors. There are also numerous ready-made modules that provide these functions, plus such things as LCD displays and simple keyboards. Although these modules might be advertised as for use with another type of computer, such as the Arduino, they should in fact be usable with any computer that has the appropriate type of interface.

### Background

SPI (serial peripheral interface) provides a synchronous serial connection. In other words, the master device in the system generates a clock signal that is used to ensure that every device in the system remains properly synchronised. Together with a fully standardised protocol for sending and receiving data, this avoids many of the problems with an asynchronous link such as an RS232C type. There are no incompatibility problems due to incorrect baud rates and word formats.

A basic SPI interface uses four connecting wires, or five if you include the earth connection. There is a clock line, plus separate lines for transmitting and receiving data. These are called MOSI (master out – slave in) and MISO (master in – slave out). The fourth connection is used to select the peripheral device that will communicate with the master unit. A daisy-chain method of connection enables several peripherals to be used with a common Slave Select line, but the more normal and versatile method is to use a separate Slave Select line for each peripheral, as in Fig.1. Here there are three slave devices, but many more can be used.

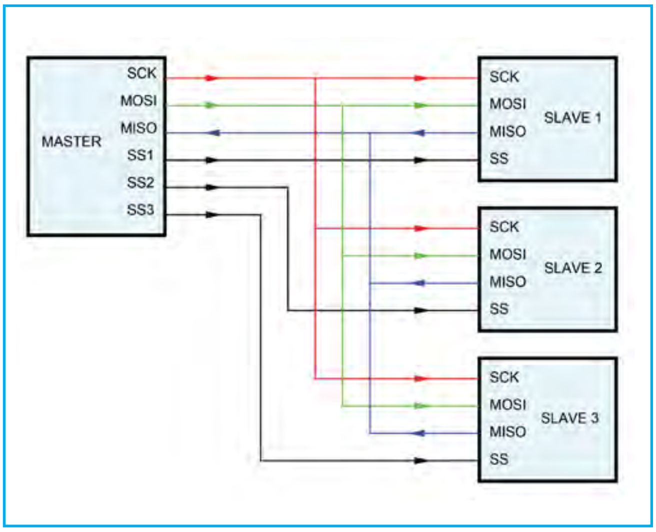



*Fig.1. An SPI system has separate lines for sending and receiving data. As in this example, there is normally a separate selection line for each slave device*

### I²C interface

An obvious drawback of using SPI with numerous slave devices is that the number of lines required on the master unit starts to become quite large. A setup of this type can soon look more like a parallel interfaced system than a serial type, and I suppose there is an element of parallel interfacing to it. The I²C (inter-integrated circuit) interface provides a simpler way of connecting the parts of a system together, with just two lines plus an earth connection being required. One line carries the data and is bidirectional. The other is used to distribute the clock signal across the system. Fig.2 shows the I²C equivalent of the SPI system in Fig.1. One master unit is shown in Fig.1, but the I²C protocol does actually permit two or more master units to be used in a system. A system having a single master device is a better starting point though.

Using one interconnection to carry data to and from every device in the system makes connecting everything together easier, but it makes the controlling software more complex. A system of software addressing is used to enable the master device to select the required peripheral. 7-bit addresses are used, but a few of these are reserved, allowing up to 112 slave devices to be used, and not the full 128. The eighth bit is used to indicate whether a read or write operation is being performed. The address byte is followed by one or more control or data bytes. The master unit or a slave device places these on the data line, depending on the state of the read/write bit in the preceding address byte.

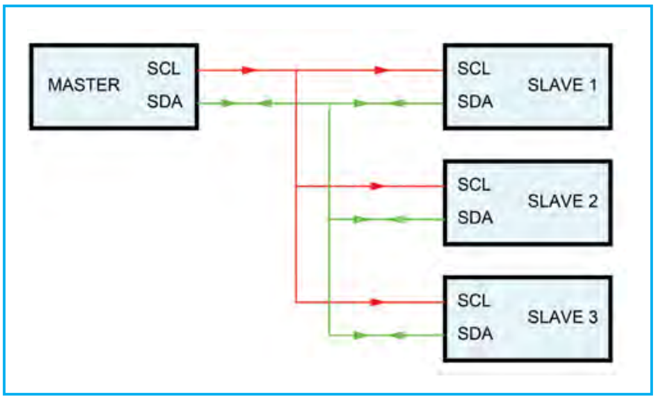



*Fig.2. An I²C interface has only two connecting wires plus a ground connection. There is a single line for sending and receiving data, and a software protocol to select slave devices*

With a single line being used for communication in two directions, plus a system that can handle numerous slave devices, there is a risk of something going awry, and two or more devices simultaneously driving the data line. Damage from hardware conflicts of this type is avoided by having outputs of the open-collector or open-drain variety. In other words, the outputs are effectively on/off switches, and there is a pull-up resistor at the master device. Devices in the system can pull the data line low, or release it to the high state, but they cannot drive current into the output of another device.

The original I²C protocol was designed by Philips in 1982, and has undergone various revisions to give higher operating speeds and provide more addresses. However, the version we are primarily concerned with here is the one produced by Intel in 1995 called the System Management Bus, or SMBus as it is generally called. This is a more tightly defined and restricted version of I²C, with basic 7-bit addressing and clock speeds of 10kHz to 100kHz. This compares to 10-bit addressing and clock rates of up to 5MHz for the full I²C, and clock rates of 10MHz plus with SPI.

An important point to bear in mind here is that both SPI and I²C were only designed to accommodate chips on the same circuit board as the master device. They were not designed to accommodate external peripherals such as those used with USB and RS232C interfaces. However, with the relatively slow clock rates of SMBus it is possible to connect external circuits to the I²C port of a computer such as a Raspberry Pi, but only if suitably short cables are used. Using cables about 200-300mm long seems to give very reliable results, and it might be possible to use cables somewhat longer than this. However, it is unlikely that reliable results would be obtained using cables a few meters long.

## Kernel bogie

Although the Raspberry Pi and the Raspian operating system support I²C interfacing, they do not do so by default. Some changes have to be made to the configuration of the Raspian operating system in order to render the I²C interface active. Start by opening a console and then launch the configuration utility using this instruction:

```
Sudo raspi-config
```

This brings up the configuration window, where '8 Advanced Options' should be highlighted using the cursor keys (Fig.3), and then selected by pressing the Return key. At the new menu screen, shown in Fig.4, highlight and select 'A7 I2C Enable/Disable automatic loading'. Next, a screen asking if you if you would like the ARM I²C interface enabled will appear, followed by the one of Fig.5, where you have the option of having the I²C kernel module loaded by default. Answer Yes at both of these windows. It is then just a matter of exiting the configuration program and rebooting the computer to make the changes take effect.

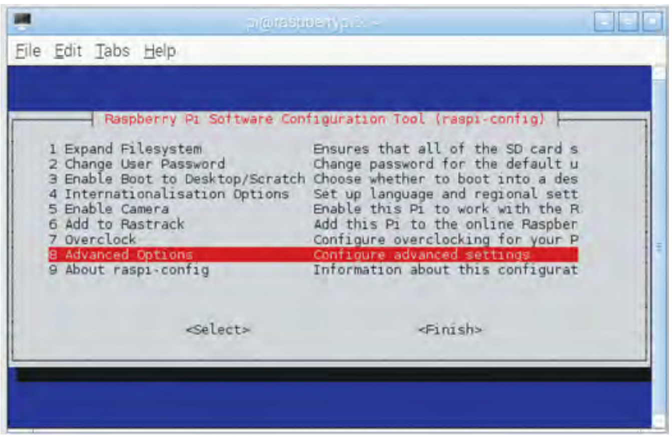



*Fig.3. Select Advanced Options from the main menu of the configuration tool*

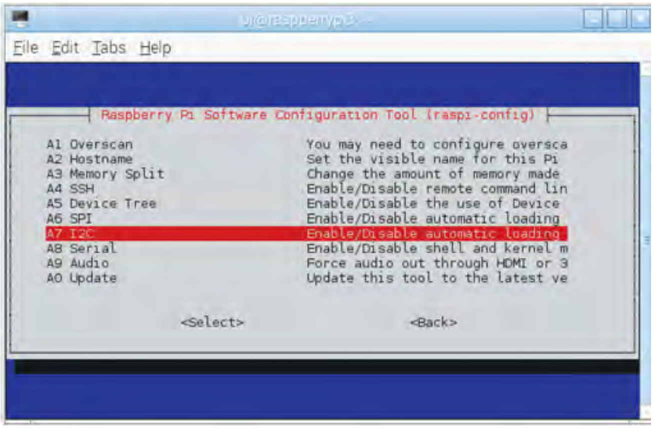



*Fig.4. Option A7 is used to enable the I²C interface*

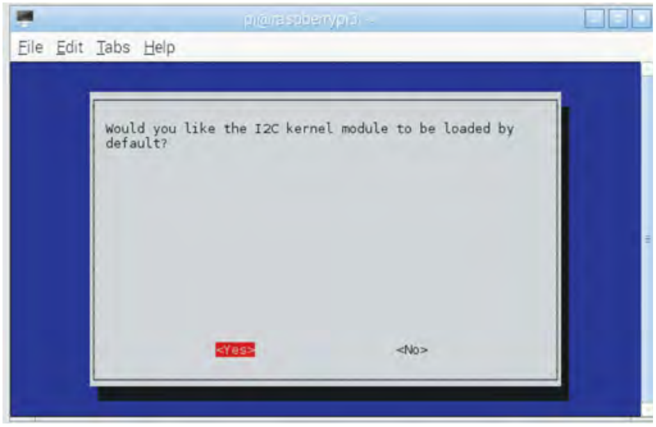



*Fig.5. Select Yes here, so that the I²C Kernel module is loaded by default*

Next, it is a good idea to make sure that everything is fully up-to-date and that all the latest packages are installed. With the Raspberry Pi connected to the Internet, use these three instructions from a console window:

```
sudo apt-get update
sudo apt-get upgrade
sudo apt-get dist-upgrade
```

It could take a fair amount of time to get everything installed, and you will probably need to respond 'Y' when prompted, possibly on several occasions. Next, the SMBus and Python Dev modules must be installed using these instructions:

```
sudo apt-get install python-smbus python3-
smbus python-dev python3-dev
sudo apt-get install I2c-tools
```

Again, downloading and installation could take a while, and it might be necessary to give appropriate responses when prompted. It will probably be necessary to update the `config.txt` file. Use this command to load the file into an editor:

```
sudo nano /boot/config.txt
```

Next add these two lines at the end of the file:

```
dtparam=I2c1=on
dtparam=I2c_arm=on
```

