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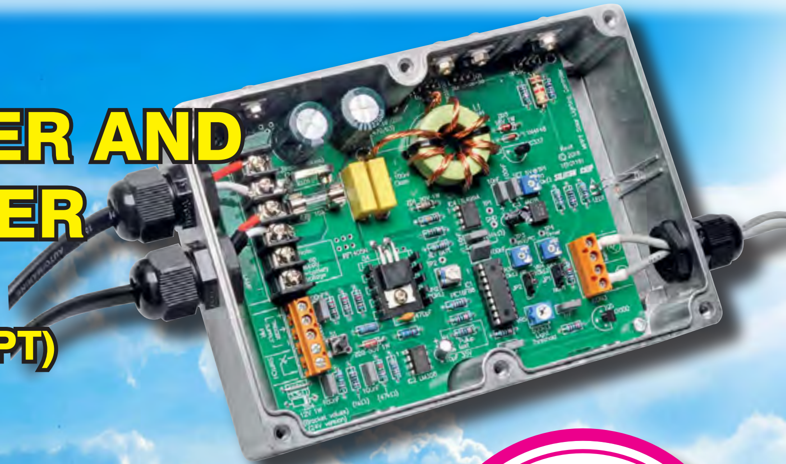

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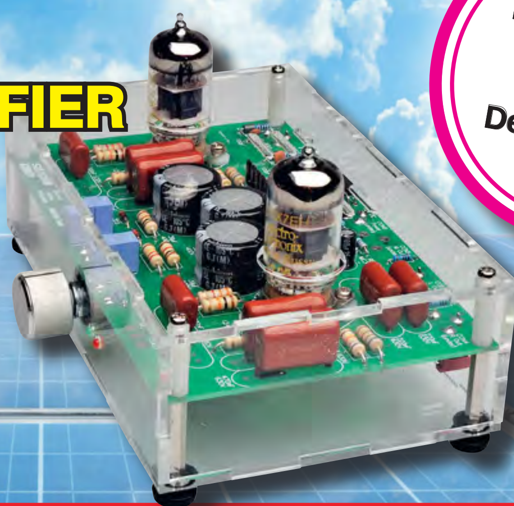

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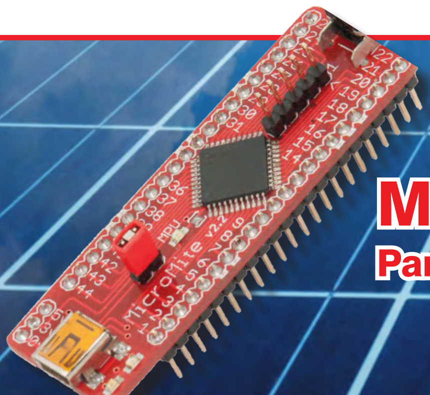

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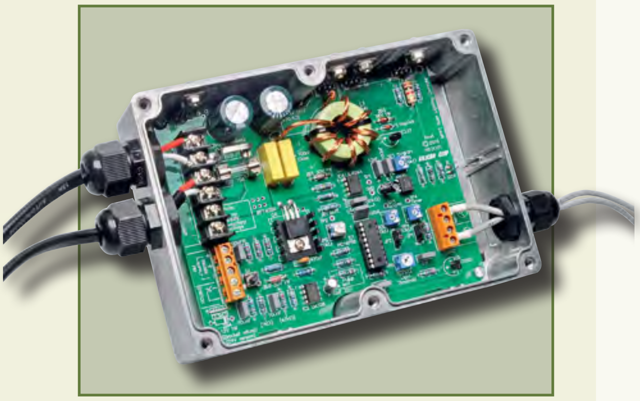

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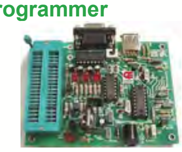

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A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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Control – spoilt for choice?

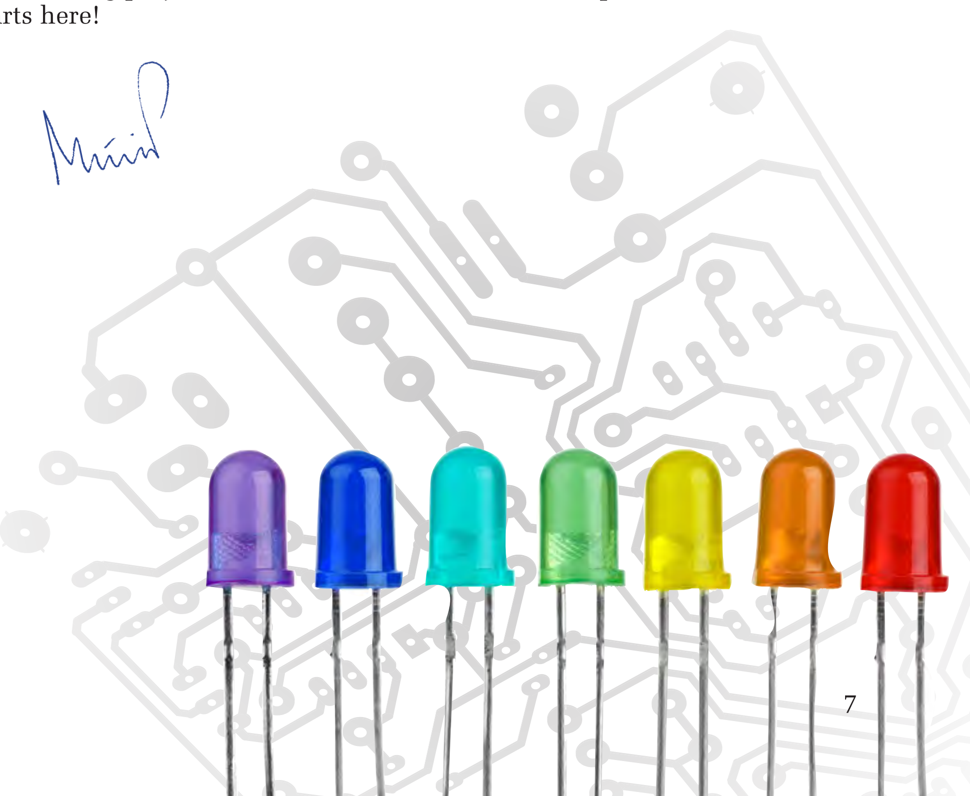
One of the biggest developments in electronics over the last couple of decades has been the increasing integration of intelligent control into products, systems and projects. The key ingredient in this revolution has been the microcontroller, a standalone IC that can interface with the real world, store and run programs, and – crucially – be 'easy' to use.

At *EPE* we have always been huge fans of Microchip's range of microcontrollers – the PIC. Long-time readers will fondly remember our early forays into PIC use with John Becker's imaginative projects, coupled with our regular *PIC n' Mix* column, in which originator Mike Hibbett and now Mike O'Keeffe describe the fascinating world of that particular brand of silicon control.

Of course, there's more than one way to skin a silicon cat, and in 2014 we ran a very popular *Teach-in* series on the Raspberry Pi, and over the last 12 months Mike and Richard Tooley have been describing the Arduino. We try to avoid too much overlap in our coverage of the silicon zoo and it's interesting to note that PICs, Pis and Arduinos do provide different, if related functions. PICs are fast and powerful devices that operate at a circuit-board level and are deeply integrated into projects. The Raspberry Pi is much more like a cut-down standalone PC, capable of running its own operating system, while the Arduino is a kind of electronic building block, which really comes into its own when teamed up with the many add-on systems, sensors and actuators – 'shields' – that have been developed for it.

And then there were four!

Now, hot on the tail of *Teach-In 2016*, we are bringing you a new microcontroller to add to your arsenal of smart silicon. Called the 'Micromite', it is the brainchild of Australian engineer Geoff Graham. So, why do we need yet another way to exert control? Put simply, the Micromite provides the ease of use that we associate with a high-level language like BASIC with the low cost, low power demands and small footprint of a PIC. In fact, it is based on a powerful and fast 32-bit PIC, but you don't need to be a PIC guru to use it. We think you're going to love constructing projects with this device, and our three-part introduction starts here!



NEWS

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

Pain-free Wi-Fi extension – report *by Barry Fox*

You don't have to live in a big house to have problems with Wi-Fi cover. Thick walls or doors can play havoc with signal strength, and some Wi-Fi modem/routers (eg, early models from BT) have small antennae buried inside the case with very limited radio reach.

So there is now a ready market for Wi-Fi extenders or signal boosters, which either pick up the signal off-air and repeat/re-transmit it, or use an Ethernet-over-mains connection from the router to a second Wi-Fi transmitter. Some extenders (eg, from Belkin) can daisy chain, so that one extends the signal from the router, and another extends the signal from the first extender.

I have tried many of these solutions and found multiple practical problems. Extenders can be tricky to set up, and the best spacing between router and extender will often depend on variables like doors that are sometimes open, sometimes closed. The extender may need a different SSID and password from the main router, so Wi-Fi devices need multiple logins. Also, using extenders can slow data speed, which really matters for homes that are using many Wi-Fi devices, some streaming HD or 4k video, along with hi-res audio.

Netgear Orbi

To date, by far the best solution I've found is Orbi from Netgear. It's expensive, costing close to £400, but there is a lot of clever technology under the hood. Orbi looks stylish and really works – without the need for extra power line or Ethernet cable connections.

Orbi is a two part solution, a router that connects by Ethernet cable to an ordinary, existing broadband modem or modem/router, and a satellite extender unit that is placed somewhere in the house where the signal would normally be getting weak. What makes Orbi special is that it's a tri-band system – it uses one Wi-Fi band (at the top end of the 5GHz band) to connect the Orbi router with the satellite unit. The satellite unit then radiates Wi-Fi at 2.4GHz and also at the bottom end of the 5GHz band.

So one band is behaving like a virtual Ethernet cable and the other two bands are filling the house with Wi-Fi. Strong cover for over 4,000 square feet is claimed.

I tried a prototype from the US, ahead of the official European launch (December 2016) and found a couple of quibbles with the *Quick Start guide* and online registration – which should now have been fixed. (If not, the early guide wrongly assumed that users will have a modem with single Ethernet port; in fact most people will have a combined modem/router with multiple Ethernet ports and multiple Ethernet cables. To avoid subnet conflicts, only one Ethernet port on the existing router should be used, to connect to the Orbi router, with the Orbi router taking all other Ethernet connections. Also, there will be Wi-Fi conflicts if two networks use the same SSID. If necessary, disable all Wi-Fi on the existing modem/router.)

The Orbi online registration process is something of an obstacle course. The password requirements and forced double-security questions and the need to verify steps by email will surely just make many people give up and not bother to register their devices. So any benefit from registering, updates perhaps, may be lost.

This sums up the dilemma now facing the IT industry. Too little security is asking for trouble; too much security drives users into using no security at all.

Fixing AOL file corruption

Talk Talk (the ISP recently hacked by a teenager to impress his friends) now runs the AOL email service in the UK. I have used AOL for decades and would love to ditch it, but I have too much back correspondence stored in the proprietary data format used by the Personal Filing Cabinet, which is an integral part of AOL's Desktop software. It recently took me weeks of work to nail a problem that may well be crippling other long-term AOL users. Since I can find no advice from AOL on this, I pass on the following simple explanation; when the PFC file hits 2GB, it corrupts! So users should archive their PFC while under 2GB and start a new one.

While (pointlessly, as it turned out)

Pain-free Wi-Fi extension *continued*

reinstalling the AOL Desktop software many times to stop the PFC data corruption, and trying both the US and UK versions, I stumbled across an intriguing piece of trivia. The US version comes with rather annoying American voice prompts, while the UK version has for years used Joanna Lumley's more appealing tones. The UK version downloads from: **http://download.newaol.com/clients/blair/waol_uk/0.4346.2018.1/roadie1.8.8.3/AOLUK_Desktop98.exe**

The US version comes from: **http://download.newaol.com/clients/bush/waol/0.4346.2023.1/roadie1.8.8.3/AOL_Desktop_9.8.exe**

So Bush and Blair are the US/UK file identifiers! Both files gave the same security warning when installed on a Windows 10 PC. 'This type of file can harm your computer. Do you want to keep anyway. Keep? Discard?'

When programming was physical

The 2016 Tony Sale Award for computer conservation has been won by the Heinz-Nixdorf Museums Forum (HNF) for its evocative and educational reconstruction showing how ENIAC, one of the first electronic computers, was programmed. The Tony Sale Award, managed by the Computer Conservation Society and sponsored by Google, recognises achievements in the growing area of computer conservation.

ENIAC was programmed by plugging wires and turning knobs, a physical skillset quite different from those deployed today. The reconstruction of part of the huge 1946 US computer has the look and feel of the original, but has been simplified to make it readily understood and even programmable by non-specialists.

Operating six days a week in the museum, the reconstructed ENIAC accumulator (the 'register' in modern terminology) is safe and robust enough to be operated unsupervised by visitors. A video discussing the new ENIAC is available at: **https://youtu.be/QUQWH1jzWoI**

Other entries shortlisted for the 2016 award included a restoration of a 1972 PDP-12 computer by the Rhode Island Computer Museum; the conservation of a 1980s IBM 30684 computer in the Jim Austin collection in York, England; and the restoration of a 1960s computer peripheral, an IBM 1403-N1 printer at the Computer History Museum in California.

For those with an active interest in preserving past computers, 'Making IT Work', a meeting on computer conservation, will be held over 22-23 May 2017.

The international meeting will be the first of its type and is jointly organised by the Computer Conservation Society and The National Museum of Computing. Conference sessions with international speakers will be on Monday, 23 May at the BCS HQ in London and workshop sessions at The National Museum of Computing on Tuesday, 24 May 2017. More details at: **www.computerconservationsociety.org** and **www.tnmoc.org**

Microchip launches new 8-bit AVR MCUs

Microchip has announced a new generation of 8-bit tinyAVR MCUs. The four new devices range from 14 to 24 pins and 4KB or 8KB of Flash and are the first tinyAVR microcontrollers to feature 'core independent peripherals' (CIPs). The new devices will be supported by START, an innovative online tool for intuitive, graphical configuration of embedded software projects.

The new ATtiny817/816/814/417 devices provide all the features needed to help to drive product innovation, including small, low pin-count and feature-rich peripherals with 4 or 8KB of Flash memory. Other integrated features include: a core-independent peripheral touch controller (PTC); event system for peripheral co-operation; custom programmable logic blocks; self-programming for firmware upgrades; non-volatile data storage; 20MHz internal oscillator; high-speed serial communication with USART; operating voltages ranging from 1.8 to 5.5V; 10-bit ADC with internal voltage references; and sleep currents at less than 100nA in power-down mode with SRAM retention.

CIPs allow the peripherals to operate independently of the core and include serial communication and analogue peripherals.

Accompanying the release of the four new devices, Microchip is adding support for the new AVR family in START, the online tool to configure software components and tailor embedded applications. This tool is free and offers an optimised framework that allows the user to focus on adding differentiating features to their application. For more information, visit Microchip's Web site at **www.atmel.com/tinyAVR**

LEDs attract fewer insects

Researchers at the University of Bristol have revealed that domestic LED lights are much less attractive to nuisance insects such as biting midges than traditional filament lamps.

The study, funded by the Natural Environment Research Council and UK lighting manufacturer Integral LED, used customised traps at 18 field test sites across south-west England, illuminated by a series of LED, filament and fluorescent light sources. Over 4,000 insects were carefully identified. The results showed that LEDs attracted four times fewer insects compared with the traditional incandescent lamps, and half as many as were attracted to a compact fluorescent lamp.

Notably, for biting flies (midges in the genus *Culicoides*, some species of which are vectors of wildlife disease), 80 percent were attracted to the filament lamp, 15 percent to the compact fluorescent and only 2-3 percent to each of the two different LED lamps.

The team urges further research on heat-seeking flies that transmit disease, including mosquitoes that are carriers of pathogens that cause damaging diseases such as malaria and Zika fever.

Unstealthy bike technology

Stealth technology for helping military aircraft evading radar is well known – but what about technology to do the exact opposite? The iLumaware Shield is a bicycle rear light that doesn't just sport a red light, but also includes a radar reflector that makes bikes more visible to cars equipped with radar-based crash-avoidance systems. The device's technology amplifies the radar's reflected signal, helping the bike and rider be seen more easily by the car's radar system – see **ilumaware.com** microchip DIRECT

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Just a flash in the pan?

TechnoTalk

Mark Nelson

How many times do you read about some amazing new development in electronics and then never hear about it again? Did the technologists really foul up? Or were other factors at play?