To save the changes use Control-X on the keyboard, and answer 'Y' when prompted. Finally, the 'modules' file can be edited so that the I²C interface is started automatically when the computer boots into Raspian. Use this command to load the file into an editor:

```
sudo nano /etc/modules
```

Then add this line at the end of the file:

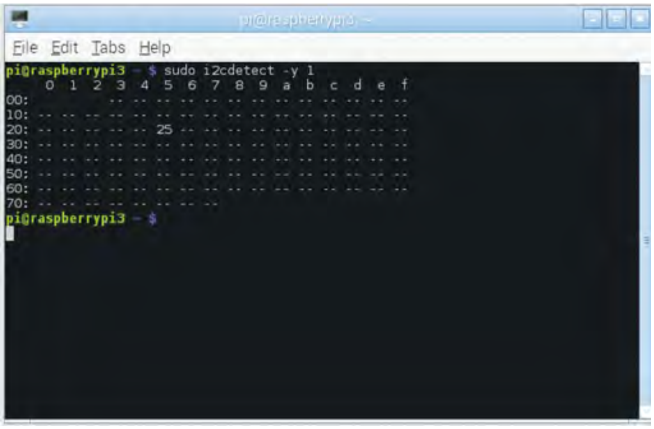



*Fig.6. An address map showing the detected I²C devices. In this case there is just one device, which is at hex address 25*

I2c-dev

The computer must be rebooted in order to make the changes take effect. Once rebooted, try opening a console window and using this instruction:

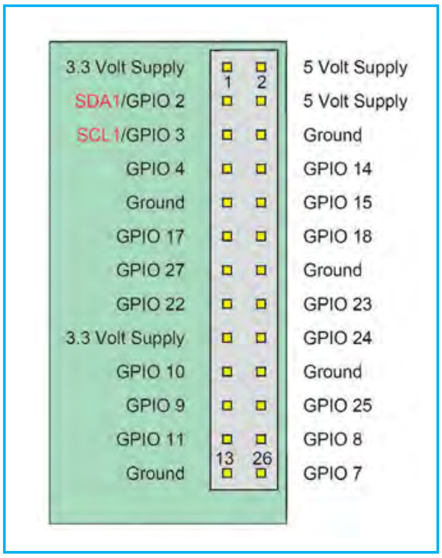
```
sudo I2cdetect -y 1
```

With an original Raspberry Pi it might be necessary to use this instead:

```
sudo I2cdetect -y 0
```

This should produce something like Fig.6, and this is an address map showing any I²C addresses that are occupied by a piece of hardware. Initially, every address will be empty, but it will at least show that the I²C interface is operational. For the sake of this example I have connected a piece of hardware to the I²C bus, and in the map it is correctly shown as being present at hex address 25.

*Fig.7. The two I²C lines are at pins 3 and 5 of the GPIO port. This is the same for the 26-pin and 40-pin versions of the port.*




Connections to the GPIO port are via pin 3 for the SDA line, and pin 5 for the SCL line, as shown in Fig.7. It is the 26-pin version of the GPIO port that is shown in Fig.7, but the same two pins are used on the 40-pin version. Even with ground and positive supply lines, it still only requires four wires to connect the GPIO port to the peripheral circuit. A 4-way ribbon cable having individual connectors for the GPIO pins is a more practical approach than using a full ribbon cable, but great care must be taken to avoid connection errors.

If the peripheral circuit will operate from a 3.3V supply and it only requires a modest supply current, it makes sense to use the 3.3V output of the GPIO port. This should guarantee that there are no compatibility issues with logic levels. However, due to the open-drain/collector method of driving the SDA and SCL lines, there should be no problem if the 5V supply output is used. This certainly gave no difficulties when I tried it with a couple of peripheral circuits.


Our periodic column for PIC programming enlightenment

# PICs and the PICkit 3: A beginner's guide – Part 12

**REDUCING** processing time and optimising memory use are worthwhile objectives that every project should incorporate. Often, we want to capture real-world values that need to be converted into quantifiable data. To do this we can use functions to convert captured values (often voltages) into temperature or acceleration values. However, there is an alternative approach using pre-calculated interpretations of input data that are stored in a table that can be easily accessed whenever they are needed.

This month, we take a look at the central theme of this approach – look-up tables – which is the topic of Lesson 12. These are arrays that are initialised at code startup, which contain pre-calculated values that can be quickly accessed throughout the code to save both time and memory. Typically, look-up tables replace executing equations such as the simple example in Fig.1. Instead, arrays that store pre-calculated values are used.

```
y = function(x);
```

*Fig.1. Example of a function to be calculated*

Before I continue, I recommend having a read of the previous articles in the series. It's not absolutely necessary for this article, but you will gain a greater insight into PICs and what we're trying to achieve here. You will also need the following software and hardware:

1. Purchase the PICkit 3 Low Pin Count Demo Board (**http://tinyurl.com/h2jj2ek**)
2. Purchase the PICkit 3 Programmer + USB Cable (**http://tinyurl.com/zcpx3le**)
3. Download *PICkit 3 Starter Kit User's Guide* (**http://tinyurl.com/jyqfeuk**)
4. Download MPLAB X IDE (**http://tinyurl.com/hmehqja**)
5. Download XC8 Compiler (**http://tinyurl.com/h5g9k5l**)
6. Download Example code for PICKit3 Starter Kit (**http://tinyurl.com/z2dm5k3**)

## Look-up tables

Lesson 12 of the *PICkit 3 Starter Kit User's Guide* gives some useful background into how look-up tables work and their advantages. I recommend giving it a read, even though it does focus on the more complex approach of using assembly code. As mentioned previously, while assembly code has its advantages, ease of use for beginners is not one of them. In saying that, it is always interesting and instructive to understand what's going on inside the microcontroller and assembly code does provide a good route to this, albeit a tougher-to-follow one. Give it a read and don't be down heartened if you can't follow *every* detail.

Let's look at an example of a common use for look-up tables. I recently built a project that used the LM35 precision Celsius temperature sensor from Texas Instruments. It has a working voltage of 4V to 30V; comes in a 3-pin TO92 package (as well as SOIC, TO-CAN and TO-220); has an accuracy of ±0.5°C and a temperature range from –55°C to 150°C. Fig.2 shows the pin out for this device. It has a linear scale factor of 10mV per °C, which means for every 1°C change in temperature the output changes by 10mV. One way to think about this sensor is to say there are 410 unique temperature values: max temperature (150) minus minimum temperature (–55), all divided by the accuracy (0.5).

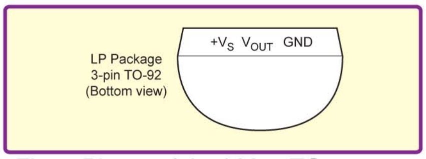



*Fig.2. Pinout of the LM35 TO-92 precision Celsius temperature sensor*

In most cases, we wouldn't expect much of a temperature change between each reading. However, every time we capture data, we must run an equation to convert from the ADC bit value into a voltage, then convert it into a temperature in Celsius. This is likely to be an excessive processing overhead for a value that probably won't change very often.

Consider an input from the LM35, using a 10-bit ADC that provides a bit value of 164. To convert that into a voltage we need to know what the reference voltage is. In this case, it's 5V. Our equation is the supply voltage (5V) divided by the maximum number of bits (1023) and then multiplied by the ADC input value (164):

(5V/1023) * 164 = 0.801V

To convert this into a valid temperature, we divide by the 10mV scale factor:

0.801V / 0.010V = 80.1°C

That value doesn't look quite right though. The problem is that 0V is –55°C so we need to compensate for this offset:

80.1°C – 55°C = 25.1°C

The temperature sensor has an accuracy of 0.5°C, so that value is rounded down to 25°C. Even if the temperature doesn't change, the microcontroller still has to go through the above calculation every time it logs a value. However, with a look-up table, the microcontroller takes the ADC bit value of 164, looks up that value in the pre-calculated array and returns the value of 25°C. This allows the microcontroller to focus on other tasks as well as optimising memory use. Storing 410 unique temperature values in an array is a small amount of data compared to the processing time saved.

Other useful examples of look-up tables include linked lists, trivial hash functions, counting bits in a byte, image processing and computing sinewaves. These can be very time consuming tasks, unless look-up tables are used.

## The code

Let's look at a simple example – one which does not need 410 unique values, but a more user friendly 16. The Microchip sample code for this lesson uses the ADC input to take a value from the potentiometer and then illustrates the changing input with the on-board LEDs. More specifically, it takes only the four most-significant bits (MSB) and converts them into Gray-coded binary using a look-up table with an array.

So what is Gray code and why do we use it? To explain that, we need to take a little diversion from look-up tables. Gray-coded binary, named after Frank Gray, is frequently used in state machines to prevent wild jumps between states due to bit errors and is common practice in high-speed designs. The basic idea behind Gray code is that only one bit changes from one state to the next. Therefore, if the state changes from one value to the next and a logic error occurs, only one bit will be affected, forcing the microcontroller to either stay in the same state or transition to the next. Without Gray-coding, the microcontroller could jump to any possible state, even states that aren't handled in the code. This is important in high-speed logic designs, if setup and hold times on signals are violated, changes in bit values can be missed. As an example, this could mean transitioning from the third state in a state machine to the seventh state as the correct bits were not changed quick enough. This can cause all sorts of very-hard-to-find problems in your design.

Just to clarify, when changing a parameter's value to a new value, it's only the bits that need to be changed that are actually changed. So, moving from binary 1 to 2 (0001 to 0010) only the third and fourth bits are changed, while the first and second are left alone. These changes are where potential problems occur, leading to bit errors. Ideally, we want to minimise the risk by minimising the number of bit changes and the best way to do this is to change only one bit at a time.

An example of how Gray coding works can be seen in Fig.3; examine the codes for decimal 3 and 4. In binary, 3 is represented by 0011, and 4 is 0100. Note that in binary, three of the bits change between the adjacent 'states' that represent 3 and 4. Any one of those three bits might not change correctly, giving any one of the following possibilities: 0111, 0110, 0101, 0100, 0011, 0010, 0001. Now consider the Gray coding for state number 3 and 4, 0010 and 0110 respectively. Only the second bit is being changed, which means only two options are available (0010 and 0110); it either stays in the same state or moves to the next state. This method reduces potential errors that can be tough to trace.

Fig.3 shows how decimal values from 0 to 15 are mapped to their Gray code equivalents. Note that as each state of the Gray code increases, only one bit changes between each state. The bit values for the Gray code are specifically ordered in such a way that the next state is only one bit change away and that each state is unique. You could try and re-order the state numbers, but you will find that you won't be able to access all the unique values.

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

*Fig.3. Decimal, binary and Gray-coded binary table.*

It's also important to note that there is only one bit change when rolling over from 15 back to 0.

OK, back to look-up tables. In theory, we could convert every ADC input value into Gray-coded binary each time we get a value. This will take up processing time and data memory. By using a look-up table, which stores our pre-calculated values, we save time and memory. It's like working smarter, not harder.

As mentioned earlier, the assembly code is much more complex. It accesses various registers, like the program counter (PC) and uses the EEPROM to store the data, which we will cover next month. The C code equivalent is 'trivial' in comparison.

```
unsigned char adc(void);

const unsigned char gray_code[] = {
    0b0000,0b0001,0b0011,0b0010,0b0110,
    0b0111,0b0101,0b0100,0b1100,0b1101,
    0b1111,0b1110,0b1010,0b1011,0b1001,
    0b1000
};
```

Looking at the code itself, there's not much new to us. Skipping the usual pre-processor directives and definitions, we see a prototype initialised for a function called `adc`. Now we set up the look-up table. The `const` value tells the compiler to place this into program memory and not into data memory. This makes considerable space savings as the program memory is stored in Flash memory and there's plenty of it, whereas data memory is stored in RAM, which is limited. Each value is stored in the array called `gray_code[]`, to be accessed later.

```
void main(void){
    unsigned char adc_value;

    OSCCON = 0b00111000;
    TRISC = 0;
    TRISAbits.TRISA4 = 1;
    ANSELAbits.ANSA4 = 1;
    ADCON0 = 0b00001101;
    ADCON1 = 0b00010000;
```

The main loop doesn't include anything we haven't seen a dozen times already in the *Beginner's guide* – initialise a variable called `adc_value`, set the clock to 500kHz using the `OSCCON` register, and set Port C to outputs using the `TRIS` register. Port RA4 is connected to the output of the potentiometer on the Low Pin Count board, so it is set as an analogue input. Port RA4 is then set up as the source of the ADC, and the ADC module is enabled using the `ADCON0` register. `ADCON1` then sets the returned values to be left justified, the speed is set to FOSC/8 and the Vref is VDD. (This has all been covered in previous lessons.)

```
    while(1){
        adc_value =  adc();
        adc_value >>= 4;
        LATC = gray_code[adc_value];
    }
}
```

The above `while` loop is where all the action takes place. Capturing the input from the potentiometer through the ADC pin and storing it in the variable `adc_value`, we then shift this value to the right by four, thus keeping only the four most-significant bits. Four bits means a maximum of sixteen values, which can be mapped to the sixteen values stored in the `gray_code[]` array mentioned earlier. The `adc_value` variable is used as the index to the `gray_code[]` array. For example, if the shifted `adc_value` is 4, we take the fifth value in the `gray_code[]` array, which is `0b0110`. This is then stored in Port C with `LATC`, which is connected to the four LEDs. Don't forget the first value in the array is index number 0, not 1. So index number 4 is actually the fifth value. See Fig.3 again to verify this.

```
unsigned char adc(void) {
    __delay_us(5);
    GO = 1;
    while (GO) continue;
    return ADRESH;
}
```

We saw `adc`, the final function, last month. There's a small 5µs delay to allow the capacitor on the ADC pin to charge before starting the conversion by setting the `GO` command to 1. Then we wait for the conversion to complete and return the eight most-significant bits, which are stored in the `ADRESH` register.

### Next month

In the next column we will finish the *Beginner's guide* series with a look at EEPROMs, followed by a small project that will use much of what we've learned in this series. Then we bid *adieu* to the PICkit 3 Low Pin Count Demo Board and move to new fun topics.

# Transmission lines

**LAST MONTH'S** article, in response to a question by *EPE Chat Zone* user ***simonbond***, was about oscilloscope probes and leads. Part of the discussion acknowledged that at high frequencies we have to take their behaviour as transmission lines into account. There was not enough space last month to look at the concepts related to transmission lines in much detail, so this month I will take a more in-depth look at the basics of this important topic.

When we connect together components, circuit boards or electronic equipment we might like to assume that the wiring or PCB tracks provide a perfect connection. Fig.1 shows the connection between two systems or circuits with two wires – this represents a generic situation with a signal wire and return path, typically the return path is the ground connection. This could apply to a wide variety of situations, including twisted pairs, coaxial cable, or a trace and ground plane on a PCB. Note that the discussion below on the nature of a single wired connections can be extended to cover more complex situations such as differential signals and three-phase power.

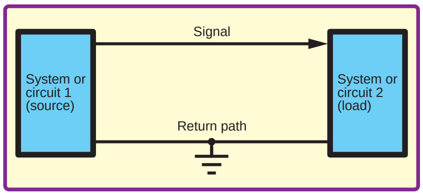



*Fig.1. Circuits connected with 'perfect' conductors*

## Wire model

If we think a bit more about the situation we may readily accept that the wiring has some resistance – perhaps in series ($R_S$, usually quite small) due to the resistance of the conductor, or in parallel due to imperfect insulation ($R_P$, usually very large) as shown in Fig.2. These resistive imperfections can be a problem in some situations. For example, with large currents (causing voltage drops across $R_S$ and subsequent heating).

We refer to the circuit in Fig.2 as a 'model' of the wire. The resistors $R_S$ and $R_P$ are not electronic components, they represent the electrical properties of the wiring and/or its environment. When designing and analysing circuits where

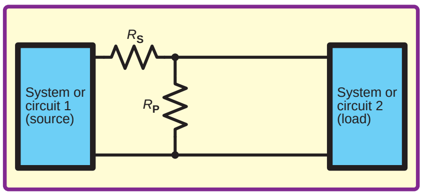



*Fig.2. Wiring with series resistance $R_S$ and insulation leakage resistance $R_P$*

the properties of the wiring may have an impact on the circuit's behaviour or performance we use such models to inform the design process. This can be in a formal and detailed way through detailed mathematical analysis or simulation, or informally through rules of thumb and known good design practice. For example, if we know that a PCB trace will carry a high current then $R_S$ will be of importance. Design guides and online calculators can help designers choose suitable trace widths so that wiring resistance does not have an adverse effect on the design.

In a typical cable the two wires run in parallel in close proximity, separated by an insulator (either as a parallel or twisted pair, or a single wire plus shield). – thus they form a capacitor. Likewise, the signal wire plus return constitute a loop (like a single 'turn' of a coil in the simplest case) – thus they form an inductor. Similar arguments apply to PCB traces – a trace running above a ground plane forms a variant of a parallel plate capacitor and the trace and ground form an inductive loop. Therefore, we can extend our model of the wiring to include capacitance and inductance, as shown in Fig.3. For AC and pulse signals we may have to take wiring capacitance and inductance into account. In general, the higher the AC frequency, or the faster the pulses, the more important these reactive parameters become.

## Lumped

The circuits shown in Fig.2 and 3 are referred to as 'lumped models' of

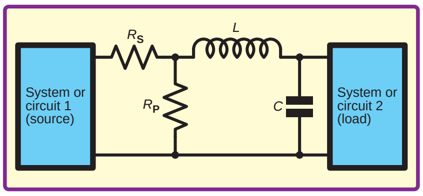



*Fig.3. Lumped model of connection with resistance, inductance and capacitance*

the connection because the various properties of the whole connection are lumped together and represented by single components. Given that nothing, including electrical signals on wires, can travel faster than the speed of light, a signal will take a finite time to travel from one end of a wire to another. For example, if we connect a voltage across one end of a coaxial cable, then that voltage will not 'see' the capacitance of the whole cable until the signal travelling down the wire reaches the other end. If we apply a fast voltage pulse to a long cable, where the travel time is longer than the duration of the pulse, the voltage of the pulse will never be applied across the whole lumped capacitance at once.

Lumping the capacitance (and other properties) of the cable into a single component model may not provide an accurate picture of how wiring behaves when a signal is applied. It all depends on the timescales that apply to the situation we are working with. If our signal cycles times, pulse durations, or circuit timescales in general, are less than, or comparable with, the time taken for the signal to travel down the wire then the effect of signal propagation time will have to be taken into account – we are then in the world of transmission lines. To put it another way, in such situations our design or analysis has to be informed by a model of wiring which takes account of the signal travelling at finite speed. It is transmission line theory that facilitates this.

## Transmission line

Transmission lines can be represented explicitly on circuit schematics, as shown in Fig.4. A variety of symbols are used, from a simple box to more graphical depictions of structures such as coaxial cables. The parameters shown on the symbol are often the characteristic impedance $Z_0$ and the transit time or propagation delay $T_d$ – we will discuss these in more detail soon. Transmission line symbols tend to be used when transmission line theory is being discussed or where particular connections, such as coaxial cable need to be shown. The lack of a transmission line symbol on a schematic does not mean that transmission line effects do not have

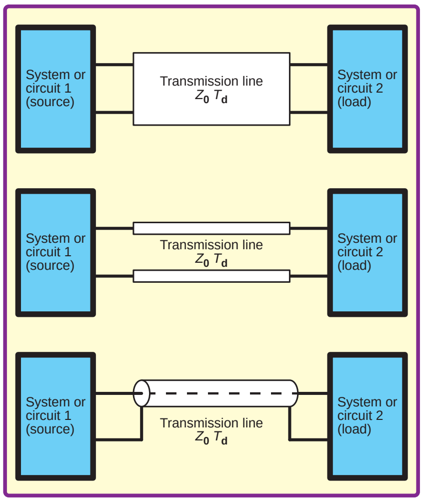



*Fig.4. Transmission line model of a connection showing various versions of the schematic symbol*

to be considered; for example, when designing a PCB layout.

Naturally, the question arises of exactly what is a transmission line model of connection. Fundamentally, we need to consider the electromagnetic field created by the signal and think of it propagating down the wire as a wave. This is more like the way in which we think of radio transmission, except the signal is guided down the wire rather than travelling through free space. A full analysis of this situation requires electromagnetic theory and some advanced mathematics.

One result of the electromagnetic analysis is that a transmission line can be characterised by a characteristic impedance $Z_0$, measured in ohms, which determines the relationship between voltage and current at any point along the line. The characteristic impedance is specified for products such as coaxial cable, where for example 50Ω is used for a wide range of applications, and 75Ω for video and TV cables. PCB traces can be designed with required $Z_0$ and various tools, including online 'calculators' are available to assist with this.

$Z_0$ depends on the geometry of the line – the shape and spacing of the two conductors. The geometry of a basic transmission line does not vary along its length and $Z_0$ does not depend on the length of the line. Non-uniform transmission lines have some applications, but this is a specialised and advanced topic.

## Characteristic impedance

Characteristic impedance also depends on the material properties of the insulator separating (and surrounding) the wiring – specifically the relative permittivity (dielectric constant) ($\varepsilon_r$) and the relative permeability ($\mu_r$), which characterise the response of a material to electric and magnetic fields respectively. In most cases (typical cables and circuit boards) the insulating materials are not 'magnetic' so $\mu_r \approx 1$ and only the permittivity is of significance.