YES, OF COURSE, SCIENTISTS DO create some duds or 'solutions looking for problems', but most new tech fulfils its promise. By the time it does, it's no longer 'hot'. You don't turn to Barry Fox's news roundup to read stale stories, so it's understandable if the media fails to report progress with technologies that are no longer novel. In this article we'll revisit and celebrate two developments that are doing very nicely thank you, even if they're no longer on everybody's lips.

What happened to supercapacitors?

'Supercapacitors' or 'ultracapacitors', which were hot stuff back in 2007, are electrochemical energy storage devices that are ideal for delivering high power for relatively short periods. The capacitance of a single device can be as high as 2.6kF (kilofarads), combining high efficiency, strong low-temperature performance with virtually maintenance-free operation. They are not a substitute for conventional batteries, which are optimised for delivering lower power for longer periods, but the combination of supercapacitors and batteries is an attractive option for powering hybrid diesel-and-electric vehicles that start and stop frequently.

The latest generation of city buses has turned out to be a classic application for supercapacitors. A diesel engine drives an integrated electrical generator that powers the bus. When the bus is not in motion the diesel engine turns off automatically to save fuel, with the supercapacitor acting as a kind of 'electronic' flywheel that can restart the bus. The supercapacitor also stores the power produced in regenerative braking, which improves efficiency by recovering energy otherwise lost as heat in the braking system. In Spain, electric trams already run off lithium-ion batteries in some sections of the networks in Zaragoza, Seville and Cadiz, and also use supercapacitors to provide on-board energy storage. The same combination of supercapacitors and lithium-ion battery banks is being used experimentally in the US by the AFS Trinity Power Corporation for hybrid petrol-electric cars, claiming up to 150mpg fuel efficiency.

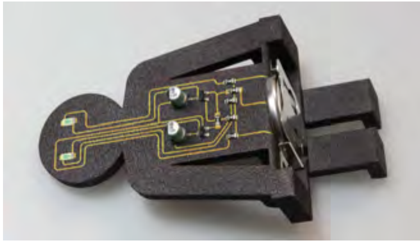
Renewable power applications too

Renewable energy production is another niche market that supercapacitors are now filling. Duke Energy, one of the largest electric power companies in the US, supplies electricity to approximately 7.4 million consumers in the Carolinas, the Midwest and Florida. Last spring, it started testing a first-of-its-kind battery technology in North Carolina. The hybrid ultracapacitor-plus-battery energy storage system provides extended operational life, rapid response, real-time solar smoothing and load shifting. Thomas Golden, technology development manager for Duke Energy, explains: 'We must look for innovative ways to better incorporate renewable energy into our system – and still provide reliable service at a competitive price for our customers. With North Carolina fourth in the nation for installed solar power, managing and maintaining these grid-connected renewable installations is critical now and in the future.'

In Ireland, where wind power is expected to generate 40 per cent of electrical power by 2020, supercapacitors are also playing a role. At Tallaght, just outside Dublin, a Smart Grid Testbed has been established by South Dublin County Council and the Micro Electricity Generation Association to demonstrate how energy storage can minimise electricity distribution issues and grid instability. With multiple sources of energy generation, the grid network in Ireland must deal with voltage and frequency issues before distributing the electricity to end users. The testbed uses a combination of lithium-ion batteries and supercapacitors for active voltage and frequency stabilisation in the grid's distributed network. Ultracapacitors made by Maxwell Technologies perform fast functions such as frequency response, leaving the batteries to handle peak shifting and operating reserve.

What became of 3D printing?

Remember how computers were going to connect to gadgets that could 'print' three-dimensional objects from liquid plastic in your own home? Well, you can still buy them at Maplin Electronics, but they're by no means cheap, the consumables are eye-wateringly expensive and the skills needed to design objects in 3D are significant. Although 'makers' love them, these devices have not become a mass-market for hobbyists. However, the same technology, often termed 'additive manufacturing', is

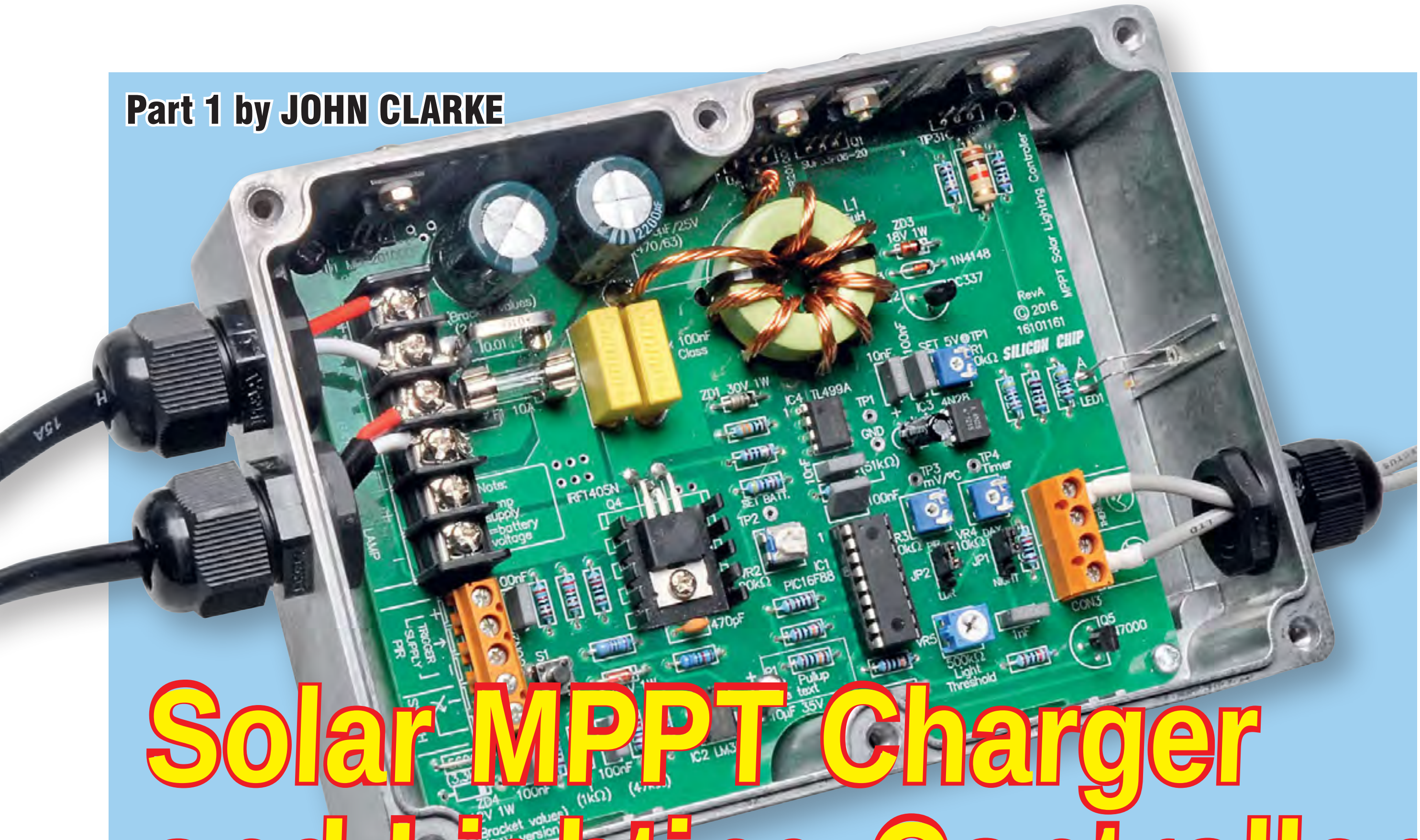


A sample multidimensional circuit carrier made by Beta LAYOUT using EOS equipment.

widely used in industry for making prototypes of all manner of products. Just recently it has also been applied to manufacturing what you might call '3D PCBs'. The correct term, however, is multidimensional circuit carriers and a leader in this field is German firm EOS (Electro Optical Systems). As the company explains, in many electronic devices there is often only a very small amount of installation space available for conventional circuit boards, and there tends to be very little space left over for the actual electronics. Often, the circuitry has to compete for limited space within the housing, which leaves product designers forced to abandon conventional PCBs and fit in everything three-dimensionally, using whatever space is left. Three-dimensional circuit carriers made of plastic are now the solution of choice.

That's all well and good, but injection moulding would be fiendishly expensive (making the moulds costs mega-money and takes time). So plastic parts manufactured by 3D printing are the solution, something that EOS's client Beta LAYOUT (well-known for its PCB-POOL operation) has perfected. Very good then, but how on earth do you add the metallic electrical connections? This is the really clever part, which takes place after the printing process itself. The parts created are coated with a special finish that contains an additive that can be turned into conductive tracks by activating the finish. A laser triggers a physical-chemical reaction that creates metallic powder while simultaneously roughening the surface. Afterwards, copper particles are deposited on the previously activated areas to create PCB tracks that can either undergo further electroplating or else be given a surface finish directly. Electronic components are then added to the initial prototypes and samples, allowing functional testing and a check of design layouts. I bet you'd like one of these gizmos at home!

Part 1 by JOHN CLARKE



Solar MPPT Charger and Lighting Controller

This MPPT charger/light controller will work with 12V or 24V solar panels to charge a 12V or 24V lead-acid or lithium iron phosphate battery. You can then use the battery to run 12V DC lighting or a 12V/24V 230VAC inverter to run lighting or other loads.

SOLAR PANELS are becoming cheaper all the time, so now you can build a low-cost system to power lighting and other loads around your home, your boat or caravan, or for a home that's not connected to the grid.

This unit gives you the choice of running a 12V solar panel up to 120W, or a 24V panel up to 220W. It can switch lights on at dusk and off at dawn. By including a PIR (passive infrared) detector, you can also have lights switch on with movement detection and off with the timer. You can also manually switch the lights on or off at any time.

The unit incorporates 'maximum power point tracking' (MPPT) to maximise the output from the solar panel, regardless of the solar intensity, and it provides three-stage charging for SLA (sealed lead-acid) batteries or two-stage charging for $LiFePO_4$ batteries. Cell equalisers will be required if using a $LiFePO_4$ battery; more about this later.

Whether you intend operating with a 12V or 24V system, you are not limited to 12V DC lighting. The battery can be used with a 12V or 24V/230VAC inverter of up 600W or more (depending on the size of your battery) to run 230VAC LED downlights, laptop computers, TV sets, power tools and so on. Mind you, while the unit can work with a solar panel rated up to 120W at 12V, or 220W up 24V, you can use a smaller panel if that is all you require.

A big advantage of using a 230VAC inverter is that you will have a much larger choice of lights than if you are confined to a 12V DC system.

Fig.1 shows the arrangement of our *Solar Lighting Controller* and depicts the solar panel, battery and the 12V lighting or 230VAC inverter. Additional inputs to the controller include a light sensor to monitor the ambient light, a PIR detector and a timer.

For use in garden lighting, the light sensor allows the lights to switch on at dusk and they can remain lit for a preset period of up to eight hours, as set by the timer. Alternatively, you may wish to have the lights lit for the entire night and to switch off automatically at sunrise, provided there is sufficient battery charge (and capacity).

For security or pathway lighting, the lights can be set to switch on after dusk, but only when someone approaches the area. In this case, a PIR movement detector switches on the lights, while the timer switches off the lights after a predetermined period, typically about one to two minutes. Periods extending up to the full 8-hour timer limit are available if you need more time.

The actual total wattage of the lights that you can use does depend on the application. With its internal MOSFET switching, it will supply a load drawing up to 10A from a 12V or 24V battery. You will get the best efficiency using LED lighting or 12V fluorescent lamps rather than using standard or halogen filament lamps.

Alternatively, the controller can switch a heavy-duty relay to drive a 12V or 24V inverter, as noted above, and it will protect the battery by switching off to prevent over-discharge, since it includes low battery detection, with a cut-off below 11V. This is most important for lead-acid or lithium iron phosphate batteries.

Standby current drain of the *Solar Lighting Controller* is quite low at 2.2mA, but this increases to around 12mA if a PIR detector is used.

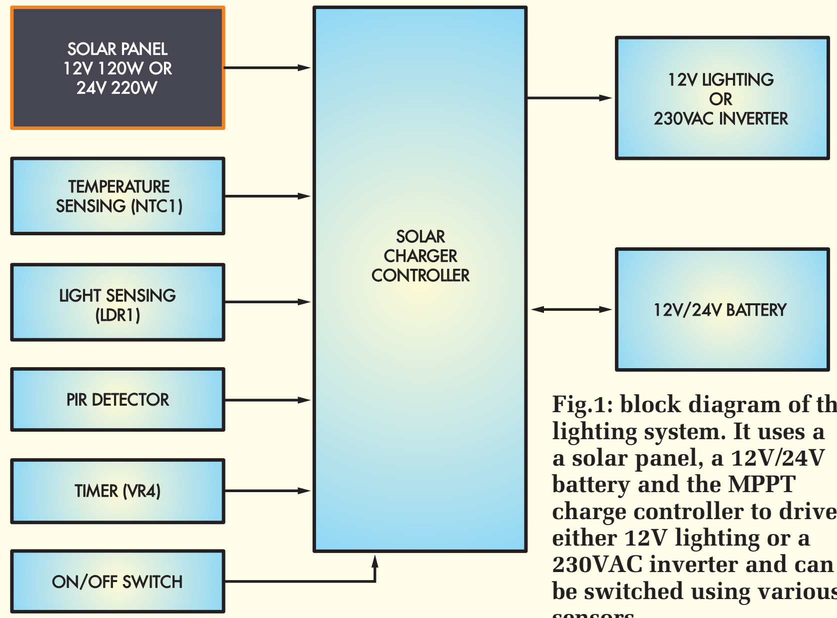


Fig.1: block diagram of the lighting system. It uses a solar panel, a 12V/24V battery and the MPPT charge controller to drive either 12V lighting or a 230VAC inverter and can be switched using various sensors.

Multi-stage charging

As mentioned above, the *Solar Lighting Controller* provides three-stage charging for lead-acid batteries or a two-stage charge for $LiFePO_4$ batteries. Fig.2 shows the three-stage charging with bulk, absorption and float modes. Bulk charge is applied when the battery voltage drops below 12.7V and feeds maximum power from the solar panel until the battery voltage reaches cut-off at 14.4V (20°C). Next is the absorption phase, where the battery is maintained at the cut-off voltage of 14.4V for one hour, to ensure full charge. After that, the battery is maintained on float charge at 13.5V.

The cut-off voltage for bulk charge and the float voltage are reduced for temperatures above 20°C, in line with the battery manufacturers' charging specifications. Typically, this is 19mV per °C for a 12V battery. So at 30°C, the voltages are reduced by 190mV, ie, 14.2V and 13.3V respectively.

The ambient temperature is measured using an NTC (negative temperature coefficient) thermistor which should be located close to the battery or preferably, attached to the case of the battery for more accurate temperature sensing. Charging will not occur if the thermistor is shorted or not connected.

The two-stage charging used for $LiFePO_4$ batteries is shown in Fig.3 and consists of bulk and absorption stages. In fact, the bulk and absorption stages are exactly the same as for lead-acid batteries, but there is no subsequent float charge mode. We based these modes on information to be found at **www.powerstream.com/LLLF.htm** and similar websites.

Note that it is important that a cell balancer is used when charging

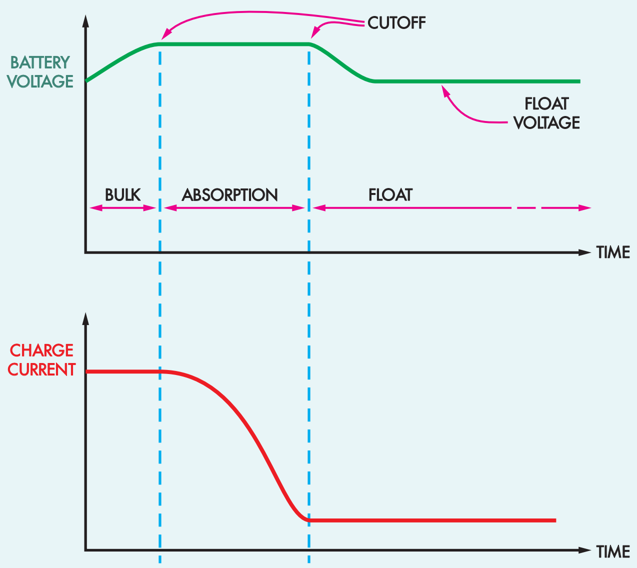


Fig.2: Three-stage charging is used for lead-acid batteries, starting with an initial bulk charge. When the battery reaches the cut-off voltage, the absorption stage takes over to fully charge it. The float stage then maintains the charge.