Because we are dealing with waves traveling along the line, the voltage and current at any point may be different from any other point, but the relationship between them will be determined by $Z_0$ and be the same at each point. It is important to point out that, although it is measured in ohms, the characteristic impedance is not like a resistor. It is not like $R_S$ or $R_P$ in Fig.2 – it does not result in dissipation of power. Ideal transmission lines are lossless – the conductors have no resistance, but real transmission lines will exhibit some loss and, as we saw in the discussion of oscilloscope leads last month, specifically lossy transmission lines with relatively high series resistance can be constructed.

Another fundamental characteristic of a transmission line is the velocity of propagation of the signal, $v_p$. Typically, $v_p$ depends on just the insulator material properties rather than the geometry and, given that usually $\mu_r \approx 1$ for relevant materials (as noted above), it is the insulator's permittivity which determines the speed. Like $Z_0$, $v_p$ is independent of the length of the line, but if the length ($L$) is known the propagation delay ($T_d$) of a signal travelling from one end to the other is easily found using $T_d = L / v_p$.

## Light speed

If the transmission line insulator is a vacuum the velocity of propagation is the speed of light, $c$. The speed of light is itself related to permittivity and permeability, specifically the permittivity and permeability of free space ($\varepsilon_0$ and $\mu_0$ respectively). The relationship between the speed of light and the permittivity and permeability of free space (which are all fundamental physical constants) is:

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

For a transmission line it is given by:

$$v_p = \frac{1}{\sqrt{\varepsilon \mu}}$$

Here, $\varepsilon = \varepsilon_r \varepsilon_0$ and $\mu = \mu_r \mu_0$. We can combine these relationships, with $\mu_r = 1$ for simplicity, to write the velocity of the signal propagation in terms of the speed of light

$$v_p = \frac{c}{\sqrt{\varepsilon_r}} = F_v c$$

Here, $F_v = 1/\sqrt{\varepsilon}$ is the velocity factor of the transmission line. This allows us to get some idea of the signal velocity in common situations. For example, coax cables that use a polyethylene dielectric (with $\varepsilon_r = 2.3$) will have a velocity factor of about 0.66. For standard PCBs built using FR4 glass-reinforced epoxy laminate (with $\varepsilon_r \approx 4$) the velocity factor is about 0.5. The situation for PCBs is more complex than for coaxial cable because the electromagnetic field may not be entirely contained in the board material (depending on the wiring structure used) and this will affect signal propagation speed.

The speed of light is about $3\text{x}10^8$m/s, so a signal will travel down a 1m cable in about 4 to 8ns, depending on the insulator characteristics. A sinusoid with a period of about 8ns has a frequency of around 130MHz, so for any signals involving frequencies anywhere near or above this frequency we would have to regard a 1m cable as a transmission line. The higher the frequencies present the shorter the distance at which we have to use transmission lines to take full account of the behaviour of circuits and interconnections. The signals on the high-speed logic boards and even the interconnections in some digital ICs (operating at GHz) have to be modelled as transmission line by circuit designers. For very long distances (eg, cables many kilometres in length) transmission line effects come into to play at low frequencies.

## Wire or transmission line?

As a rule of thumb we have to use transmission lines rather than basic circuit theory when the length of a connection is more than about one tenth the wavelength of the signal. The wavelength is given by $v_p / f$, where $f$ is the frequency. For a connection with velocity factor of 0.5 this is 1.5km at 10kHz, 15m at 1MHz and 15mm at 1GHz. Remember that digital signals with sharp 'square wave' edges have important frequency components at much higher frequencies than the data or clock repetition rate and this must be taken into account.

The preceding discussion of electromagnetic waves helps establish the idea of a signal moving through space along an electrical connection, but may seem somewhat removed from basic circuit theory. It is helpful therefore to consider an electrical circuit model of a transmission line. We can start with the circuit in Fig.3. If we are considering lossless transmission lines the resistances are not present, so we just have the inductance and capacitance. Now imagine that Fig.3 represents a connection that is of the maximum length where we can get away without considering transmission line effects. What happens if we double the length? If we simply double the $L$ and $C$ values the model will be inadequate, but we could think of the situation as two shorter connections in series and use two copies of the $LC$ section in series to model it. This would go some way to address the fundamental idea that the signal 'sees' a different point on the wire as it moves down it, but just using two sections will be a very crude approximation.

If we divide the model of the connection into a large number of

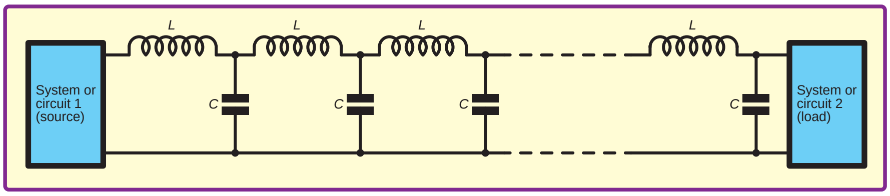



*Fig.5. Ladder network model of a lossless transmission line. The LC sections are repeated many times.*

elements, each of which is an *LC* circuit representing a short section of the connection then we arrive at a circuit like that in Fig.5. This is known as the ladder network model of a transmission line. A similar approach can be used to model a lossy line by including the resistance, as shown in Fig.6.

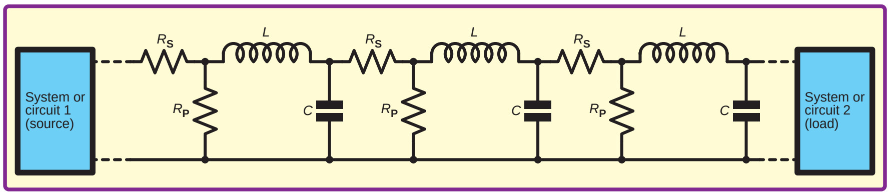



*Fig.6. Ladder network model of a lossy transmission line. The RLC sections are repeated many times.*

## Distributed model

The ladder network model is an approximation, but we are free to increase the number of elements as much as we like. If we have an infinite number, then each *LC* element represents a single point along the line and we need to consider the inductance and capacitance per unit length rather than individual *L* and *C* values for the elements. Along with this, we have the voltage and current at each point along the line. This approach is known as the distributed component model and is the basis of transmission line theory. Oliver Heaviside carried out fundamental work using this model this in the 1880s. He developed the telegrapher's equations. These relate the current and voltage on a transmission line in terms of both time and distance along the line to the capacitance and inductance per unit length. The telegrapher's equations are directly related to wave equations, which describe the propagation of the signal (relating back to our earlier discussion).

The telegrapher's equations lead to expressions for the key transmission line parameters, namely the characteristic impedance, $Z_0$, and the propagation velocity, $v_p$, in terms of the capacitance and inductance per unit length (*C* and *L* respectively), specifically:

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$v_p = \frac{1}{\sqrt{LC}}$$

To get a better feel for how transmission lines behave in circuits we will consider the simple case where a DC voltage (source voltage, $V_S$) is applied to an ideal (lossless) transmission line. If we assume that the voltage and current on the line are zero prior to applying the voltage we will get a step in voltage travelling down the line away from the source at velocity $v_p$. Initially, assuming the line is infinitely long, if we measured the voltage ($V$) and current ($I$) at any point on the line where the signal has already passed we will get the same $V/I$ ratio. As discussed above, this is the characteristic impedance ($Z_0$) of the transmission line.

## Reflections

Now imagine the line is not infinitely long, but the far end is connected to a resistor – the load resistor ($R_L$) as shown in Fig.7. The resistor also has a specific current-to-voltage ratio, set by its resistance. What happens when the signal reaches the resistor? If the characteristic impedance of the line matches the resistor value then there will be no discrepancy in current and voltage values at the interface between the line and the resistor. The power delivered by the signal (remember the line is lossless) will be exactly dissipated by the resistor. However, if the resistance does not match the characteristic impedance then it seems there will be a discrepancy in current and voltage values at the interface. But this discrepancy cannot exist because it would break the laws of physics – specifically the conservation of energy (or power). The outcome is a change in voltage and current and hence another wave – a reflection – that travels back up the line resulting in a change of voltage and current all along the line as it progresses.

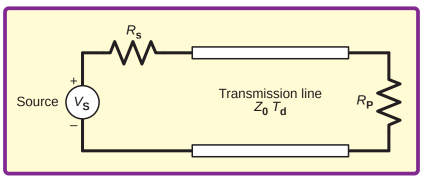



*Fig.7. Transmission line with source and load resistances.*

When a reflection occurs the voltage of the reflected signal (wave) can be calculated by multiplying the voltage of the arriving wave by the reflection coefficient (gamma, Γ) which is given by

$$\Gamma = \frac{R_L - Z_0}{R_L + Z_0}$$

The current is reflected with the same coefficient, but opposite sign. From this we see that if $R_L = Z_0$ the reflection coefficient is zero and no reflection occurs – the load is matched to the line. If the load is a short circuit, $R_L = 0$ and $\Gamma = -1$, then the reflected wave will have equal and opposite voltage to the arriving wave and the two will exactly cancel out resulting in a total of zero volts propagating back up the line, which makes sense for a short circuit.

## Bouncing backwards and forwards

If a reflection occurs then the reflected wave will eventually get back to the source. Here, exactly the same scenario exists as when the signal reached the load. If the impedance connected to the line, specifically the source impedance ($R_S$ in Fig.7), does not match the characteristic impedance another reflection will occur and another wave will set off down the line back towards the load. The voltage of this wave can be found by multiplying the first reflected wave voltage by the reflection coefficient applicable at the source. In general, to find the reflection, the voltage of the individual arriving wave is multiplied by the reflection coefficient, not the total voltage on the line. For sources and load impedances that are resistances the magnitude of the reflection coefficient will always be less than or equal to one ($|\Gamma| \leq 1$).

Many reflections, backwards and forwards, will occur if both source and load resistances are not matched, but given $|\Gamma| \leq 1$ the amplitude of the reflections will diminish each time and the voltage along the whole line (in Fig.7) will settle to a value given by applying the potential divider formula to $V_S$, $R_S$ and $R_L$. To put it another way, if the applied signal remains unchanged for a large multiple of the line's transit time it will then behave like a simple pair of wires and 'normal' circuit theory can be used (see Fig.8).

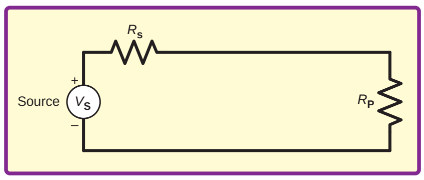



*Fig.8. After applying a DC voltage and waiting many times longer than the signal transit time the transmission line circuit in Fig.7 behaves like a potential divider.*

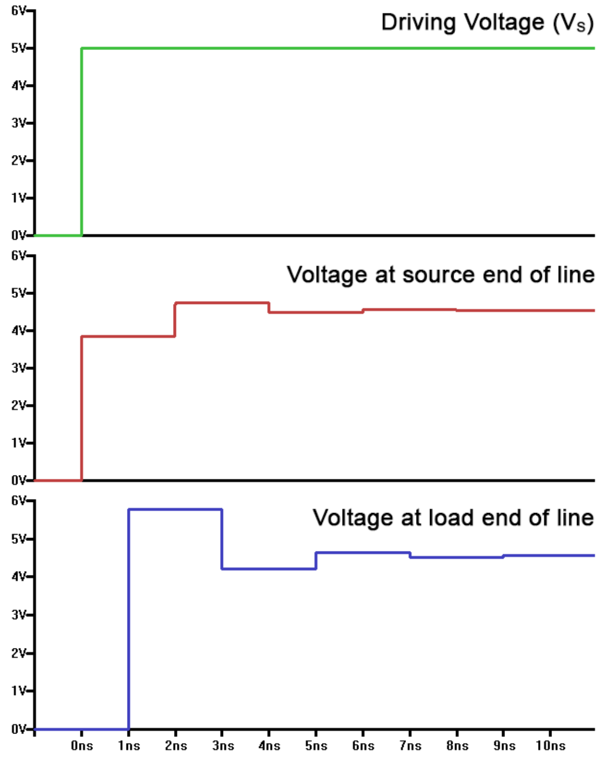



*Fig.9. Graphs showing the effect of applying a DC step voltage to an unmatched transmission line.*

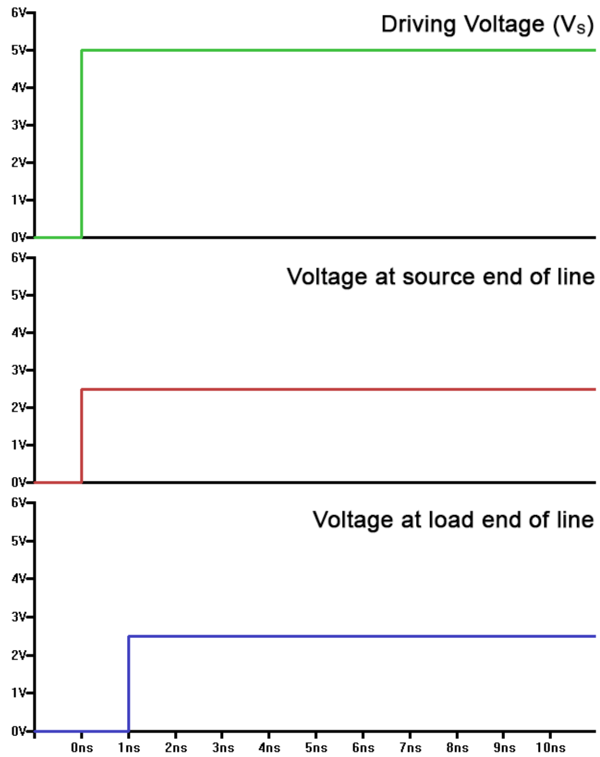



*Fig.10. Graphs showing the effect of applying a DC step voltage to a matched transmission line.*

An interesting point related to this concerns what would happen if you try to measure the resistance of a standard 50Ω coax cable with a meter. As you attach the multimeter it applies a voltage across the cable. Then, if you and your multimeter were fast enough (probably nanoseconds or less), you would see a 50Ω reading between the conductors until the reflected wave got back from the end of the cable to the meter. After that the meter would simply read the load (open, shorted, resistor value) across the other end of the coax, which is what you might expect as the coax is providing low-resistance copper conductors to connect the load to the meter.

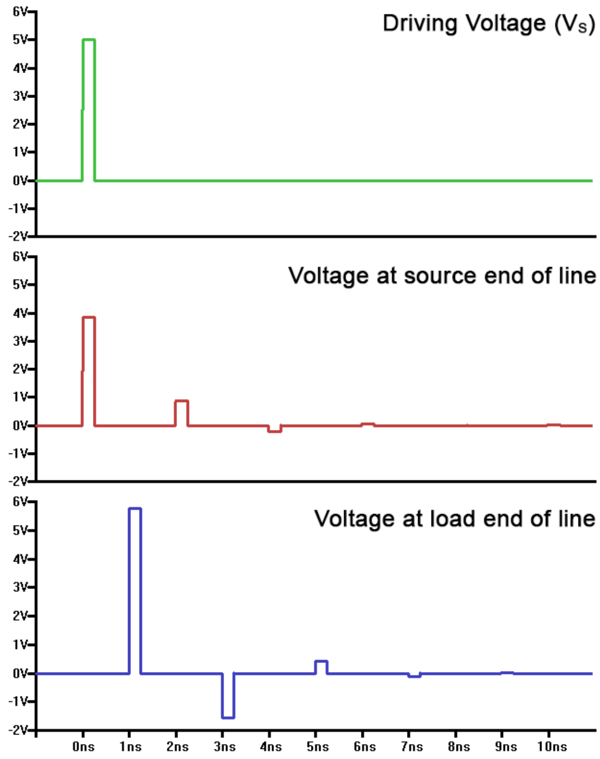



*Fig.11. Graphs showing a reflected short pulse on an unmatched transmission line.*

**Examples**

The waveforms in Fig.9 provide an example of how a transmission line, connected as in Fig.7, behaves when a DC voltage is applied. In this example the line characteristics are $Z_0$ = 50Ω and $T_d$ = 1ns. The resistors are $R_S$ = 15Ω and $R_L$ = 150Ω, which means the reflection coefficient at the load end is (150 – 50) / (150 + 50) = 0.5, and at the source end it is (15 – 50) / (15 + 50) = –0.538. The voltage source switches from 0V to 5V at time zero. At this instant the line presents a 50Ω load to the source, so it forms a potential divider with $R_S$, resulting in a voltage of (5 × 50) / (15 + 50) = 3.846V across the line.

This voltage travels down the line, taking 1ns to reach the load (the voltage at the load end remains zero until 1ns on the graph). As the load is not matched a reflection occurs with voltage 0.5 × 3.846 = 1.923V. The reflected voltage is added to the arriving voltage to give 3.846 + 1.923 = 5.769V at the load. The 1.923V reflected signal travels back down the line changing the voltage to 5.769V as it goes. When the 1.923V reflected signal gets back to the source (at 2ns on the graph) it causes another reflection, with voltage –0.538 × 1.923 = –1.035V. This adds to the existing voltage shifting it to 5.769 – 1.035V= 4.734V.

The second reflection gets back to the load at 3ns. The line voltage is 4.734V and the next reflection is 0.5 × (–1.035) = –0.518V, shifting the voltage to 4.734 – 0.518 = 4.217V. The signal keeps bouncing backward and forwards like this, with diminishing reflected voltages. Eventually, both ends of the line settle at 4.545V, which can be found by applying the potential divider formula to $V_S$, $R_S$ and $R_L$ that is (5 × 150) / (150 + 15) = 4.545V. Note that temporarily the voltage across the load was larger than the source voltage (between 1 and 3ns on the graph).

**Perfect match**

The graph in Fig.10 shows the same situation, except with $R_S$ and $R_L$ both changed to 50Ω to give perfect matching to the line at both ends. Initially, $R_S$ and the 50Ω line form a potential divider to give 2.5V at the source. This travels to the load (in 1ns) where no reflection occurs due to perfect matching. The voltage stays at 2.5V. When $R_L$ ‘takes over’ as the potential divider resistor the voltage does not change because it has the same value as the line impedance. The line behaves ‘nicely’ acting as a pure delay of 1ns.

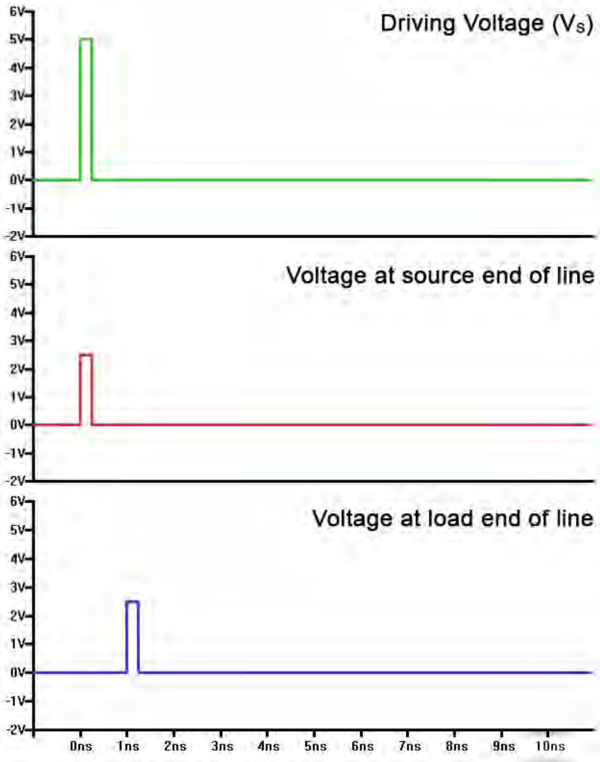



*Fig.12. Graphs showing a short pulse applied to a matched transmission line*

The graphs in Fig.11 and 12 show the effect of a pulse shorter than $T_d$ to a transmission line. The line characteristics are the same as in the previous examples. It can be seem that multiple pulses occur due to reflections on the unmatched line, but a perfectly matched line cleanly conveys a 2.5V pulse from one end to the other. These examples give some idea of the problems that might occur in high-speed circuits, such as fast digital data buses, if transmission lines effects are not considered during design. Even if the connections are correctly matched, the delay needs to be taken into account, for example by making PCB traces exactly the same length for multiple related high-speed or high-frequency signals.

# AUDIO OUT

By Jake Rothman

## ICStripBoard – product review

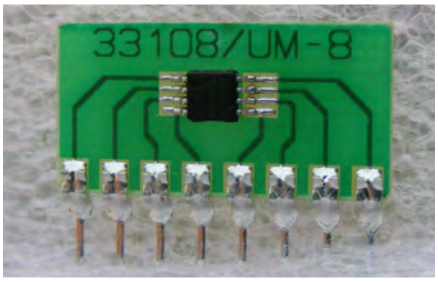



*Fig.1. Surface-mount adaptors are available from all the distributors, but are disproportionately expensive.*

Every so often an idea comes along that's so obvious you kick yourself for not having thought of it first – ICStripBoard is one such idea. Terry Fitzpatrick invented copper stripboard at AV Roe engineering in 1959 for prototyping transistor circuits, avoiding the proverbial 'birds-nest' of wiring. This was commercialised by his boss Geoffrey Verdon-Roe to become the Veroboard we all know and use. Dr Daniel Brennan has now done the same for surface mount technology. Expensive SMT adaptor boards have been available for some time, but I feel ripped off using a £5.00 board to connect a 26p class-D amplifier chip (Fig.1). As with overpriced software, it takes an innovative individual to come up with the right countermeasure.