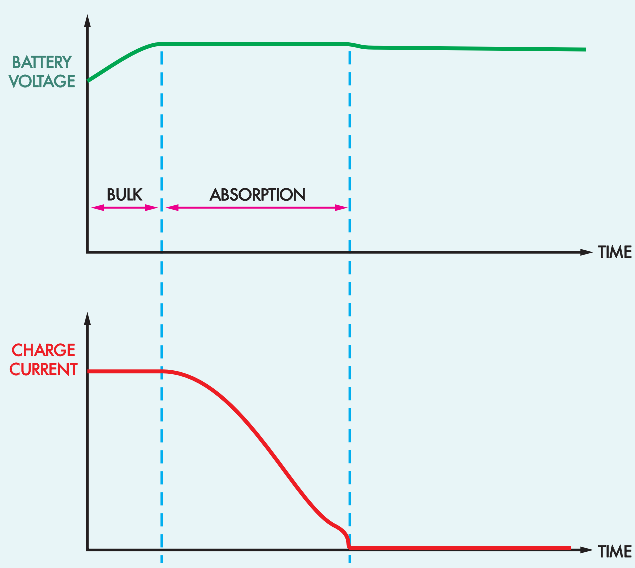


Fig.3: Two-stage charging is used for $LiFePO_4$ batteries and consists of bulk and absorption stages. These stages are exactly the same as for lead-acid batteries, but there is no subsequent float charge mode.

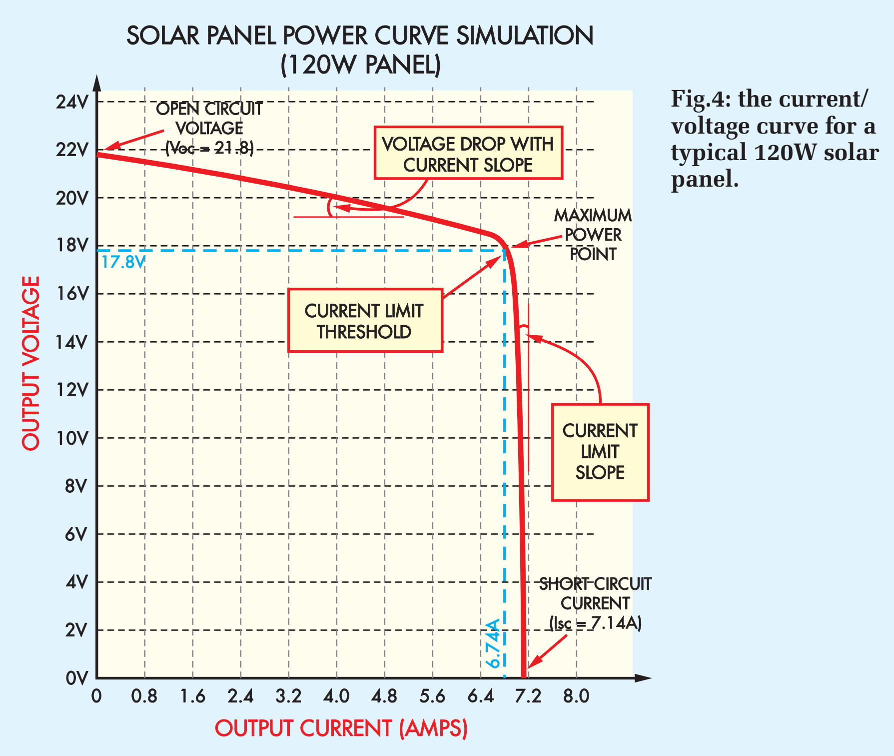


Fig.4: the current/ voltage curve for a typical 120W solar panel.

$LiFePO_4$ batteries. We intend publishing a suitable cell balancer shortly after *Part 2* of this project.

Charge indication

An LED indicator shows the charging stage. It is on continuously for the bulk charge mode; flashes on for 0.5s and off for 0.5s for the absorption mode, and flashes on for one second and off for one second during float mode. If you have a battery that has been discharged below 10.5V, it will be charged with short bursts of current until it reaches 10.5V, whereupon bulk charging will begin. This initial charging will be indicated by a short flash of the charge LED every four seconds.

MPPT operation

Fig.4 shows the output of a typical 12V solar panel. It will deliver maximum current when the output is shorted and maximum voltage when the output is open-circuit (ie, no load). So the maximum short circuit current might be around 7.2A and the maximum voltage can be anywhere between 21.8V and 22.5V, or maybe a little more. However, the maximum power output for a nominal 12V 120W panel will be between those extremes, at a load current of 6.74A and a voltage of 17.8V (or very close to those figures).

When we consider the power delivered to the battery, the story becomes more interesting. If we were to connect the 120W solar panel directly to the battery, the charge current would be about 6.9A at 12V (ie, 82.8W) and about 6.8A at 14.4V (ie, 97.9W). Both these values are far less than the 120W available from the solar panel when its voltage is at 17.8V.

Ideally, the solar panel should be operated at peak efficiency, to deliver maximum power. And that is where the MPPT aspect of the controller comes into play. It's essentially a switchmode step-down power converter, which increases the available power from the solar panel to the battery with minimal power loss. At the same time, it provides the required two-stage or three-stage charging to the battery.

Fig.5 shows how this takes place. When MOSFET Q1 is closed, current from the solar panel flows through paralleled dual diode D1 and this is filtered with two 2200µF capacitors. The current (i1) flows through inductor L1 into the battery. The inductor charges (ie, current rises to its maximum value) and after a short period, Q1 is switched off and the stored charge in L1 maintains current flow (i2) via paralleled dual diode D2. The ratio of the on-to-off period (duty cycle) for Q1 is controlled so that the solar panel delivers the maximum available power.

The solar panel is not required to supply the peak current into the inductor, as this is drawn from the 2200µF capacitors. Incidentally, these capacitors are low-ESR (effective series resistance) types, suited to the switching frequency of 31.24kHz.

The voltage from the solar panel is monitored by op amp IC2a, and the current is monitored by measuring the voltage across a 0.01Ω shunt resistor. This voltage is multiplied by –45 in op amp IC2b, which also acts as a low-pass filter. Both op amps feed their signals to microcontroller IC1 and this controls the whole circuit operation.

Circuit details

The full circuit for the *Solar Lighting Controller* is shown in Fig.6 and is based around a PIC16F88 microcontroller (IC1). This monitors the solar panel voltage and current signals from IC2, a PIR sensor (if used), switch S1, a light-dependent resistor (LDR) and an NTC thermistor, and controls the lighting using MOSFET Q4.

A 12V supply is provided for the PIR sensor at CON2 via resistor R2 from the 12V battery supply. Many PIR sensors can be operated from a 9-16V supply, and in these cases R2 can be a wire link and zener diode ZD4 omitted. If the PIR sensor requires a fixed 12V supply, then R2 should be 270Ω and zener diode ZD4 is included. For 24V operation, R2 should be 1.2kΩ.

A pushbutton switch (S1) is monitored by IC1's RB1 input, normally held high at 5V with a 100kΩ pull-up resistor. Pressing the switch pulls the RB1 input low. S1 is included for test purposes, but an external on/off (pushbutton) switch can be connected as well, using two of CON2's terminals. The 100nF capacitor at RB1 prevents interference from causing false switching when long leads are used to an external switch.

Ambient light is monitored using a light-dependent resistor (LDR) at the AN5 analogue input of IC1. The LDR forms a voltage divider with a series-connected 100kΩ resistor and trimpot VR5, all across the 5V supply.

In normal daylight, the LDR is a low resistance (about 10kΩ) but this rises to over 1MΩ in darkness. Therefore, the voltage at the AN5 input will be inversely proportional to the ambient light. If the voltage across LDR1 is below 2.5V, IC1 determines it is daylight; above 2.5V it reads it as dark.

This measurement is made when MOSFET Q5 is switched on, tying

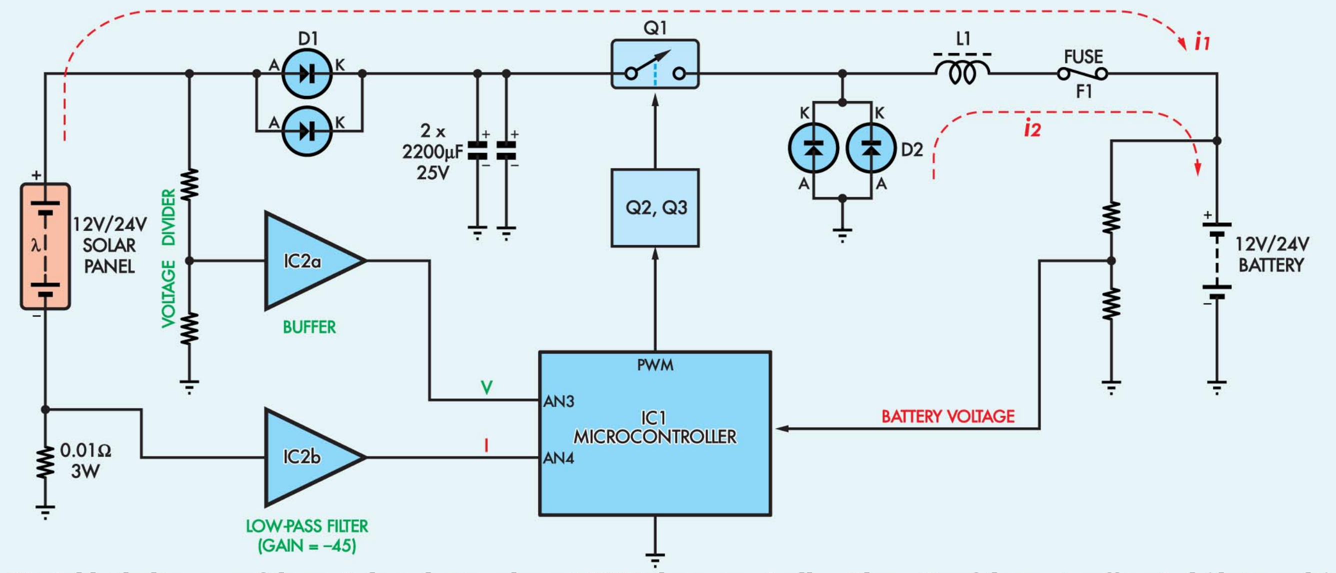


Fig.5: block diagram of the switchmode step-down MPPT charge controller. The ratio of the on-to-off period (duty cycle) for MOSFET Q1 (shown here as a switch) is controlled by IC1, which acts in response to the solar panel's current and output voltage. This ensures that the solar panel delivers the maximum available power to the 12V or 24V battery.

the lower end of the LDR close to 0V. VR5 allows threshold adjustment of the LDR sensitivity.

Link Options

There are three options available for turning on the lighting: (1) only at night; (2) only in daylight; and (3) both day and night. The position of link JP1 selects the first two options, while the third option operates with the link in the night position, but with the LDR left out of circuit. The lamp can also be switched on using pushbutton switch S1 (internal or external), provided the ambient light level is correct according to the selection made with JP1.

When JP2 is in the PIR position, the lamp can also be switched on when the PIR detects movement; again dependent on ambient light, according to the JP1 selection. If JP2 is set to the LDR position, the PIR does not switch on the lamp and the lamp is switched on at the change of ambient light: day to night or night to day (again, dependent upon JP1) – see Table 1.

Timer

The lamp can also be switched off using either a timer or the ambient light level. The various options are summarised in Table 1. The lamp ON period is adjustable using trimpot VR4, connected between +5V and the drain of Q5.

When Q5 is switched on, the trimpot is effectively connected across the 5V supply. The wiper voltage is monitored at the AN0 input of IC1.

Features and specifications

Main features

- 12V or 24V operation
- 120W/220W solar panel rating
- 120W/600W lighting
- Lamps on with movement, on/off switch or with ambient light changes
- Three-stage charging for SLA batteries
- Two-stage charging for $LiFEPO_4$ batteries
- Switchmode charger operation with maximum power point tracking (MPPT)

Specifications

- Lamp driver: up to 10A
- Lamp timer: 2s to 8 hours
- Lamp switch on: PIR sensor or LDR light-level sensor
- Low battery cut-off voltage: 11V
- Quiescent current: 2.2mA
- Charge compensation: adjustable from 0 to 50mV per °C, reducing charge voltage above 20°C and increasing below 20°C. No increase below 0°C. (SLA only) (For $LiFePO_4$ set at 0mV per °C)
- Open or short-circuit thermistor LED warning
- Low-battery charge LED indication: at less than 10.5V charging via a 6.25% duty-cycle charge burst (Charge indicator flashes 260ms each 4.2s)
- Bulk charge initiation when battery drops below 12.7V
- Charge LED indicator: bulk charge = continuously lit; absorption = flashing 0.5s on, 0.5s off; float = 1s on, 1s off
- Charger: charging starts when solar panel output is >12V

Table 1: Lamp operation options			
JP1	**JP2**	**Lamp on**	**Lamp off**
Day position	LDR position	Night-to-day transition. With S1 during day	Day-to-night transition, with S1 or timer time-out
Night position	LDR position	Day-to-night transition. With S1 during night	Night-to-day transition, with S1 or timer time-out
Night position	LDR position and with the LDR disconnected from CON3	S1 during day or night	Timer time-out or S1
Day position	PIR position	PIR movement detection or with S1 during the day only	Day-to-night transition, with S1 or timer time-out
Night position	PIR position	PIR movement detection or with S1 during the night only	Night-to-day transition, with S1 or timer time-out
Night position	PIR position and with the LDR disconnected from CON3	PIR movement detection or with S1 during the day or night	Timer time-out or with S1

We'll cover the procedure for adjusting VR4 later.

Lamp driver

The lamp or lamps are powered on using MOSFET Q4. This is switched on with gate voltage from the RB0 output of IC1. Q4 is an IRF1405 and this can be driven using a low-voltage gate signal such as the 5V from IC1. The expected voltage drop between drain and source is around 0.12V when conducting 10A. A small heatsink ensures that this MOSFET runs relatively cool.

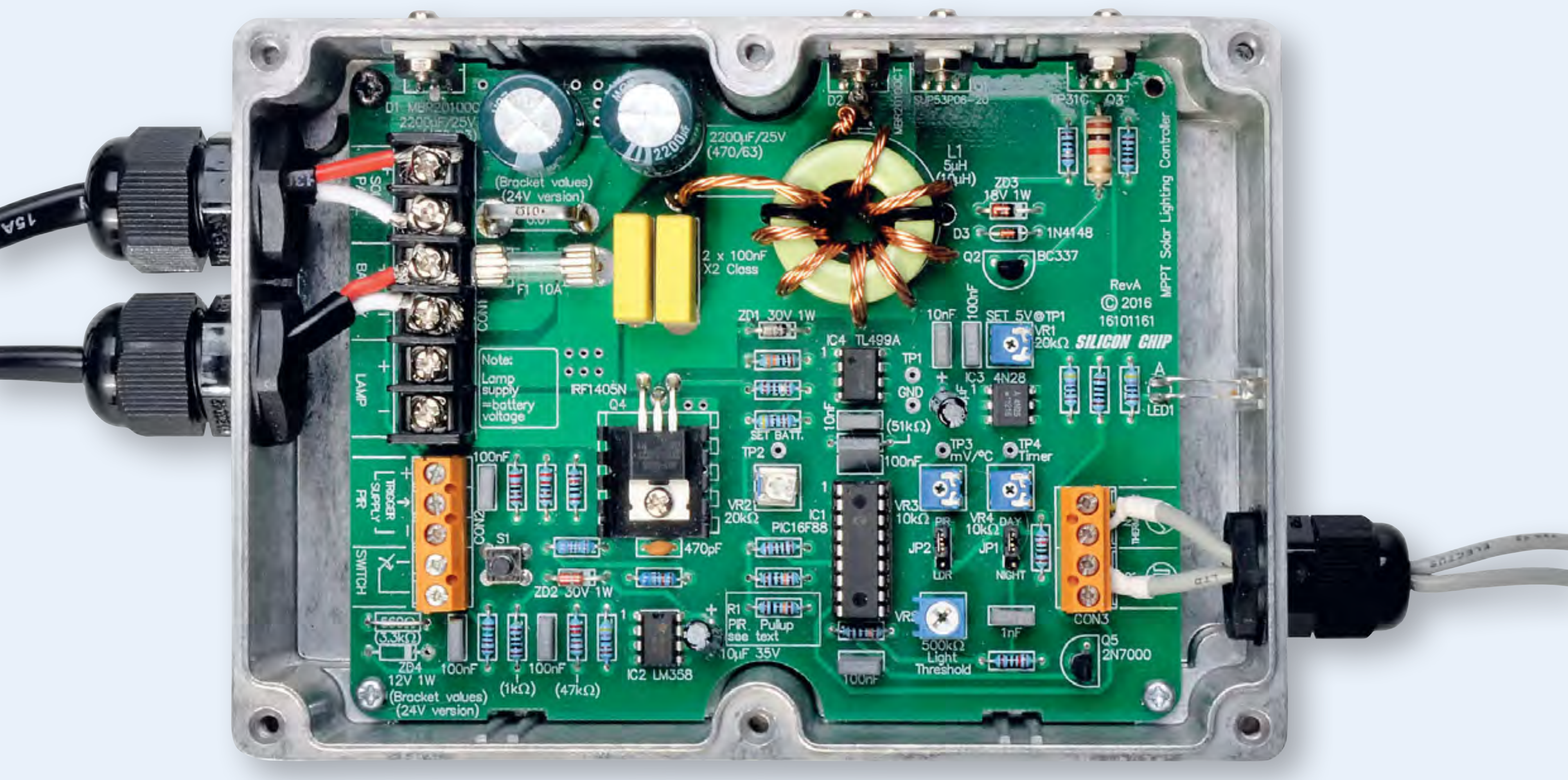
Note, if an inverter is to be controlled, Q4 is used to switch a heavy-duty relay.

Charging

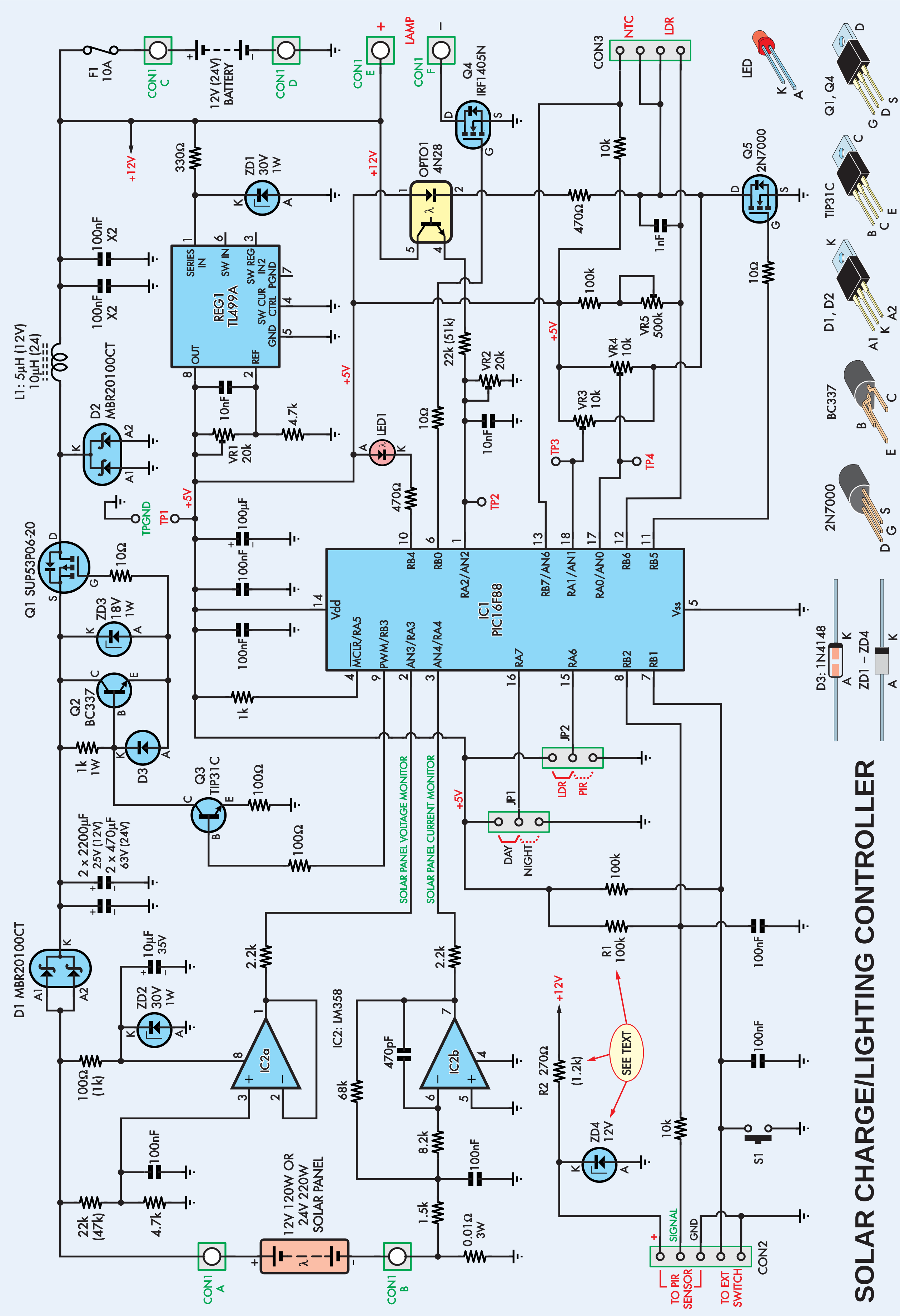
For charging, we use the switch-mode step-down circuit previously described in Fig.5. MOSFET Q1 is a P-channel type that switches on with a gate voltage that is negative with respect to its source. The voltage at Q1's source (from the solar panel and diode D1) can range up to about 22V when the solar panel is not delivering current.

D1 is a twin-diode package, which has the advantage that both diodes are closely matched for forward voltage, since they are both on the same silicon die. This means that they will share current equally when they are connected in parallel, to give a total rating of 20A.

MOSFET Q1 is controlled by NPN transistor Q3 that's driven by the PWM output at pin 9 of ICI via a 100Ω resistor. Q3's emitter is connected to ground via another 100Ω resistor. With about 5V at Q3's base, the emitter is at about 4.3V and so there is 43mA through its



Building the *Solar Charger and Lighting Controller* is easy, with all parts mounted on a single PCB. This is housed in a diecast metal case which provides the necessary heatsinking. The full assembly details are in *Part 2* next month.



SOLAR CHARGE/LIGHTING CONTROLLER

Fig.6: the full circuit for the 12V/24V *Solar Lighting Controller* is based on PIC16F88 microcontroller IC1. This monitors the solar panel voltage and current signals from IC2, a PIR sensor (if used), switch S1, a light-dependent resistor (LDR) and an NTC thermistor. The resulting PWM (pulse-width modulation) output on pin 9 of IC1 then drives power MOSFET Q1 via transistors Q3 and Q2 to control the charge current for the battery, while Q4 controls the lighting.

Parts list: Solar MPPT Charger/Lighting Controller

1 double-sided PCB, available from the *EPE PCB Service*, coded 16101161, 141 × 112mm
1 diecast box 171 × 121 × 55mm
1 6-way PC-mount screw terminal block (CON1)
1 3-way PC-mount screw terminal block, 5.08mm pin spacing (CON2)
3 2-way PC mount screw terminals 5.08mm pin spacing (CON2,CON3)
1 powdered-iron toroid 28 × 14 × 11mm
1 SPST PC mount tactile membrane switch with 3.5 or 4.3mm actuator (S1)
1 10kΩ NTC thermistor
1 LDR with 10kΩ light resistance, 1MΩ dark resistance
2 IP68 cable glands for 8mm cable
1 IP68 cable gland for 6.5mm cable
1 DIL18 IC socket
2 M205 PC mount fuse clips
1 10A M205 fast blow fuse (F1)
1 TO-220 U shaped heatsink, 19 × 19 × 10mm
1 M3 × 10mm machine screw
4 TO-220 silicone insulation washers
4 TO-220 insulating bushes
4 M3 × 12mm machine screws
5 M3 nuts
2 3-way pin headers with 2.54mm pin spacings (JP1,JP2)
2 jumper shunts for pin headers
2 100mm cable ties
1 3m length of 0.5mm enamelled copper wire
1 50mm length of 0.7mm tinned copper wire (for PIR, see text)
4 PC stakes

Semiconductors
1 PIC16F88-I/P microcontroller programmed with 1610116A.hex (IC1).
1 LM358 dual op amp (IC2)
1 4N28 optocoupler (OPTO1)
1 TL499A regulator (REG1)
1 SUP53P06-20 P channel MOSFET (Q1)
1 BC337 NPN transistor (Q2)
1 TIP31C NPN transistor (Q3)
1 IRF1405N N-channel MOSFET (Q4)
1 2N7000 N-channel MOSFET (Q5)
2 MBR20100CT fast dual diode (D1,D2)
1 1N4148 diode (D3)
2 30V 1W zener diodes (ZD1,ZD2)
1 18V 1W zener diode (ZD3)
1 12V 1W zener diode (ZD4) (for 12V PIR, see text)
1 3mm high intensity LED (LED1)

Capacitors
2 2200µF 25V low-ESR PC electrolytic (12V version)
2 470µF 63V low-ESR electrolytic (24V version)
1 100µF 16V
1 10µF 35V
6 100nF MKT polyester
2 100nF X2 class metallised polypropylene
2 10nF MKT polyester
1 1nF MKT polyester
1 470pF ceramic

Resistors (0.25W, 1%)
1 100kΩ (R1) – see text
2 100kΩ
1 68kΩ
1 47kΩ (24V version)
1 51k (24V version)
2 22kΩ (12V version)
2 10kΩ
1 8.2kΩ
2 4.7kΩ
2 2.2kΩ
1 1.5kΩ
1 1.2kΩ (use for 24V supply with 12V PIR see text)
1 1kΩ (24V version)
1 1kΩ 1W
1 1kΩ
2 470Ω
1 330Ω
1 270Ω (for 12V PIR, see text)
2 100Ω
1 100Ω (12V version)
3 10Ω
1 0.01Ω 3W resistor

Trimpots
2 10kΩ mini horizontal trimpots (103) (VR3,VR4)
2 20kΩ mini horizontal trimpots (203) (VR1,VR2)
1 500kΩ mini horizontal trimpot (504) (VR5)

Miscellaneous
1 12V or 24V SLA or $LiFePO_4$ battery
1 12V (up to 120W) or 24V (up to 220W) solar panel array
12V lamps suitable for 14.4V use
1 12V PIR
10A cable, battery clips, shielded cable, heatshrink tubing

collector. When Q3 is on, MOSFET Q1's gate is pulled negative with respect to its source via diode D3 and the 10Ω resistor, thus switching Q1 on. Q1's gate is protected from voltages in excess of 18V (which could damage it) by zener diode ZD3. Q3's emitter resistor is set at 100Ω so that ZD3's current is limited to 43mA.

Whenever Q3 is on, NPN transistor Q2 is off since the base is one diode drop below the emitter, due to D3 being forward biased. Conversely, when IC1 switches Q3 off, Q2's base is pulled to Q1's source voltage via a 1kΩ resistor. This switches Q2 on, pulling Q1's gate to its source and thus switching it off. Q1 is switched on and off by IC1 at 31.24kHz.

Voltage/temperature monitoring

The battery voltage is monitored at IC1's AN2 input via optocoupler OPTO1 and a resistive divider comprising a 22kΩ resistor and 20kΩ trimpot VR2. This divider is adjusted using VR2 so that the voltage appearing at AN2 is actually 0.3125 times the battery voltage.

The reason for this is so that the 5V limit of analogue input AN2 is not exceeded. For example, a 15V battery voltage will be converted to just 4.69V. We'll cover this in the setting-up procedure later.

The resistive divider is not directly connected to the battery but via the transistor within optocoupler OPTO1 and this connects the battery voltage to the divider whenever the LED within OPTO1 is on. The collector-emitter voltage of the transistor has a minimal effect on the battery voltage measurement, as it is only around 200µV. The divided voltage is converted to a digital value by IC1. The optocoupler's

LED is driven from the 5V supply through a 470Ω resistor to 0V when MOSFET Q5 is switched on.

The NTC thermistor forms a voltage divider with a 10kΩ resistor across the supply when Q5 is switched on. IC1's AN6 input monitors this voltage and converts it to a value in degrees Celsius. At the same time, IC1's AN1 input monitors the setting of trimpot VR3.

This trimpot is effectively connected across the 5V supply when Q5 is switched on. The AN1 input voltage is converted to a mV/°C value and this can range from 0mV/°C when VR3 is set to 0V to 50mV/°C when VR3 is set for 5V.

Power saving

As mentioned, MOSFET Q5 connects trimpots VR3 and VR4, the LDR and the NTC to 0V and also powers the optocoupler LED. Q5 is powered on with a 5V signal from the RB5 output of IC1. The MOSFET then momentarily connects these sensors to 0V so that microcontroller IC1 can measure the values. When Q5 is off, these trimpots, sensors and battery divider are disconnected from the supply to reduce battery drain.

One problem with using Q5 to make the 0V connection for the trimpots, battery and sensors is that these sampled voltages cannot be easily measured with a multimeter. This is because a multimeter will not capture the voltage when Q5 switches on momentarily. And we do need to measure some of these voltages for setting up.

For example, we need to be able to set VR2 so that the battery divider is correct and we need to measure the timer and mV/°C values as set with VR4 and VR3. So in order to make these measurements, Q5 is switched on whenever S1 is pressed.

Other power saving techniques include driving the charge LED (LED1) from the solar panel instead of the battery. The only time this LED will light using battery power is if the thermistor is open or short circuit. In these cases, the LED flashes at a low duty cycle, again conserving power.

Op amp IC2 is also powered from the solar panel, because we only want to measure the solar panel voltage and current when solar power is available. Therefore, IC2 is fed via a 100Ω series resistor for a 12V panel and a 1kΩ resistor in the case of a 24V panel. Zener diode ZD2 limits the voltage to 30V.

Diode D1 prevents the battery from powering IC2 via Q1's internal diode and L1. The solar panel voltage is monitored using a 22kΩ and 4.7kΩ voltage divider, while a 100nF capacitor filters any transient voltages or noise that could be induced through long leads from the panel. IC2a is connected as a unity-gain buffer and its output is applied to the AN3 input of IC1.

As noted previously, current from the solar panel is measured by the voltage developed across a 0.01Ω shunt resistor. This is around 70mV for a current of 7A. The voltage developed across the shunt is negative and this is inverted and amplified by IC2b, which has a gain of –45. Therefore, IC2b's output will be around 315mV per 1A of current from the solar panel. This output is applied to the AN4 input of IC1 via a 2.2kΩ current-limiting resistor.

Note that the actual calibration of voltage and current is not particularly important. The software within IC1 multiplies the voltage and current readings obtained at the AN3 and AN4 inputs to find where the maximum power point is for the solar panel

This calculation is not after any particular value, but just the maximum in a series of power calculations. It does this calculation periodically (once every 20 seconds) and varies the on/off duty cycle of MOSFET Q1 to find the duty cycle that provides the maximum power from the solar panels.

Power for the remainder of the *Solar Lighting Controller* circuit comes from the 12V battery via REG1, a TL499A regulator. This is a low quiescent current type that can run as a linear step-down regulator and as a switchmode step-up regulator. We have used it as a 12V to 5V linear regulator, with the output voltage trimmed using VR1 to as close to 5V as possible. This then calibrates the analogue-to-digital conversion within IC1, ensuring correct charging voltages for the battery.

Protection against reverse polarity connection of both the 12V battery and solar panel are included. If the solar panel is connected with reverse polarity, IC2 is protected because ZD2 will conduct in its forward direction, preventing more than 0.6V reverse voltage from being applied across its pin 4 and pin 8 supply rails. D1 prevents reverse voltage from the solar panel being applied to the remainder of the circuit. Finally, should the battery be connected back to front, D2 will conduct via inductor L1 and the fuse will blow, breaking the connection.

Next month, we'll cover constructional details and set-up procedure.

By JOHN CLARKE

Check your turntable's speed with this white LED strobe

So you have dragged out the old turntable and are playing vinyl records again. Good. But how do you know that the turntable speed is correct? The old way to do it was to use a circular disc with strobe markings, but that does not necessarily work these days. Why not? Read on.

PLAYING VINYL records has made a big comeback in recent years and many people are resurrecting their old turntables or buying new ones. But there are a few hurdles before you get the optimum result, such as making sure the cartridge stylus is not worn out and that your preamplifier provides the correct equalisation.

On a more prosaic note, many turntables which have been out of action for decades may not necessarily operate at the correct speeds of 33.3, 45 and 78 RPM. So you need to check that aspect. How do you do that?

The old tried and true method was to use a circular card which had stroboscopic markings on it and run the turntable under mains voltage lighting; 230VAC 50Hz in the case of Australia, New Zealand and most of Europe or 120VAC 60Hz in the case of the Americas, parts of Japan or Asia.