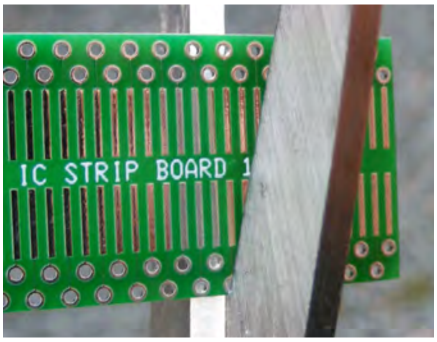



*Fig.3. The boards can easily be cut to size with scissors – no hacksaw needed.*

All surface-mount devices come in a few standard pad pitches and there is an ICStripBoard available for each one, as shown in Fig.2. The epoxy fibreglass board is 0.8mm thick, so it can easily be cut to size with scissors (Fig.3). Each board is 100mm long, sufficient for around a dozen components. At £3.99 a board this is over ten-times more cost effective than other systems. At this price it is also ideal for use as an SMT soldering training board. Although the samples I have had are in standard tinned industrial green, the new ones will be colour-coded and gold plated. Each pad is brought out to a plated-through hole to which tinned copper wire can be soldered. The assembly can then be used for breadboarding or soldering to conventional circuit boards.

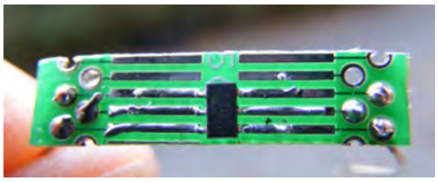


*Fig.4. SMT dual-JFET mounted on board; it costs 30-times less than a metal-can version.*

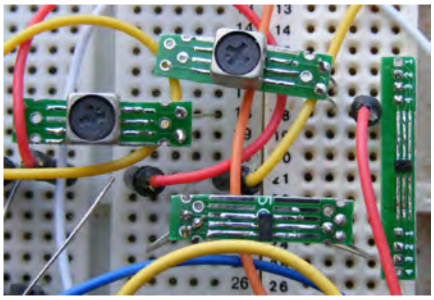


*Fig.5. ICStripBoard is very useful for incorporating SMT components in conventional prototyping, such as breadboards.*

There are many components that are either only available in SMT packages or through-hole versions that are very expensive. One problem I've had is with the dual JFETs used in low-noise preamplifiers. The Toshiba 2SK2145 costs about 56p, whereas an equivalent TO18 device from interFET costs almost £16.00 from Mouser. Fig.4 shows the 2SK2145 mounted on the 0.95mm board. My only criticism is that the gaps down the centre between the pads is slightly too wide for most SMT discrete transistors.

I have made a full collection of ICStripBoard-connected devices for prototyping and design work. Fig.5 shows some examples using a breadboard prototype and TDK adjustable SMT coils.

As well as individual boards, a prototype pack that contains one of each board and a foot of Solder Wick is sold for £11.99 (academic and quantity discounts also available). For further details just contact: **sales@icstripboard.co.uk**

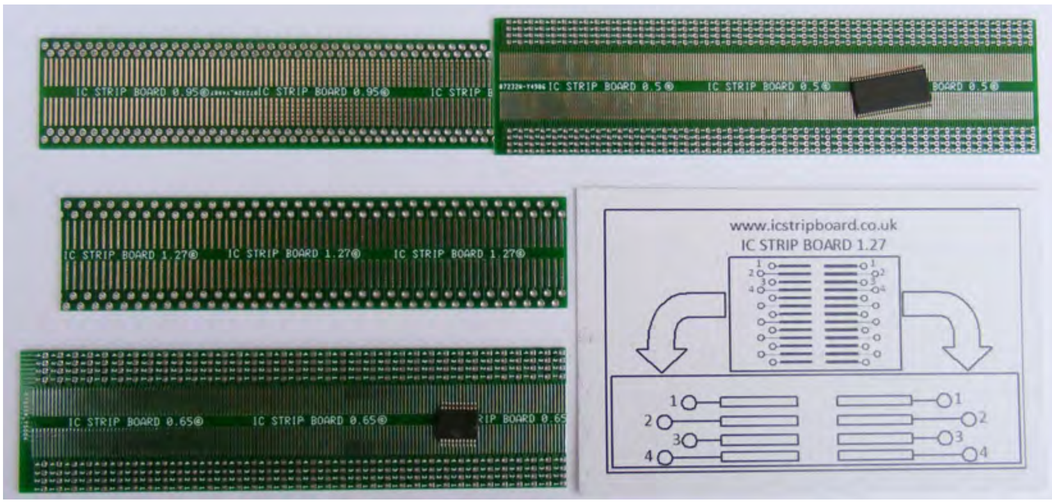



*Fig.2. ICStripBoard is available in the four common surface-mount pitch standards.*

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# Max's Cool Beans

By Max The Magnificent

### Scared of heights?

Earlier today, the folks in the next office had a visitor from the machine shop down the road and they asked if I'd mind letting him try out my Oculus Rift Virtual Reality (VR) system. It turned out that he had heard about VR on television, but had little idea what it all entailed. I asked, 'Are you scared of heights?' He replied 'Not really.' I gave a knowing grin and said 'You will be.' I just heard on the grapevine that he cannot stop telling his workmates about the experience.

*Fig.1. Steve Manley with his PSVR (Photo: Sharon Syme)*

### Which system's right for you?

In previous columns, we've talked about the various VR systems that are currently available. At the low-end of the spectrum we have headsets into which you connect your smartphone, which is used to provide the computation and graphic processing. There are a lot of these around, the best-known being the Google Cardboard headset, which works with any smartphone; the Google Daydream headset, which works with Google Pixel phones and a few others; and the Gear VR headset, which works with Samsung phones. Personally, I think these are great for introducing people to VR, but they really offer nothing more than a taster that will leave you gasping for more.

To the best of my knowledge, there's currently only one serious mid-range player in VR space at the time of this writing, and that's Sony with the PlayStation VR (PSVR). Note that you will also need a PlayStation 4 (PS4) or 4 Pro console to drive the PSVR. I've not tried one of these myself, but I've been told that the image quality is very good. Also, Sony has enough 'weight' to command a lot of AAA-rated games.

When I visited my dear old mum in England last year, I took my VR system with me to show my friends. One of them, Steve Manley, was so impressed that he determined to buy a system of his own.

I asked Steve to share his experiences with me for the purposes of this column. Steve says that he's been a big fan of computer games since his early teens (about 40 years ago), starting with a very early cartridge-based console running games like Pong.

Steve had his first VR experience some 14 years ago at the Ideal Home Exhibition in London, but there was a huge queue, the experience was rushed and not very exciting, and it totally failed to impress him. Later, Steve had a chance to try an early Oculus Rift at the Channel 4 Grand Designs Exhibition in Birmingham, but – once again – the experience wasn't all that great. Steve says

*Fig.2. Arizona Sunshine (Screenshot: Vertigo Games)*

*Fig.3. Arizona Sunshine (Screenshot: Vertigo Games)*

that it was only when he tried my setup that he was blown away. He became convinced that VR had landed and that 'I had to get my own VR rig.'

Since Steve already had a PS4, he decided to purchase a PSVR. Unfortunately, he waited to hear the initial reactions of other users, so when he finally went to buy one 'the darn thing had sold out!' Happily, Steve's better half – Sharon – found an Argos Click and Collect around 30 miles from where they live that had one, so they reserved it over the phone and immediately raced down to pick it up, along with a bunch of games.

Steve is constantly emailing me, telling me about new games they've tried. He also tells me that 'anyone who has come to visit, including my 74-year-old mum, has tried the PSVR and they've all been blown away!'

Steve also asked Sharon to comment, and she spoke thus: 'Having never been much of a gamer, I found VR fascinating; it really is like stepping into a new world. From deep sea diving to being Batman to solving puzzles, you feel like you can be anyone and go anywhere – like being a top sportsman – all in the comfort of your own home. I also enjoy watching other people play; from extreme reactions like screaming on the edge of a cliff edge and asking me to hold onto them, to the very cool, who seem to take it all in their stride, but are still amazed. I do worry that with time and progress, some people with addictive personalities may find it hard to distinguish between true life and VR, as it can feel quite real, and it provides an easy way to escape from the real world.'

### I'm still shaking

There are two contenders at the top-end of the commercial VR spectrum: The Oculus Rift and the HTC Vive. Each system has its fanatical followers that denigrate and disparage the other. I know some people who have both systems on the basis that some games are available only on one platform or the other.

In my case, I opted for the Oculus Rift. This has now been augmented by Oculus Touch controllers, which let you manipulate things in the virtual world (you can see your virtual hands and use them to push virtual switches, pull virtual levers, and pick up and use virtual tools and weapons, from axes to guns). I much prefer these to the HTC Vive's original controllers, which looked like large television remote controls (I've heard that the latest generation are better, **http://bit.ly/2oiVfpn**, but I've not yet seen these in the flesh).

Unlike Steve, I've never really been a fan of computer games. I've enjoyed looking at the graphics and observing how things have evolved over the years, but it was only the advent of VR that pushed me over the edge. Now, it's difficult to prize me out of the thing.

There are too many amazing games to cover, so let me just regale you with two that I'm really enjoying. Do you like the TV series *The Walking Dead*? I must admit that I've often wondered what it would be like to live in a post-apocalyptic zombie-infested world. Well, now that I've played *Arizona Sunshine* from Vertigo Games (**http://bit.ly/2b2i6et**), I think I have a pretty good understanding. Fig.2. gives you an idea of what it looks like to see your hands holding a virtual gun in the virtual world.

Things start off fairly gently. The zombies are on the slow side (although they do tend to twitch a bit, which can throw you off your aim) and you have time to help them on their way while wandering around looking for clues and ammunition. You also have time to practise ejecting your magazine (which holds only seven bullets) and reloading.

The graphics and sound effects are amazing. You really feel like you are there. But you may decide that this is not such a good thing as the zombies start to speed up and there are more of them and – *OMG!*, where did that one come from? – and your gun is empty and you can't remember how to eject the magazine and… *ARRGGGH!* I tell you, I come out of this game with my heart racing and my hair standing on end.