These stroboscopic cards have four or six bands of markings and depending on the speed selection, one of those bands would appear to be stationary. The reason for this was that incandescent or fluorescent lighting had a strong 100Hz or 120Hz component and this would act to make the relevant strobe band on the circular card appear to stop moving.

The same method applies to those turntables that have strobe markings on the rim of the platter. But while the principle is still correct, it does not work very well in most homes these days. Why not? Because our political masters have deemed that old-fashioned incandescent lights are 'wasteful' and 'bad for the environment'. At the same time, fluorescent lighting in most homes is now out of fashion, unless it is using those ugly compact fluorescent lamps (CFLs) with their unnatural hues and copious electromagnetic interference.

So why can't these modern lamps provide the same stroboscopic effect? The reason is that they run at much higher frequencies so that any residual AC component in the light output is very small. This applies to any lighting which uses electronic ballasts.

Mind you, even when you are using incandescent or fluorescent lighting powered by 50Hz or 60Hz mains, the strobing effect is not particularly strong, and it is even weaker with halogen lamps with their much hotter filaments. We will explain why later in this article.

Turntable speed variations

Turntables that rely on a 50Hz or 60Hz mains supply to drive a synchronous or shaded pole motor may not necessarily run at the correct speed. Typically, the 50Hz mains frequency can vary between 49.85Hz and 50.15Hz (ie, ±0.15Hz) over the course of a day. Typically, the mains frequency will be slightly low during periods of peak power demand and a little high at other times.

That variation would mean that middle C could be as low as 260.841Hz and as high as 262.411Hz. Whether this is noticeable or not depends on how well you discern pitch.

Further turntable speed problems can be present if an incorrect-sized pulley on the motor spindle is used to drive the belt. This could be because you have an imported turntable that's been designed to operate from 60Hz instead of 50Hz (or instead designed to run with 50Hz instead of 60Hz). You may be able to supply the correct voltage for the motor using a transformer but the frequency will not be correct.

For precision speed from a synchronous motor drive, an electronic driver circuit could be used to produce a suitable sinewave source for the motor. This could be a low-powered crystal-locked sinewave inverter such as for an uninterruptible computer supply. Modified sinewave inverters may not be suitable since the square wave supply may introduce noise into the motor and cartridge pick-up leads.

Why is this white LED strobe necessary?

In the 'olden days' the usual method of providing a strobe light source involved using an in-built Neon discharge lamp powered from the 240VAC 50Hz or 120VAC 60Hz mains supply. The neon would produce light pulses at 100Hz or 120Hz and this would give a stationary pattern for the set speed.

However, using the mains supply is most unlikely to give a completely steady strobe pattern when you are using a crystal-controlled direct-drive turntable unless the mains frequency is precisely 50.000Hz or 60.000Hz. Even a slight error will cause the strobe pattern to rotate slightly. Of course, with a belt-driven synchronous motor turntable, you would never be aware of these speed errors (unless you build our *Turntable Strobe*).

Turntable types

Most good turntables are either belt-driven or direct drive. Cheaper turntables were driven from an idler wheel inside the rim of the platter. The belt-driven types usually have a small synchronous motor which can be assumed to be locked to the mains frequency, provided the belt is not slipping on the motor shaft. This could happen if the belt is perished, kinked or hardened. Idler-driven turntables typically have a shaded pole motor and they are not so tightly locked to the mains frequency (and because of the idler-drive, they are more likely to produce rumble).

Direct-drive turntables should run at the correct speed but again, that cannot be taken for granted. Also, some direct drive turntables had or have a variable speed feature which allows the music pitch to be shifted over a a range of about a semitone. Again, how do you know what is the correct speed setting (unless you have absolute pitch)?

Any substantial speed variation is liable to cause any music to sound off-pitch. And if you want to dance to records and the number of beats per minute is important, then again, the turntable speed should be correct.

Our solution has been to design a white LED stroboscope which produces one millisecond pulses of light at a very precise 100Hz or 120Hz (ie, twice the mains frequency). But our recommendation is to use it at 120Hz to give the most accurate speed indication with a strobe card.

So why is that? Funnily enough, a lot of strobe cards are not necessarily accurate and if you want the most accurate speed indications at 33.33 and 45 RPM, you should use a strobe pattern designed for 60Hz operation. Interestingly, as far as 78RPM records are concerned, it is not possible to get an absolutely accurate speed indication at 100Hz or 120Hz, but 100Hz is the more accurate, with a speed error of 0.1%.

Because of these issues, we have also designed a PCB strobe disc that you can place on your turntable to check its speed. It is just the right size to fit on the record label and will not cover the playing area. Since it is precisely etched and machined, it will not have the common fault of some printed strobe discs which can be slightly off-centre or the centre hole is a little over-size.

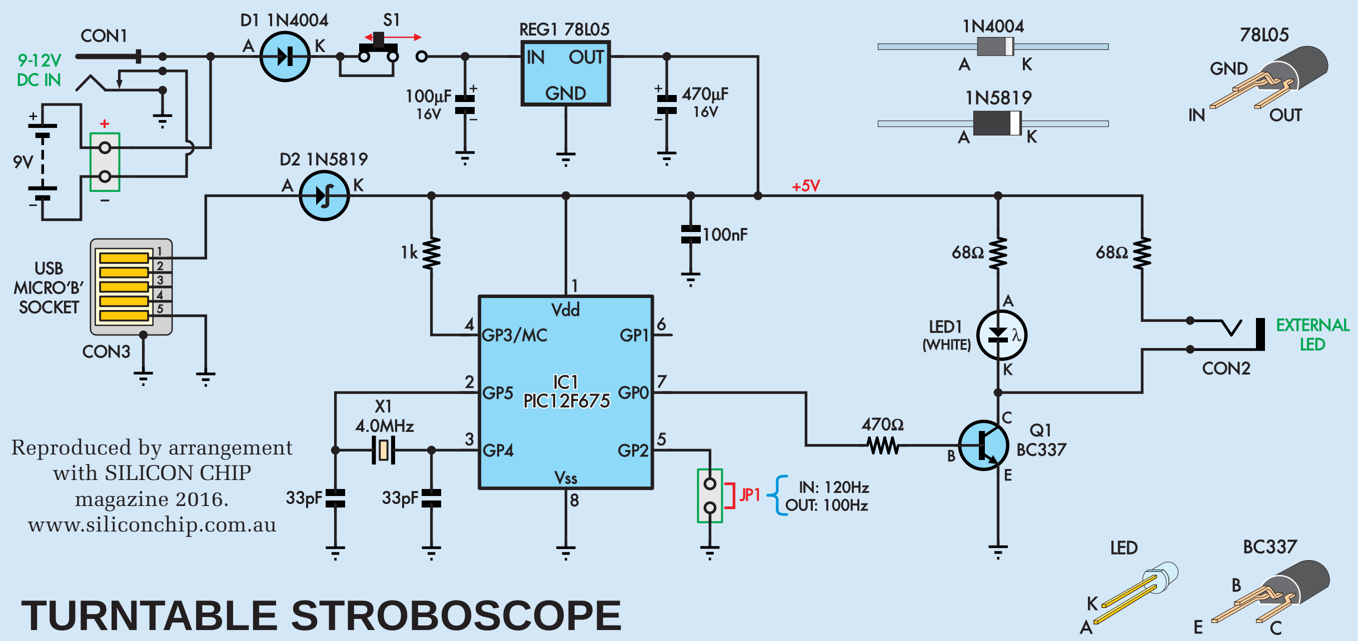
A turntable rotating at the correct speed will have one band of the strobe disc markers remaining stationary. If the markers drift clockwise, then the turntable speed is fast and if the markers drift anticlockwise, the turntable speed is too slow. Any slight wavering forwards or backwards of the markers will be due to irregular speed variations and significant variations of this nature may be audible as 'wow and flutter'.

What can be done about a turntable that doesn't run true to speed? More information on this is detailed in the above panel.

Our *LED Turntable Strobe* is built on a small PCB that fits into a small plastic utility box. Alternatively, the PCB can be installed inside the turntable cabinet and the strobe LED can be mounted to illuminate strobe markings on the platter's rim. It can be powered with a 9V battery, an external DC supply or a 5V supply via a USB connector.

Circuit description

Fig.1 shows the circuit and it is based on a PIC12F675 microcontroller (IC1). The microcontroller vastly simplifies



TURNTABLE STROBOSCOPE

Fig.1: the circuit is based on a PIC12F675 microcontroller (IC1), with 4MHz crystal X1 used as the reference clock. Pin 7 of IC1 drives transistor Q1 to flash white LED1 while jumper JP1 sets the strobe frequency to 120Hz or 100Hz.

the circuit, compared to using a separate crystal oscillator and dividers. In addition, the microcontroller makes it easy to incorporate 100Hz and 120Hz operation.

IC1 uses a 4MHz crystal as the reference clock for its program to run the strobe. The un-calibrated accuracy of the crystal (typically 50ppm) is sufficiently accurate for the strobe. IC1 internally divides the 4MHz frequency by four, so that the program runs at 1MHz. Single clock instructions of the program are therefore 1µs in duration.

As already noted, the strobe LED is driven with 1ms pulses and this gives a duty cycle of 10% at 100Hz or 12% at 120Hz. This will ensure that the strobe disc markings appear quite sharp. Longer pulse durations will cause noticeable blurring of the strobe pattern as the markings move further during the on-period. This is a distinct advantage of our LED strobe compared to the light from an incandescent lamp powered from a 50Hz or 60Hz mains supply, with the resultant display being quite indistinct by comparison.

The white LED (LED1) is driven via transistor Q1 and a 68Ω resistor connected to the +5V supply rail. Q1 is switched on/off by the GP0 output of IC1, using a 470Ω base resistor. The LED is driven at a nominal current of 29mA, assuming a 3V drop across the LED.

Connector CON2, a 3.5mm jack socket, is provided so that an external LED can be connected.

We have provided several options for the power supply: a 9V battery, a 9-12V DC plugpack via CON1 or 5V via a micro-USB 'B' socket. If using a 9V battery or a DC supply via CON1, the 78L05 3-terminal regulator (REG1) provides 5V to the micro. Alternatively, if you are using a 5V USB supply, this is fed to the micro via Schottky diode D2. **If you intend using a USB power source exclusively, you can omit the other supply components such as CON1, D1, switch S1, REG1 and the 100µF capacitor.**

For those interested in the effects of the strobe flash length, you can select a 2ms flash duration by tying pin 6 of IC1 to pin 8 using a short piece of wire under the PCB. This will set the strobe to flash for 2ms but it will still run at 100Hz or 120Hz, as selected with JP1. This change needs to be done while power is off. A return to a 1ms flash duration will only occur when pin 6

Designing the strobe disc

We have designed our strobe disc to suit 120Hz operation for 33.33 RPM and 45 RPM. We have also provided a strobe band for 78 RPM at 120Hz, but it will produce a speed error of –0.325%. To counter that, we have also provided a 78 RPM strobe band for 100Hz operation and this will have a speed error of –0.1% (close, but no cigar). Mind you, precision speed setting at 78 RPM is not so important because most records from that era were not cut at a precise 78 RPM.

Note that there are lots of strobe disc patterns that can be down-loaded from the Internet, but most are incorrect. They may be correct at one speed, say 45 RPM, but incorrect at 33.3 RPM or 78 RPM. As an example, some patterns are designed for 33 RPM, not the correct value of 33.33 RPM.

If you already have a strobe disc, how do you check that the pattern is correct? It's a simple calculation. Just multiply the strobe frequency (100Hz or 120Hz) by 60 to convert to pulses per minute. Then divide the turntable speed in RPM into this number. So 33.33 RPM requires 100 x 60 ÷ 33.33333 or 180 bars for a 100Hz strobe or 216 bars for 120Hz. It's not possible to obtain a correct pattern for 45 RPM at 50Hz, since the number of bars is not an integral number; it is 133.333. So any card with 133 bars is doomed to error. So, if you want to be sure of the result, use our strobe disc from the Silcon Chip On-line Shop, part number 04101162.

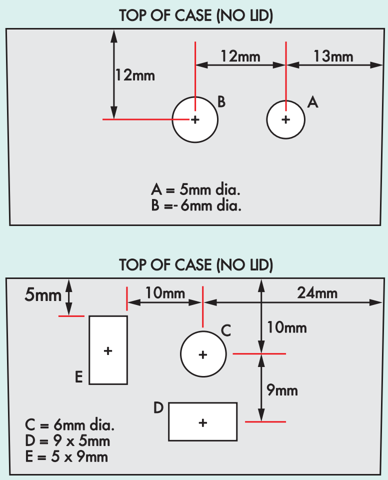


Fig.2: the two end-panel drilling templates. They can either be copied or downloaded as PDF files from the *EPE* website.

is disconnected from pin 8 with power switched off and on again.

The program checks the GP2 input level and produces the 100Hz strobe signal when this input is high at 5V. It produces a 120Hz signal when the input is low. The GP2 input is pulled high via an internal pull-up resistor in IC1 when JP1 is out and is pulled low when jumper shunt JP1 is inserted. The jumper setting can be altered while the strobe is operating and the strobe frequency will change immediately.

Drilling the case

The *Turntsable Strobe* is housed in a UB5 plastic utility box (83 × 54 × 31mm) with holes cut in one end for the LED and the external LED socket (if fitted) and in the other end for the on/off switch, the DC socket and micro-USB socket.

It's necessary to drill and cut the case before installing any parts on the PCB. There are a few options here, though. First, if you will be running the unit from battery power only, then there's no need to cut holes in the case for the DC socket and the micro-USB socket and these two parts can be left off the PCB. Alternatively, if you will be supplying power via the DC socket or micro-USB socket only, then the battery and on/off switch can be left out and there's no need to cut a hole for the switch.

You could also leave out either the DC socket or the micro-USB socket, depending on the external supply.

At the other end of the case, you can leave out the 3.5mm jack socket if you don't intend using an external LED.

By the way, the micro-USB input does not have to connect to the USB port on a computer. Any USB output from a 5V plugpack or power board can be used to supply power. Some modern turntables even include a USB port on the turntable plinth.

The first job with the case is to remove the internal ribs on each side and this can be done using a small pair of sidecutters. You can then finish off by using a sharp chisel to remove any remaining rib material.

The next step is to use the PCB as a template to mark out its three mounting holes in the case. That's done with the PCB sitting inside the case and pushed hard against two of the side pillars (see photo). The PCB is then removed and the mounting holes drilled to 3mm. Countersink these holes on the outside of the case using an oversize drill.

You now have to cut and drill the holes in the end panel and that's done using the templates shown in Fig.2. These templates can either be copied from the magazine or downloaded in PDF format from the *EPE* website and printed out.

Once you have the templates, cut them to size and attach them to the end panels using adhesive tape. Be sure to attach the correct template to its panel – the template with the two circular holes must go on the end that matches the LED end of the PCB.

It's now just a matter of drilling and cutting the holes in the panels as required. The square cut-outs for the micro-USB socket and switch S1 can be made by drilling a series of small holes in a row, then joining them and filing to the required shape.

Note that it's a good idea to always use a 1mm pilot drill to start the holes (to ensure precise location) and then enlarge them to the required size using successively larger drills.

PCB assembly

All parts (except the battery) are mounted on a PCB which measures 79 × 31mm and is available from the *EPE PCB Service*, coded 04101161. Fig.3 shows the parts layout. Begin by soldering the surface-mount micro-USB socket (if used) to the underside of the PCB, then flip the board over and install the resistors on the top side. It a good idea to check each one using a digital multimeter before soldering it into place.

Parts List

1 PCB, available from the *EPE PCB Service*, coded 04101161, 79 × 31mm
1 set turntable templates (see text)
1 UB5 case, 83 × 54 × 31mm
1 4MHz crystal (X1)
1 DIL8 IC socket
1 SPDT vertical slider switch (S1)
1 2-way header (2.5mm pin spacing) (JP1)
1 pin header shunt
3 6.3mm tapped nylon stand-offs
3 M3 × 5mm countersink head screws
3 M3 × 5mm machine screws
1 Micro-USB type B socket (CON3) (FCI 10103594-0001LF) (**element14.com** – Part No. 2293752)
1 PCB-mount DC socket (CON1)*
1 9V battery*
1 9V battery snap connector*

Semiconductors
1 PIC12F675-I/P microcontroller programmed with 0410116A.hex (IC1)
1 78L05 regulator (REG1)*
1 5mm white LED (LED1)
1 BC337 NPN transistor (Q1)
1 1N4004 diode (D1)*
1 IN5819 Schottky diode (D2)

Optional external LED parts
1 5mm white LED
1 switched stereo 3.5mm PCB-mount jack socket (CON2)
1 mono 3.5mm jack plug
1 length of single-cored shielded cable
1 100mm length of heatshrink tubing (1mm and 5mm)

Capacitors
1 470µF 16V PC electrolytic
1 100µF 16V PC electrolytic*
1 100nF MKT polyester
2 33pF ceramic

Resistors (0.25W, 1%)
1 1kΩ
1 470Ω
2 68Ω

***Note:** omit DC socket CON1, diode D1, switch S1, the 100µF capacitor, regulator REG1, the 9V battery and the battery snap connector if the unit is to be exclusively powered via the micro USB socket.

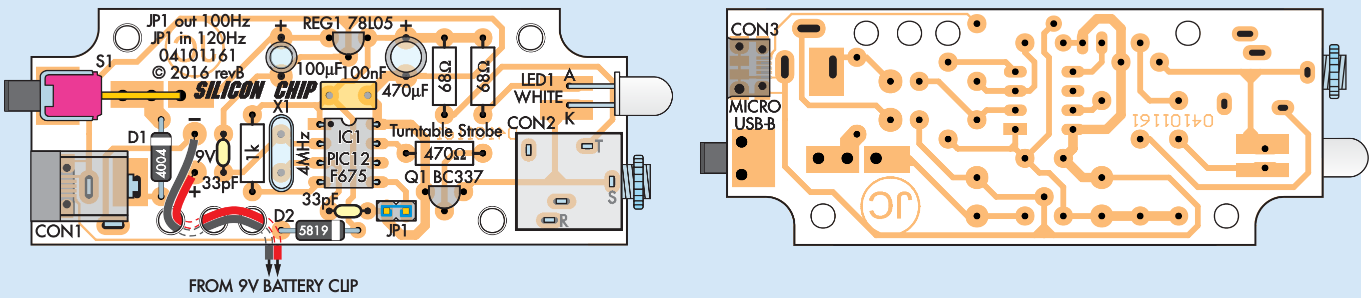
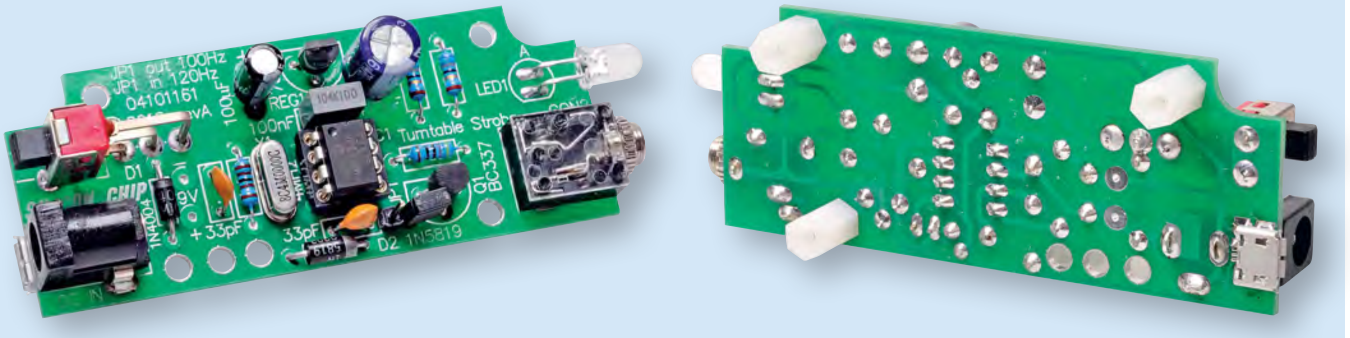


Fig.3: follow these two parts layout diagrams and the photos below to assemble the PCB. The micro-USB socket (CON3) should be soldered to the underside of the PCB first, after which the remaing parts are installed on the top side.



Left: inside the completed unit. The battery and switch S1 can be omitted if the unit is to be powered only via the DC socket or micro-USB connector. Similarly, CON2 can be left out if you won't be using an external LED.

Follow with diodes D1 and D2, making sure that the 1N5819 is used for D2. Make sure also that D1 and D2 are correctly oriented. The DIL8 socket can be then installed, followed by the 100nF capacitor and the two 33pF ceramic types.

Crystal X1, transistor Q1 and REG1 are next on the list, but don't get Q1 and REG1 mixed up. The two electrolytic capacitors can then go in, along with the 2-way pin header (the header's shorter pins go into the PCB). Once the header is in place, install the jumper shunt (ie, to short the pins) so that the unit will operate at 120Hz.

As explained earlier, DC socket CON1, jack socket CON2 and switch S1 are optional. CON1 is required if you are using a 9-12V DC plugpack (ie, one with no USB output) to power the unit, CON2 if you are using an external LED and S1 if you are using battery power. If you are using a DC plugpack to power the unit (via CON1) but will not be fitting a battery, switch S1 can be replaced by a wire link.

LED1 is installed by first bending its leads down by 90° exactly 10mm from its plastic body. Make sure that it is correctly oriented before doing this though (the anode lead is the longer of the two). The LED is them mounted with its leads 4mm above the PCB (use a 4mm-thick spacer to set this height), so that the centre of its lens lines up with the adjacent jack socket.

The last part to connect is the battery snap. Feed its leads through the stress relief holes as shown in Fig.3 before soldering them to the PCB.

If you intend using an externally connected LED, this can be now wired to a length of single-core shielded cable. Connect the centre lead to the LED's anode and the shield wire to the cathode.

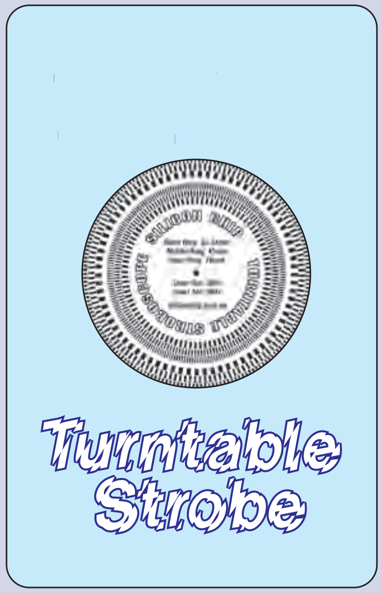


Fig.4: the front panel label can be downloaded as a PDF file from the *EPE* website.

These two views show the completed unit. Note that some of the holes in the end panels can be omitted, depending on the options chosen when you build the unit (see text).

The other end of the cable is then terminated in a 3.5mm jack plug, with the centre lead going to the tip contact and the shield to the outer sleeve contact.

Final assembly

Now for the final assembly. First, attach three M3 × 6.3mm tapped nylon stand-offs to the PCB mounting holes and secure them using M3 × 5mm machine screws. The PCB assembly is then installed by angling it down into the case so that LED1 and CON2 pass through their respective holes, then squeezing the sides of the case together and pushing the other end of the PCB down until the switch and micro-USB socket go into their panel cut-outs.

The PCB is then secured in position using three M3 × 5mm countersink-head screws which go through the base and into the stand-offs. Once it's in place, fit the battery snap to the battery and slide the battery into the case as shown in the photo.

Testing

Now for the smoke test. Apply power and check that there is 5V (4.85-5.15V) between pins 1 and 8 of IC's socket (or 4.5-5.2V if using USB power). If this is correct, switch off and install IC1 (watch its orientation), then reapply power and check that the LED lights.

If it does, then your *Turntable Strobe* is working and you can attach the lid which now becomes the base of the unit. If you now move the unit rapidly from side-to-side with the LED viewed side-on (ie, not looking directly into the lens), it should be seen to light in several different positions. That indicates that the LED is being flashed on and off. By contrast, if you look directly at the LED when it is stationary, it will appear to be continuously lit due to its 120Hz flash rate.

Finally, if you have made up an external LED cable, plug it in and check that its LED also operates.

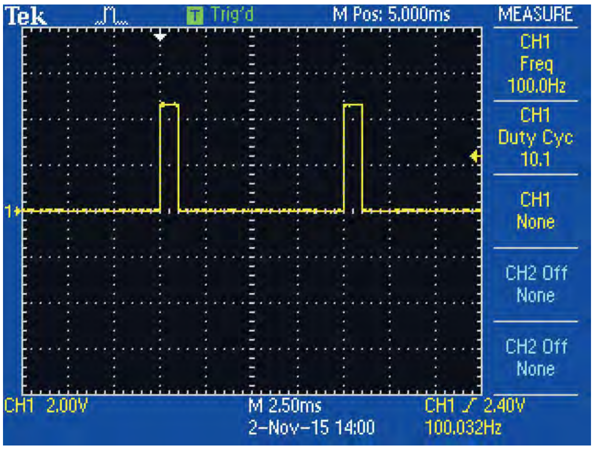


Fig.4: this screen grab shows the waveform at the GP0 output, pin 1, of IC1. In this case, the circuit is set for 100Hz operation (JP1 out). The LED is lit for 1ms at a 10% duty cycle. Ignore the error of the displayed 100.032Hz, which is because the oscilloscope frequency calibration is not particularly precise.

Front panel label

The front-panel label is available in PDF format on the *EPE* website. It's just a matter of downloading it and printing it out onto an A4-sized synthetic Dataflex or Dataplex sticky label (see panel). This label is then attached to the top of case (ie, not the lid), as shown in the photos.

Alternatively, you can print out a paper label and attach this using double-sided tape. That's it – your *Turntable Strobe* is ready for use.

Dataflex/Datapol Labels

(1) For Dataflex labels, go to: **www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335**
(2) For Datapol labels go to: **www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326**

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Part 2 by Nicholas Vinen

High-performance Stereo Valve Preamplifier

Having described how our new stereo valve preamp works and how to put the PCB together, now it's time to build the case. This houses the PCB so that you can still see all the components but can't touch the high-voltage sections. It's custom designed and made from clear acrylic, glued and screwed together.

THE *Stereo Valve Preamplifier* PCB was originally designed to fit inside a UB2 'jiffy' box. However, because it has connectors on the back and controls on the front (including a volume knob), it's pretty much impossible to actually get it inside such a box, even after drilling the required holes.

Rather than compromise the practicality of the device to allow it to fit in that box, by doing something like putting the inputs on the front or side, we have designed a custom case instead. This is made in three sections which screw together so you can get it apart if necessary. We think the result is much more attractive – hopefully you'll agree after seeing the photos of the prototype.

We're using clear 3mm acrylic to show off the components and the cutting pattern is shown in Fig.8. It can be downloaded from the *EPE* website in a variety of formats to suit typical laser cutter software, including AutoCad DXF.

We used a 60W CO_2 laser operating at full power and at a speed of 8mm/s (10mm/s also works, but we're being a little conservative to ensure it cuts reliably).

The parts are cut from a sheet of acrylic measuring at least 230 × 315mm. The cuts shown in red are done first, in case the sheet isn't perfectly flat. In this case, if the outer sections were cut first they could shift slightly and then the inner cuts would be less accurately placed. We have optimised the cutting path to eliminate the duplication of overlapping cuts, although typical laser cutters have an extremely high degree of repeatability so this will generally not affect the quality of the end result.

The case pieces incorporate holes in the top for the valves and some cooling slots over the power supply. The front panel has holes for the power switch, volume pot, its anti-rotation tab and the two power LEDs, while the rear panel has holes for the input and output RCA sockets and the DC power connector. There are also four screw holes in the top and bottom panels corresponding to holes on the PCB, to hold the whole thing together.

If you're building the musical instrument version of the PCB with the extra panpot (VR2) and mixed output (CON5), we'll supply a modified version of the cutting diagram with these extra holes. Their locations are shown in Fig.9, relative to the pre-cut holes.

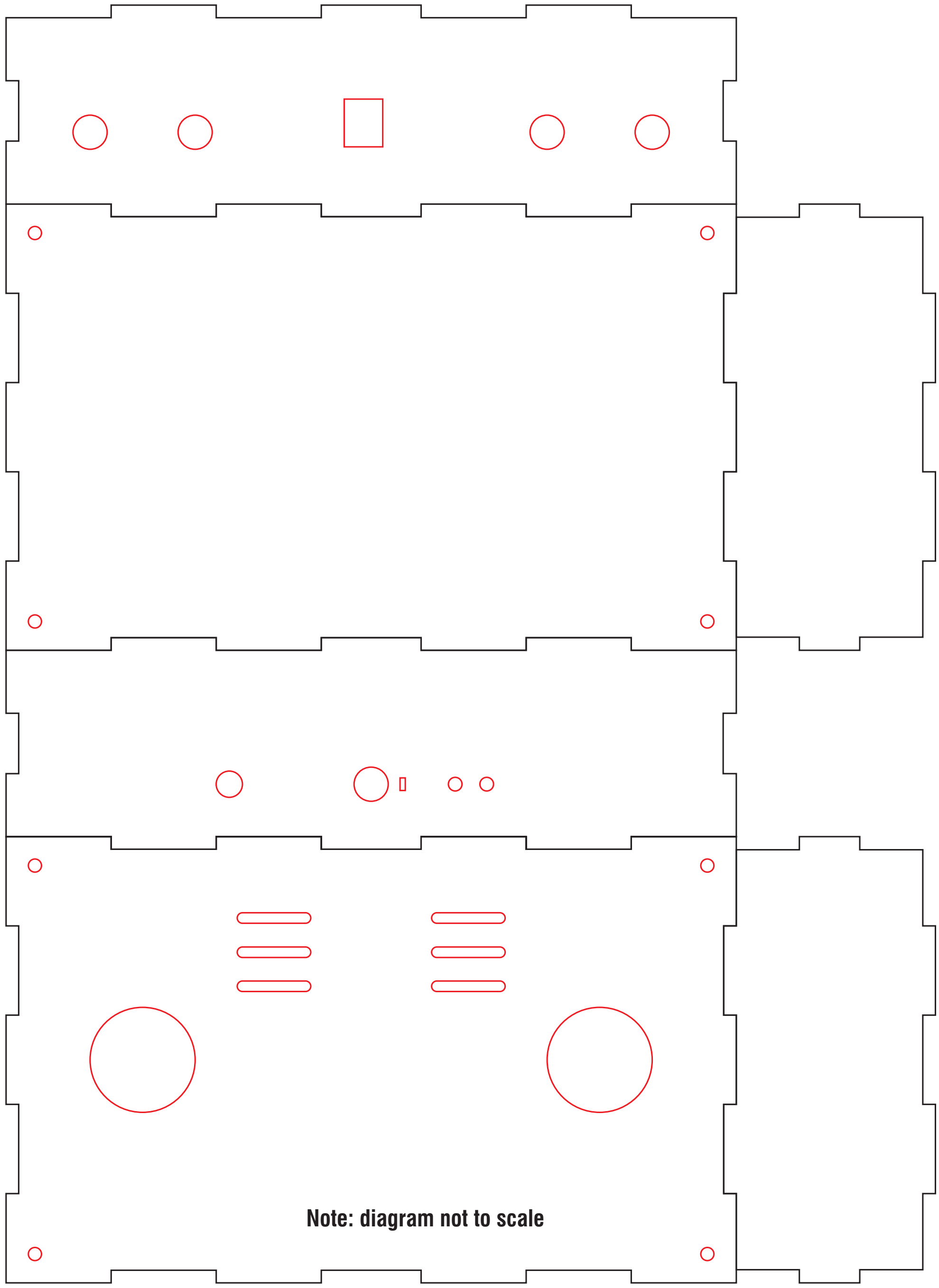

Fig.8: the laser cutting pattern used to produce the six pieces for the *Stereo Valve Preamplifier* case, from a 230 × 315mm piece of 3mm-thick clear acrylic (perspex). The sections shown in red are cut first to maximise precision of the hole placement. Note the cooling slots in the top cover, which go over the power supply circuitry. The prototype lacked an onboard power switch, so a hole has been added to the front panel for the final version (note: diagram *not* to scale).

Putting it together

You will now have the completed PCB, six case pieces (with protective film on both sides) and an assortment of machine screws, tapped spacers and feet (as specified in the parts list last month). Start by removing the two 12AX7 valves (or 'vacuum tubes', if you prefer) and set these aside so they won't get damaged – don't put them on a surface they might roll off!

The bottom, rear and side panels of the case are glued together into one assembly, which screws to the PCB. The top panel is also screwed to the PCB while the front panel is held on by the potentiometer nut(s). The PCB is sandwiched between the top panel and the bottom panel assembly and held in place with screws and spacers.

It's a good idea to check that everything will fit before gluing. Leave the protective film on the case pieces for now, so they don't get scuffed or dirty – clear acrylic shows fingerprints quite well unfortunately, so you want to avoid getting these on the inside of the case if possible, where they're hard to clean off.