The other amazing game is *Rock Band VR* from Harmonix (**http://bit.ly/2mWEzEp**). Have you ever had a dream where you are in a band, on stage, looking out over the audience, and 'strutting your stuff'? I know I have. Well, this game is more amazing than my dreams, and that's saying something.

As part of this you have to buy a full-sized plastic guitar that's festooned with knobs and buttons and other controls. You attach one of your Oculus Touch controllers to the neck of the guitar, which lets the Oculus system know where it is, and allows it to create a representation in the virtual world that exactly maps on to the physical guitar in your hands. In Fig.3, the head of the guitar at the bottom of the image is the one you are holding (the guy standing next to the microphone is one of your virtual bandmates).

Things start off with just you on the empty stage with a voice telling you what to do and guiding you to learn how to manipulate your virtual guitar. Once you are ready to rock-and-roll (no pun intended), your bandmates arrive and the hall fills up with cheering fans. You turn around and nod at the drummer, who nods back and starts to play. The other band members join in and off you go. All I can say is that my fans adore me! Until next time, have a stadium-filling great one!

Any comments or questions? – please feel free to send me an email at: **max@CliveMaxfield.com**

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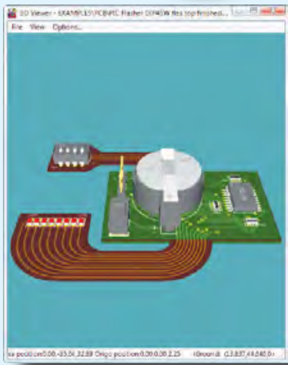

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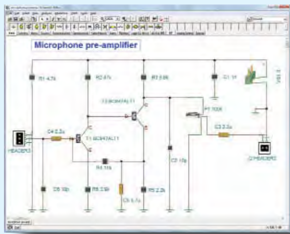


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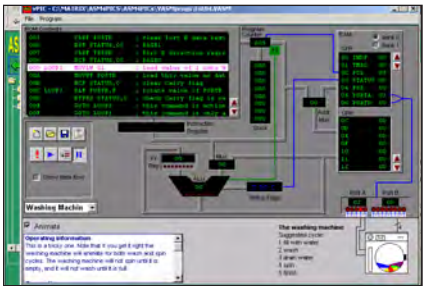

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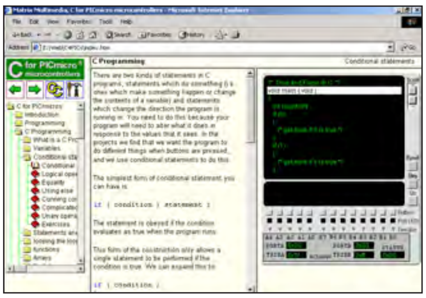

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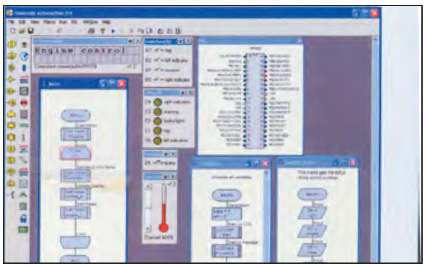

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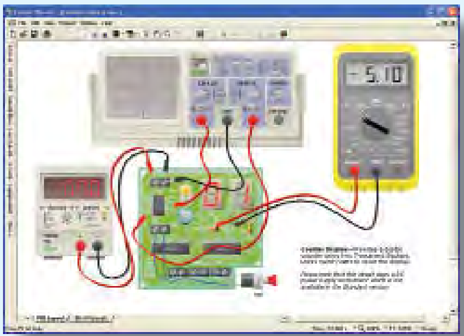

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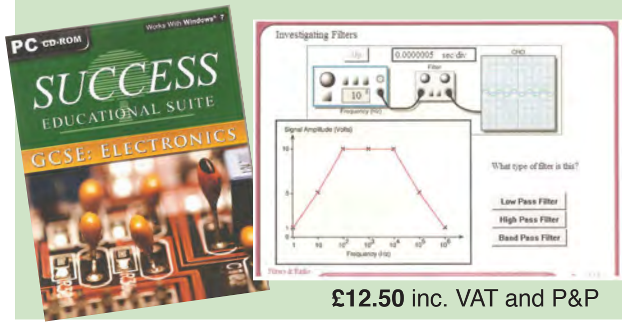


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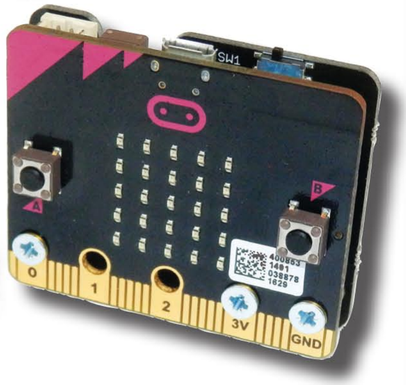


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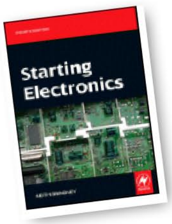


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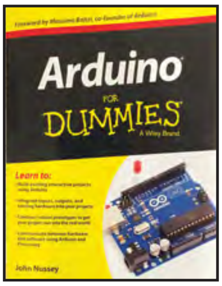
# Teach-In 2016
## Exploring the Arduino




### ARDUINO FOR DUMMIES
**John Nussey**

Arduino is no ordinary circuit board. Whether you're an artist, a designer, a programmer, or a hobbyist, Arduino lets you learn about and play with electronics. You'll discover how to build a variety of circuits that can sense or control real-world objects, prototype your own product, and even create interactive artwork. This handy guide is exactly what you need to build your own Arduino project – what you make is up to you!

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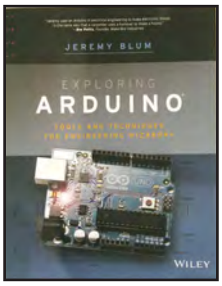


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Arduino can take you anywhere. This book is the roadmap.

Exploring Arduino shows how to use the world's most popular microcontroller to create cool, practical, artistic and educational projects. Through lessons in electrical engineering, programming and human-computer interaction this book walks you through specific, increasingly complex projects, all the while providing best practices that you can apply to your own projects once you've mastered these. You'll acquire valuable skills – and have a whole lot of fun.

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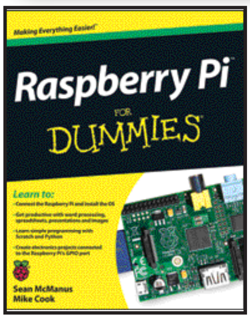


### RASPBERRY Pi FOR DUMMIES
**Sean McManus and Mike Cook**

Write games, compose and play music, even explore electronics – it's easy as Pi! The Raspberry Pi offers a plateful of opportunities, and this great resource guides you step-by-step, from downloading, copying, and installing the software to learning about Linux and finding cool new programs for work, photo editing, and music. You'll discover how to write your own Raspberry Pi programs, create fun games, and much more! Open this book and find: What you can do with Python; Ways to use the Raspberry Pi as a productivity tool; How to surf the web and manage files; Secrets of Sonic Pi music programming; A guide to creating animations and arcade games; Fun electronic games you can build; How to build a 3D maze in Minecraft; How to play music and videos on your Raspberry Pi.

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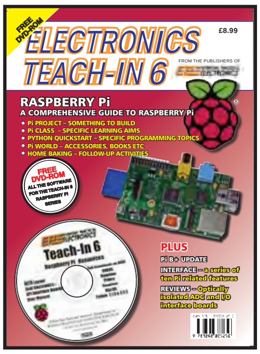


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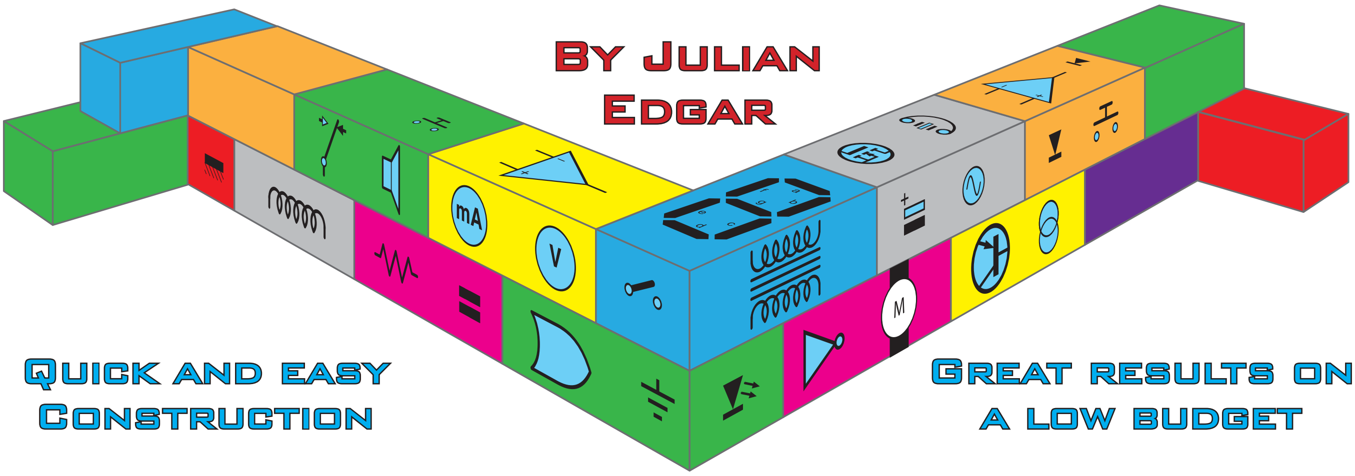
# Electronic Building Blocks




**By Julian Edgar**

**Quick and easy construction**

**Great results on a low budget**

## Two £3 modules!

**Large complex projects are fun, but they take time and can be expensive. Sometimes you just want a quick result at low cost. That's where this series of *Electronic Building Blocks* fits in. We use 'cheap as chips' components bought online to get you where you want to be... FAST! They represent the best value we can find in today's electronics marketplace!**

This month – two pre-built modules for the price of one! A super-economical way to amplify music, or bring out your inner meteorologist and detect when it's raining.

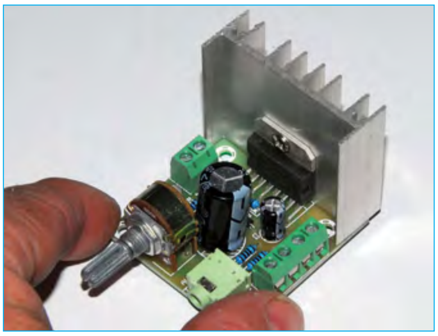
### Bargain #1 – amplifier module

Here's a tiny amplifier module that is cheap and effective – and even more so with a simple upgrade.