Using Fig.10 as a guide, pass an M3 × 32mm machine screw through a hole in the top panel and screw on one of the shorter spacers. Do it up tight against the underside of the lid, then thread the other spacer on and repeat the procedure for the remaining corners.

Next, orient the lid so that the valve socket holes are above the sockets, then push the protruding screw threads through the PCB mounting holes and attach the M3 × 25mm tapped spacers to hold the PCB in place.

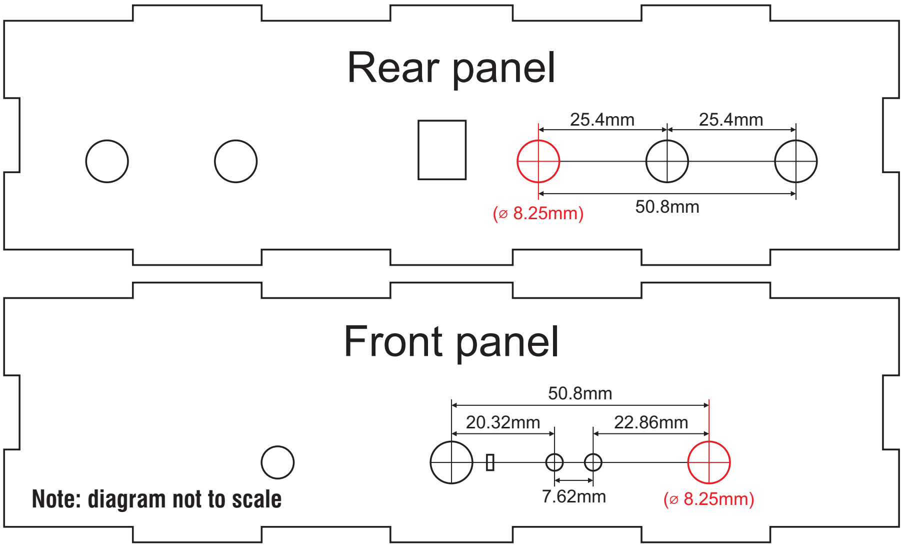

Fig.9: here's where to drill the extra holes in the rear panel (for the mixed output RCA socket, CON5) and in the front panel (for panpot VR2) if required

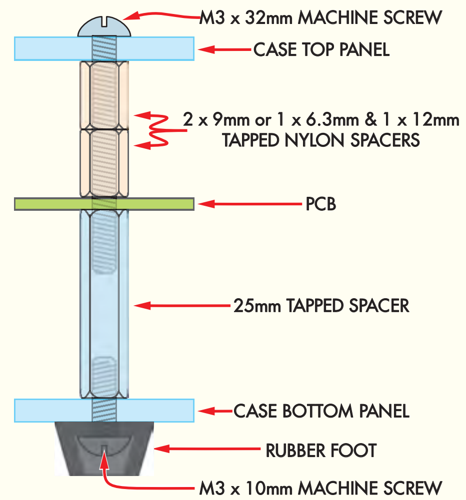

Fig.10: the top panel, bottom panel and PCB are sandwiched together using four sets of machine screws and tapped spacers. This spaces the top and bottom panels the correct distance apart for the front, back and side panels to fit. If they're too close together, add 3mm inner diameter washers in each stack as spacer shims.

You can then screw the bottom panel on using the remaining 10mm machine screws (no need to fit feet just yet).

With the top and bottom panels held rigidly in place, check that the rear panel fits. The RCA sockets will be a relatively tight fit through the holes, but assuming they have been soldered evenly, it should slide into place. Otherwise, you may need to use a tapered reamer to open the holes up slightly.

RCA sockets

Note that, on our prototype, we used the RCA sockets which are available from the Silicon Chip Online Shop, because it's hard to find white sockets of this type at the usual retailers. They have a slightly different footprint but will fit on the board with some slight bending of the pins.

We mention this because this is likely to affect the height that the sockets sit at, so if you use a different type, they may not line up with the holes in the case. In that case, you would either need to adjust the RCA socket height by melting the solder joints (tricky) or simply enlarge the panel holes until they fit through.

You may find, depending on the exact height of the spacers you have used, that the rear panel will be slightly too tall to fit between the top and bottom panels. In our prototype, it was an almost an exact fit, but spacer lengths can vary slightly. In this case, you may need to add some sort of a shim (eg, a washer or two) somewhere in the spacer stack to increase the gap enough for the panel to fit correctly.

Assuming it fits OK, remove the nut from the pot(s) and fit the front panel. This can be held in place temporarily with the potentiometer nut(s). If necessary, reach behind the front panel using small pliers to push the LEDs through their respective holes.

Changing the preamplifier's gain

The circuit as presented last month has a maximum gain of four (12dB). While the output swing is limited by the valve operating conditions, if you have a situation with low-level input signals, you may wish to increase this. This can be achieved by increasing the value of the 10kΩ 1W resistors to the lower left of each valve socket.

For example, using a 15kΩ resistor will give a gain of 15kΩ / 3.3kΩ + 1 = 5.5 or 15dB. A 22kΩ resistor will give 22kΩ / 3.3kΩ + 1 = 7.5 or 17.5dB. And a 30kΩ resistor gives a gain of 10 or 20dB.

Note that increasing the gain will slightly prejudice the performance by increasing the distortion and reducing the signal-to-noise ratio. Having said that, the performance as specified is sufficiently good that you probably won't notice the difference.

With the front and rear panels in place, it should be possible to slide the side panels into place.

Gluing the case

Once you've confirmed that everything fits, disassemble it and peel the protective film off the pieces. Reassemble the top and bottom halves and the PCB as before, using the screws and tapped spacers, to form a rigid assembly.

The parts are glued together using a specialised, solvent-type plastic adhesive formula. We used SciGrip 'Weld On 16' fast set clear, medium-bodied solvent cement. This is available from **www.multibondsolutions.co.uk**

With a clean cloth at hand to wipe up any excess, the next step is to glue two pieces of the case together (see below) by applying a moderate amount of the adhesive to all the mating surfaces and then pressing and holding them together. Try to avoid getting any of the adhesive on the faces, especially via your fingers.

Start by gluing the rear panel to the base. Make sure it's pressed in fully until the adhesive sets (this takes a few minutes). You may find that friction holds it in for you, otherwise you may have to hold it. Once it's nice and rigid, carefully unscrew the base and remove the two panels which are now

The rear panel of the case has holes for the RCA stereo input and output sockets and a square cut-out to provide access to the DC power socket. Note the ventilation slots in the top cover above regulator REG1 and MOSFET Q2.

Warning!

Voltages of up to 285V DC are present on the PCB when power is applied and whenever the red LED is lit. Never operate this unit without the top cover in place!

joined. You can then glue the two side panels on, again making sure they are pressed in fully before it sets.

Don't use great dollops of glue but don't be too stingy either. If you're quick, you can wipe off any excess from the outside with a cloth.

Leave this assembly aside for some time (ideally, overnight) before refitting it using the four screws. If you have stick-on rubber feet, stick them on now, otherwise attach screw-on feet using the four mounting screws. That's what we did on the prototype (see photos).

Fitting the front panel

All that's left is to push the front panel in place, ensuring the LEDs pass through the two holes, attach the potentiometer nut and fit the knob. **DO NOT glue the front panel or any of the panels to the top cover.** If you find the front panel won't sit flat, it may be that the LEDs are protruding too far and pushing on it. Pressing them carefully

The case is assembled by first fastening the top and bottom panels and the PCB together (see also Fig.10). The rear panel is then glued to the base, after which the base is removed and the remaining panels fitted as detailed in the text. DO NOT glue the front panel or any of the other panels to the top cover.

Improving the bass response

A reader has brought to our attention the fact that the circuit, as presented last month, could have a significant amount of bass attenuation when driving a fairly typical power amplifier load impedance of around 10kΩ.

This is because the 220nF output coupling capacitor is not quite large enough. Our Audio Precision test equipment has a 100kΩ input impedance and in combination with the 220nF coupling capacitor and 1MΩ onboard bias resistor, this results in a –3dB point of around 8Hz.

However, with a 10kΩ load impedance, the –3dB frequency increases by nearly a factor of 10, to 72Hz. We've confirmed this by simulating the full preamp circuit. This is not an unrealistic load impedance for a power amplifier.

The solution is simple: increase the coupling capacitor value. At the very least, use 470nF 630V capacitors (one in each channel) for a –3dB point of 34Hz for a 10kΩ load. Ideally, though, they should be at least 1µF. The simplest way to achieve this is to use pairs of parallel 470nF capacitors, one on either side of the PCB for each channel. This will yield a –3dB point below 20Hz.

back into the case should fix this. You will need to do this to both LEDs or the result could look strange.

It's now ready to use. Remember that it takes 10-15 seconds each time you power it up before the HT rail rises to its normal level and all the bias voltages stabilise. Until then, you aren't likely to get much output. Ideally, wait 30 seconds or so after powering up for it to achieve a reasonable level of performance. The valves will continue to warm up for some minutes and this may affect performance slightly.

Kit of parts

Altronics has prepared a kit for this project, Cat. K5192. This complete kit includes the parts required to make the case. However, the case may not be identical to the *one described here.*

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High Visibility 6-Digit LED GPS Clock

Last month, we introduced our GPS high-visibility 6-digit LED clock. We want to emphasise its main feature: it automatically changes time zones as you travel – is important if you are cruising the world on a yacht or just touring the world. This second article provides all the information you need to build and use the clock.

WE'RE VERY pleased with this clock because its big, bright display is so eye-catching and can be viewed from quite some distance. It also has quite a few features beyond just displaying the time, as will become apparent when you read the operating instructions below.

In *Part 1*, we mentioned you can use a module with RS-232 signalling but that TTL is preferred. Modules with RS-232 signalling have a bipolar voltage swing on their serial port pins of between ±3V and ±15V. This allows longer cable runs and improves noise immunity.

However, with the module only a few centimetres away from the microcontroller this is unnecessary and complicates interfacing. As a result, many GPS modules simply use a 0-3.3V (or thereabouts) swing, ie, TTL levels and the signals are inverted too.

You may get a better deal on an RS-232 module, and in this case you can simply wire a resistor of say 4.7kΩ-10kΩ between the GPS module's TX line and the clock's RX pin. The microcontroller's internal clamp diodes will then limit the applied voltage to a safe level.

This works despite the signal inversion because if the clock detects gibberish from the GPS module, it tries inverting the signal level. If that doesn't work, it will also try various baud rates from 2400 bps up to 115,200 bps with both inverted and non-inverted sense until it detects valid NMEA data. The most common rates of 4800 and 9600 baud are tried first.

By the way, GPS modules are now becoming available with GLONASS support. GLONASS is a GPS competitor built by Russia, and modules which support this will typically work better indoors or in poor signal areas because they have access to more satellites – in other words, they can use both GPS and GLONASS satellites to get a fix.

Last month, we mentioned the u-blox Neo-6M, available for around US$10.42, but do consider the Neo-7M for around $20, which is very similar to the 6M but with GLONASS support.

Part 2
by Nicholas Vinen

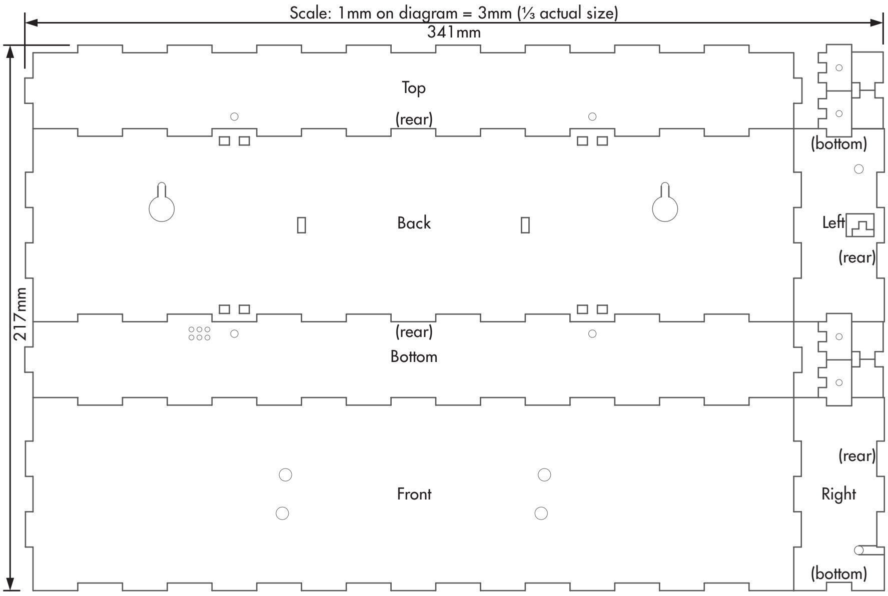


Fig.4: this diagram shows how the single sheet of 350 × 225mm (or larger) acrylic is cut up into the six large pieces and six smaller pieces that are then glued together to form the case. Cutting takes about five minutes. The case includes slots for wall-hanging and some holes to make the piezo sound louder.

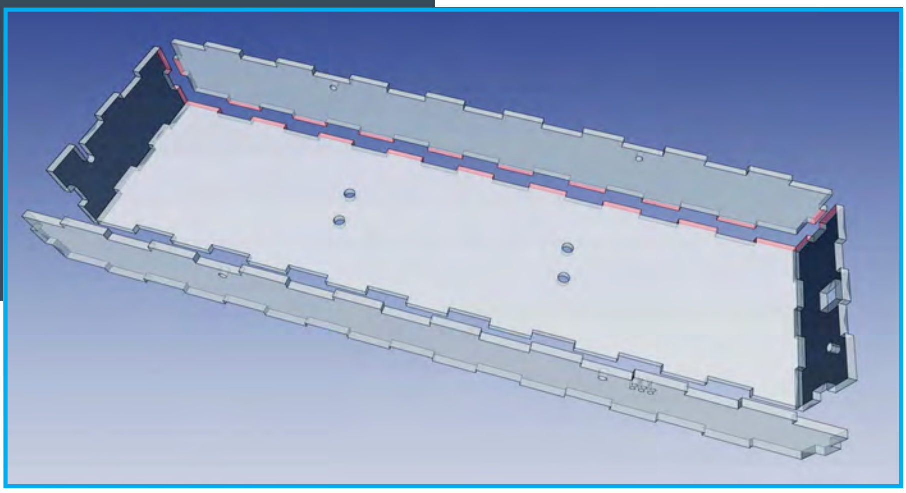


Fig.5: the front of the case with the left and right panels already in place and the top and bottom about to be glued. The red shaded areas show where adhesive would need to be applied for the top panel to be glued, although as stated in the text, you could apply adhesive to only the top piece as long it's applied to all the faces that will contact the shaded ones. Note carefully the hole positions in the four surrounding panels so that you glue them with the correct configuration.

We should point out that like most other modules, both the Neo-6M and Neo-7M come with ceramic patch antennas, but these are external antennas connected via a short cable. This means you could in theory connect it to a larger external antenna.

Testing

There isn't much to testing the clock. The simplest method is to power it up briefly. There might be a short delay (of no more than a few seconds) while the supercap charges up, but it should then immediately perform a display test where each segment on all the digits lights up in turn and then the piezo buzzer will sound a 100ms beep.

If that doesn't happen after a few seconds, switch off and check for faults, such as incorrectly installed components or bad solder joints. You can also check that the output voltages of REG1, REG2 and REG3 are correct.

After the test procedure, IC1 will fire up its 32kHz oscillator. If you get the digit test but nothing else, check for the presence of the 32kHz signal on pin 11 of IC1. If that's missing, it may be that one of the leads of crystal X1 is shorted to the case or some other adjacent metalwork.