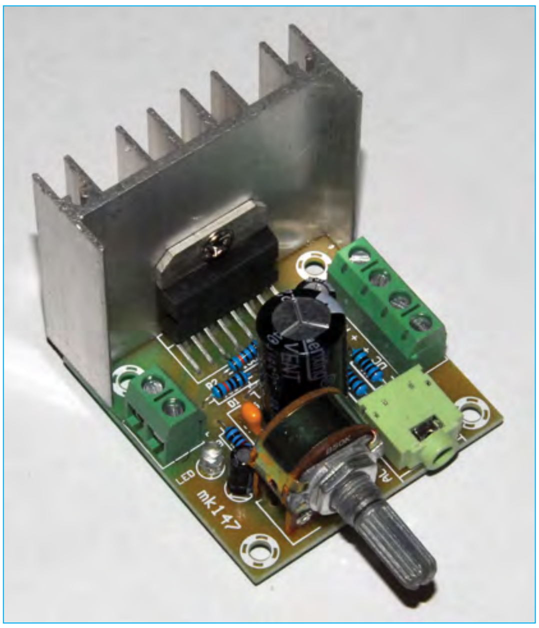
In this column we've covered a number of amplifier modules, but none has been as low in cost as this one. Costing just £3 including postage from **www.banggood.com**, the stereo module is claimed to have an output of 15W per channel. That's extraordinary – and a bit too good to be true in fact! (To find it, search under '15W TDA7297 Dual-Channel Amplifier Board For Arduino'.)

### So what's the story?

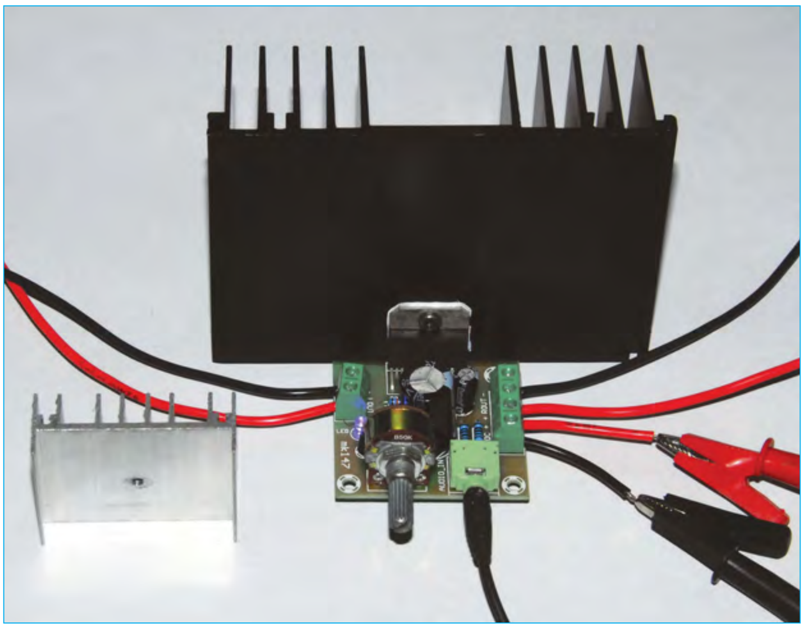
The amplifier uses the TDA7297 chip. The specs for this chip include the claimed 15W × 2 output – but that's at no less than 10% total harmonic distortion (THD). So why would you bother? Well, there's no need to use anywhere near full power in many applications, and at power outputs of up to 5W, distortion is a much more pleasing 1 per cent. In fact, at normal listening levels (say, a few watts per channel), THD is less than 0.1 per cent. As an amplifier for a desktop or kitchen sound system, that makes it unbeatable.



*A compact amplifier that is perfect for a desktop or kitchen sound system*



*This tiny amplifier module costs under £3 delivered! Just connect DC power and speakers, feed it an audio source and away you go.*



*If you want to play music at more than very modest listening levels, you should add a much larger heat sink than the one provided. Pictured here is an adequate heat sink, with the original shown at bottom-left.*

Not including the heat sink, the module's PCB is about 50mm square. Screw connections are provided for the speakers and power, with the input signal connections using a 3.5mm stereo socket. The module I bought came without a knob, but a knob is sometimes supplied.

Set-up is dead-easy – connect speakers and DC power (spec is 6.5 – 18V), plug in an audio source – and away you go!

### ... well, not quite

First, as stated previously, you won't want to drive the module anywhere near flat out – not if you value the quality of the music anyway. But with efficient speakers, good listening levels can be achieved at inaudibly low distortion. The maximum available audio power rises with supply voltage, and so at minimum you should aim to feed the module with a 12V, 2A supply.

Second, the supplied heat sink gets alarmingly hot! At listening levels where distortion was not obvious, the measured temperature of the IC was 76°C after about 10 minutes of playing music (in an ambient room temperature of 20°C.) Fitting a bigger heatsink is mandatory if you ever want to crank up the listening levels, even a bit. With the larger heatsink shown in the photo, the maximum IC temperature was 45°C.

Of course, if you need to buy a 2A, 12V plugpack and a new heatsink, the £3 starting price could easily double or quadruple. But if you have these items already on the shelf, then this module is outstanding value.

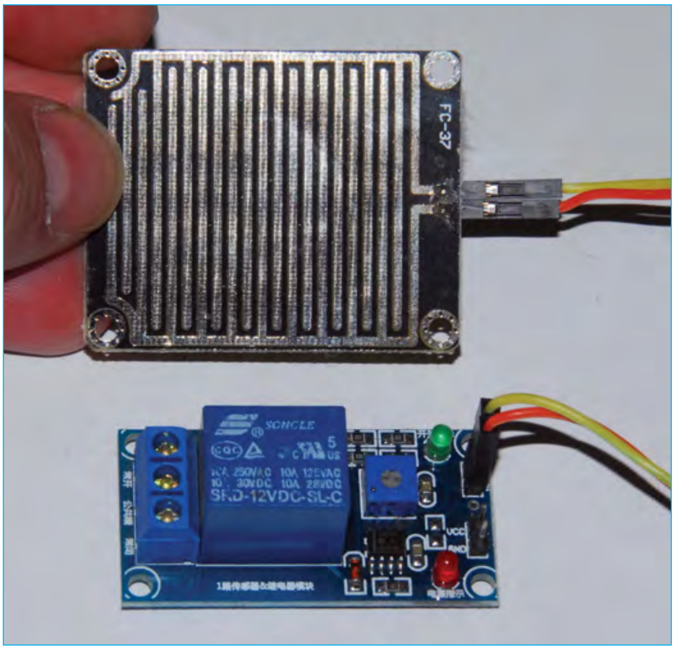
### Bargain #2 – rain sensor module

Here's a fun item that is easy to use, and it also costs under £3 delivered.

So what is it? It's a moisture sensing module that has a single-pole, double-throw (SPDT) relay output. The relay means it's easy to have something switch *on* when moisture is detected (like an alarm) or switch *off* when moisture is detected (like a garden sprinkler).

You can find the module on eBay by searching under '12V Raindrops Controller Module Rain sensor' – at the time of writing, eBay item 112324917571, £2.81 including postage and packing.

The module PCB is 50 × 27mm, with a separate sensing plate measuring 50 × 40mm. A connecting cable between the module and sensor is provided – this could easily be extended as required. Power (nominally 12V) is supplied via two pins to which wires can be soldered (positive to Vcc). An on-board pot is included to allow sensitivity adjustment. A red LED shows power and a green LED shows when the relay has tripped.




*This cheap module (also under £3 delivered) trips a relay when moisture is detected by the sensing panel. The SPDT relay allows something to be switched on when moisture is detected (like an alarm) or switched off when moisture is detected (like a garden sprinkler).*

Plug the moisture-sensing panel into the module and connect power. The red LED should light. Rotate the pot anticlockwise until the green LED lights, then rotate the pot clockwise until the green LED just goes out. Dampen your finger and place it on the sensor, and the green LED should light (and the relay click over). By adjusting the pot, you can reduce sensitivity until a wet finger will not trigger the module – instead, the sensor needs to be immersed in water.

While being nominally a 12V module, the module works fine at 9V, allowing easy battery operation. At 9V, the quiescent current draw is 5mA (most of this being the red LED – you could remove this if desired), rising to 33mA when tripped with the relay pulled-in.

### Next month

In July's issue we'll have some fun with a very smart module. It allows you to easily set up a solar-powered LED lighting system. You definitely do not want to miss the next super *Electronic Building Block* article!

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Where available, software programs for *EPE* Projects can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

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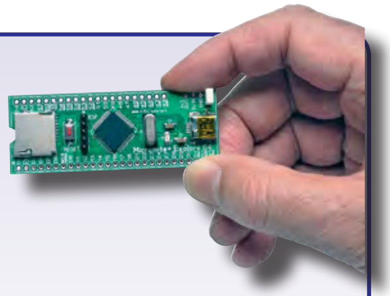
# Next Month

**AUGUST '17 ISSUE ON SALE 6 JULY 2017**



## Micromite Plus & the Explore 64

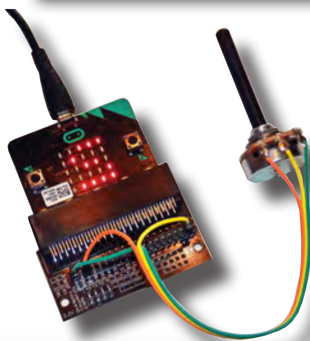
This module really packs a punch. Based on the new Micromite Plus, it's more than twice as powerful as the original Micromite, with much faster performance, substantially more RAM, greater program space (Flash memory), more I/O pins, support for a wide range of touchscreen displays (up to 8-inch!) and additional functions including support for USB, SD cards and a PS/2 keyboard.


## Touch-Screen Boat Computer With GPS

Would you like an accurate digital speedometer for your boat? Perhaps you need a large clear display? This low-cost unit with touch control is just the shot. It can also display a raft of other information, including your heading, location and the relative bearing to a point of interest, which can be anything from the harbour entrance to a great fishing spot.

## Low-cost Attenuator

If you like to build your own signal generators for audio and radio frequency work then a recurring problem is how to make a good output attenuator. Traditional attenuators can be huge, expensive and use dozens of weird value resistors. This project show you how to make wide-range reasonably accurate attenuator built with easy-to-find components on a single wafer switch that fits nicely into a small space.



## Teach-In 2017: Introducing the BBC micro:bit – Part 3

In this third part of *Teach-In 2017* Mike will be delving into analogue I/O. The accompanying practical project shows how a micro:bit can be used with a low-cost analogue temperature sensor and a two-channel relay module to form the basis of a thermostatic controller.

## PLUS!

All your favourite regular columns from *Audio Out* and *Circuit Surgery* to *Electronic Building Blocks, PIC n' Mix* and *Net Work.*

Content may be subject to change



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