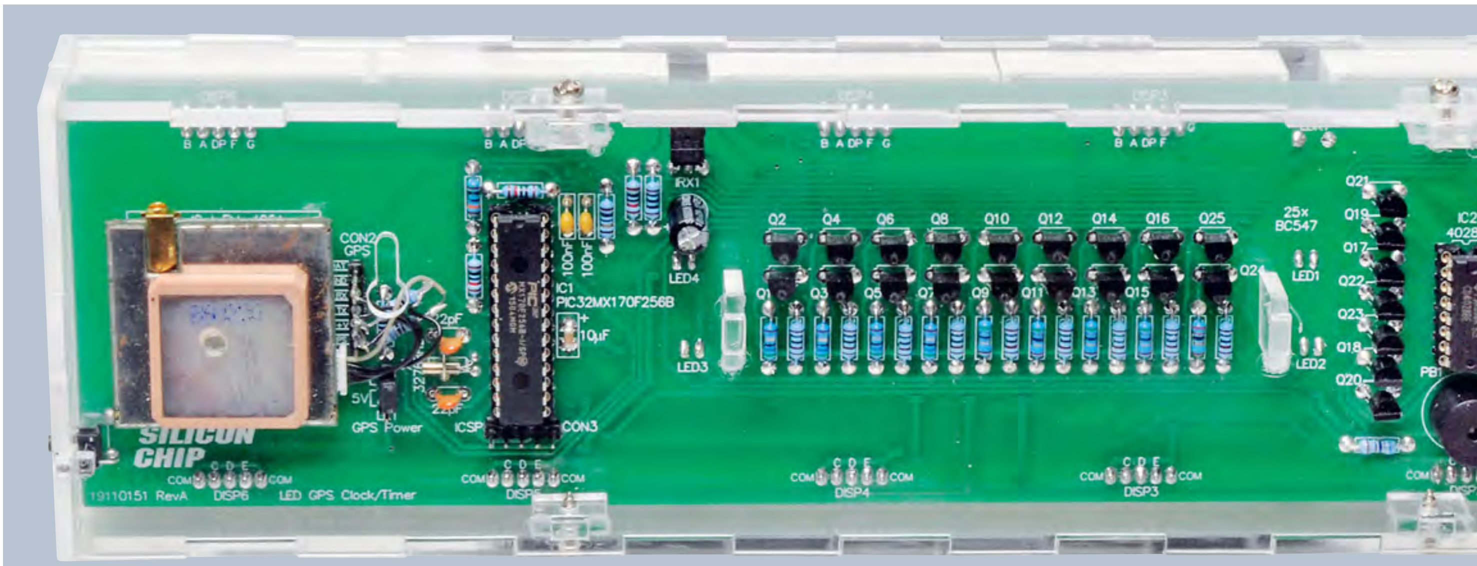
If a GPS module is detected, the unit will indicate that it is waiting for a position fix by showing 'GPS' on the display, along with a progress display. Otherwise, the clock will flash '12:00:00' until you set the date and time (see below for information on how to do this). Assuming it's working, you can move on to making the case.

Assembling the case

The case is made from a single piece of clear or tinted acrylic which starts out at 350 × 225mm and is laser-cut into six large pieces plus a number of smaller pieces, which are then glued together. The back is not glued on; it's held with four self-tapping screws so that it can be removed to allow access to the PCB module for maintenance. The cutting pattern is shown in Fig.4.

If you have a laser cutter, or access to one, you can download this pattern from the *EPE* website in DXF or SVG format and cut it yourself. With a 50W laser, we used settings of 8mm/second at 80% power. **Pre-cut case kits are available form the Silicon Chip On-line Shop – see Parts List last month – together with the PCBs, programmed microcontrollers and some of the 7-segment displays.**

You can use clear acrylic, as shown on our prototype or acrylic tinted with a colour that matches the displays (ie, green, blue, red). You will see more of



This view shows the completed clock PCB from the rear. The PCB is held in position by the two small centre pieces that mount at right angles to the rear panel (see Fig.6).

the workings of the clock with the clear case, but the tinted case may provide better contrast for the display. The clear case is suited to any display colour whereas a tinted case will need to match the display colour used.

The case is glued using a special solvent-based adhesive that makes very strong bonds between pieces of acrylic. You could use cyanoacrylate (super glue) in a pinch but we can't guarantee that the result would last.

We used SciGrip Weld-On 16, fast-setting 'clear, medium-bodied solvent cement'. It states on the label that it's suited for butyrate, polycarbonate, styrene and acrylics. You are unlikely to find this adhesive in a shop, so go to: **www.multibondsolutions.co.uk**

This forms a strong bond quickly, so you only have about a minute to apply the adhesive to the pieces to be mated, press them together and get them lined up properly. Full strength is achieved after about 24 hours, but it sets well enough to manipulate the pieces after about 10-15 minutes.

The bond is clear but you don't want to get excess adhesive on the material as it will affect the surface finish and you definitely don't want to drip it on the front face. It tends to get a bit 'stringy' (sort of like melted mozzarella) after coming in contact with the acrylic. Keep a clean (disposable) rag on hand to mop up any excess adhesive. Also make sure you have a large, clean, flat surface to lay the pieces down on, eg, lay down some sheets of plain paper on your workbench.

Gluing the pieces

The front section (ie, where the display will be seen) can be identified by the four 5mm holes for the colon LEDs. Four more sections are glued to this to form an open box. These sections must be fitted with a specific orientation so before gluing them, put them together loosely to make sure you have the right pieces and understand the required orientations.

Start the assembly by gluing the top, bottom and side pieces to the front panel, as shown in Fig.5. Note that the front panel does not have mirror symmetry, so be sure to orient it so that the LED colons will slant in the correct direction. The other pieces can then be laid out around the front panel in the correct orientations before you start gluing any pieces.

That done, start with one of the smaller left or right end panels. When gluing these pieces, you will need to coat all the mating surfaces with a decent amount of adhesive to make sure the bonds are good. An example is shown in Fig.5 for gluing the top panel; the areas shaded red are where adhesive would need to be applied, assuming the left and right panels were already in place.

Note that you could coat just the surfaces of the panel being introduced to the assembly each time – you would need to apply adhesive to those surfaces which would mate with the red surfaces shown on the other pieces (which would have been difficult to depict from this angle).

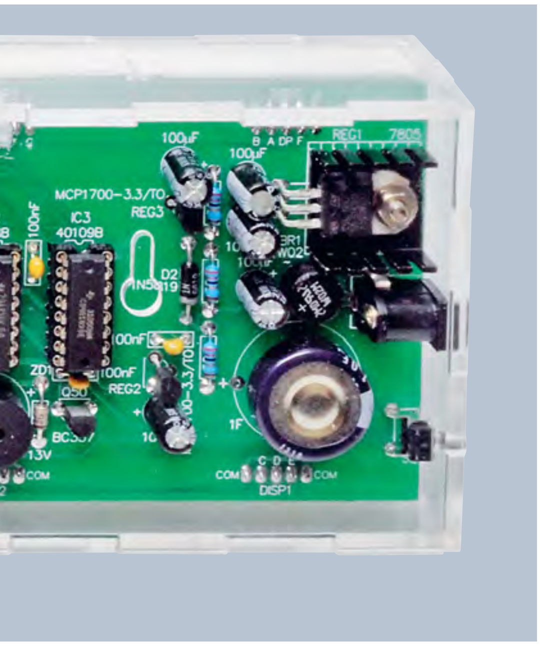
Glue the first panel, then wait a few minutes for the adhesive to make a decent bond before moving on to one of the adjoining panels. Repeat until all four sides are in place, then quickly drop the rear panel into place (being careful not to get any glue on it) to check that everything is nice and square and nothing will foul the rear panel once the adhesive finishes curing.

The next step is to glue six small pieces to the rear panel, as shown in Fig.6. The trick is to use enough adhesive to give a good strong bond without the excess spreading out too much. You also need to be careful to make sure each piece is glued exactly perpendicular to the rear panel. Check that the four pieces which have holes in them are not angled out towards the edge of the panel, as they must slot inside the top and bottom pieces of the case.

You can check this once the six pieces are in place and the adhesive has started to set; gently drop the rear panel into place and then remove to set.

It's best to leave the pieces overnight so the bonds achieve full strength. You can then introduce the PCB assembly into the case. Hold it at an angle and slide the DC socket and pushbutton into one side of the case, then rotate it until the 7-segment displays rest on the inside of the front panel.

The rear panel can then be attached using four 4GA self-tapping screws through the holes in the top and bottom that bite into the parts glued into the rear panel earlier. The basic idea behind this is illustrated in Fig.7.



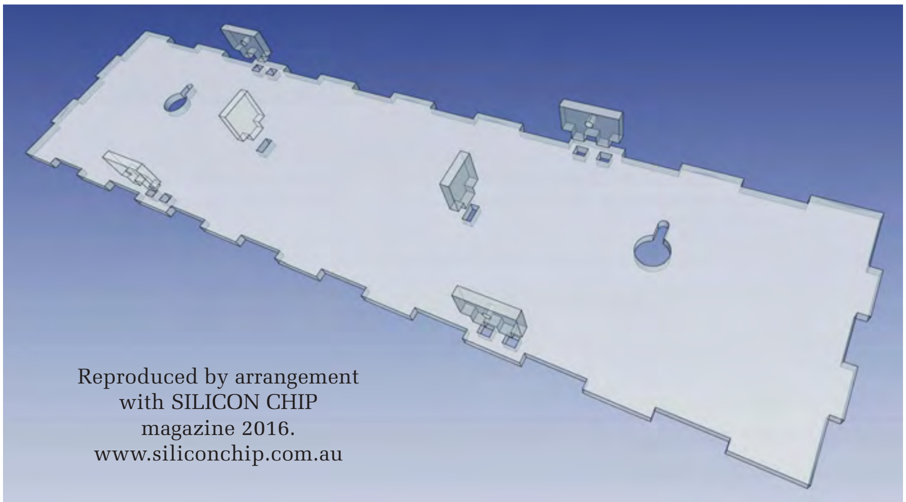


Fig.6: the six smaller pieces are glued into the rear panel. Be sure to use sufficient adhesive to form strong bonds. The four upper and lower pieces with holes are used to hold the back onto the case and by extension hold the case and whole assembly to the wall. The two smaller pieces glued in the middle press the PCB assembly up against the front of the case. The rear panel is symmetrical so the parts can be glued to either side as long as they're all on the same side.

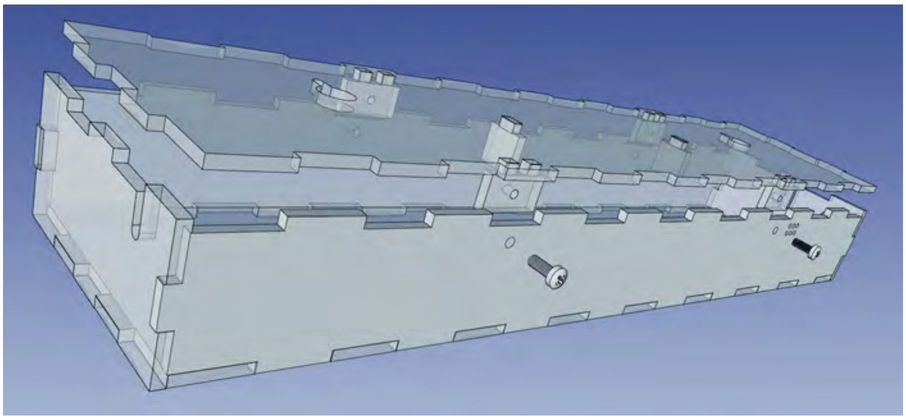


Fig.7: this shows the two halves of the case being put together. Machine screws are shown, but we recommend you use No.4 self-tapping screws. Be gentle when cutting the threads initially; if any of the smaller pieces break off during this process you will have to re-glue them and wait for the adhesive to set again.

For desk use, fit a small rubber foot to each corner at the bottom. For wall mounting, two screws placed 200mm apart will fit into the slots on the back. The heads must be between 4mm and 9.5mm in diameter. Most small wood screws should fit; check before screwing them into the wall. Don't hang it until the adhesive has achieved full strength.

LDR calibration

Once the unit is in place and powered up, calibrating the LDR is simple. Shine a bright light on the LDR for a few seconds (eg, a torch), then cover the unit up for a few seconds (eg, with a pillow case) to block out all light – or simply place it in a dark room and turn the lights off. The unit will automatically record the highest and lowest values read and adjust its calibration to suit.

GPS time acquisition

If there is no GPS module fitted, by default the unit will power up showing a flashing '12:00:00' display, waiting for the time and date to be set, as explained below. However, if a GPS unit is detected, the display will change to 'GPS 00'. As satellites are picked up, the number will be updated to show how many are 'seen'. If the unit has a 1PPS output, the decimal point after 'GPS' will flash in time with it, until a GPS lock is acquired.

Once the unit has a GPS fix (latitute/longitude), the display will change to 'GPS FI'. It will then wait to receive valid date/time information, at which point the display will change to 'GPS SE' as it searches for valid time zone data based on that information. Once the data is found, the display will change to show the local time.

If GPS fix is lost, the unit will fall back on its 32.768kHz crystal for timekeeping. After several minutes, the display will start pulsating (ie, varying in brightness over time) to indicate that it is no longer 100% accurate. If a GPS fix is re-acquired, the time is updated and it stops pulsating.

Setting up the IR remote

By default, the clock is set to respond to infrared remote commands from an Altronics/DynaLink A1012 learning remote on TV code 170. Fig.8 shows the default mapping. The various functions indicated are described below.

We've chosen this remote because it's relatively inexpensive, easy to get, looks good and has all the buttons needed for this project. Having said that, just about any universal remote control can be used, including Jaycar's Cat. AR1719.

Whichever remote you use, it just needs to be set up to produce Philips RC5 or NEC-compatible infrared commands. To check this, point the remote at the clock and press the buttons. You may need to guess at some appropriate code settings first (eg, Philips TVs). Check the manual supplied with the remote.

If it's producing commands that the clock can receive, the last decimal

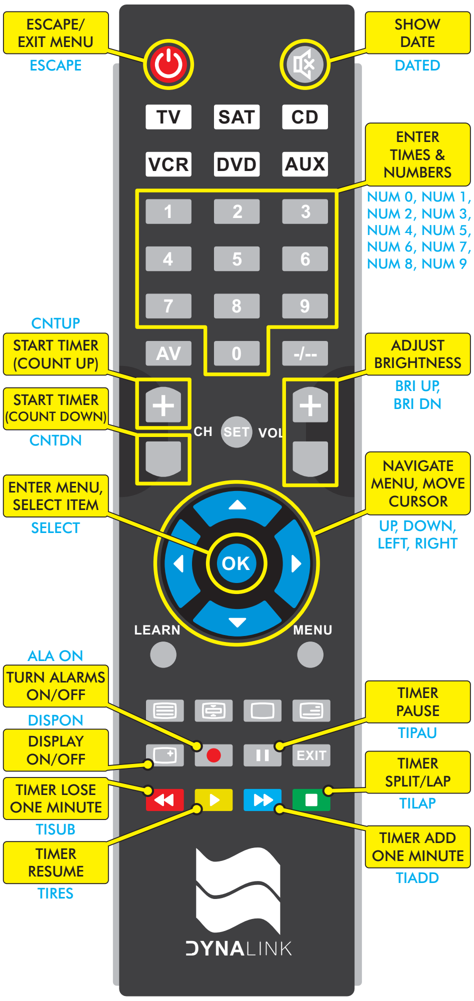


Fig.8: the default button mapping on the Altronics DynaLink A1012 remote control set to TV code 170. Other remotes can be used, but you may have to program the button codes into the clock, as described in the text. If so, use this as a guide as to which buttons to map to which functions. The button function names displayed on the clock during set-up are shown in blue on this diagram.

point on the display will flash. While many different modes will produce some valid commands, you may need to try several different codes before you find one where all the buttons you need actually work. Refer to Fig.8 for guidance, but note that the button mapping for your remote doesn't need to match exactly (ie, your remote may not have an identical button layout).

Once you have decided which remote to use and the setting to use it on, power up the clock and put it in IR set-up mode by holding down the buttons on either side of the clock simultaneously for several seconds. The display will show 'IR SET'. Release the buttons, then press the right-side button to continue.

The display will flash 'NUM 0', indicating the button code that is to be set. Hold down the '0' button on your remote control for a second or two. It will then briefly show the remote code received and then the display will switch to flashing 'NUM 1'. Repeat this procedure for the remaining buttons. The codes corresponding to each button are shown in Fig.8.

If at any point you make a mistake, you can go back and reset the previous button code by pressing the left-hand pushbutton on the clock. If you don't want to assign a button to an IR code, press the righthand pushbutton to skip that one.

Once you have set all the codes, 'IR FIN' will be shown. You can then press the right-hand button on the clock to go back to normal operation or the left button if you need to change a code first.

If necessary, buttons can be re-assigned later, using the 'CHANGE' option in the 'IR' menu. Menu operation is described below.

Setting the time and date

This is only necessary if you haven't fitted a GPS module. Press the OK button on the remote control and then press the down button until the display shows 'SETDA'. Press OK; the display will then show '010116' representing 1st January 2016 (assuming your date format is set to the default of DDMMYY). Use the keypad on the remote control to enter the correct date then press the select button.

You can then go back into the menu and select 'SETTI'. It will change to show '000000' representing midnight (HHMMSS). Check the current time, then enter what the time will be in a minute or two, in 24-hour notation using the keypad – but don't put in the last digit yet. Do that the instant that the reference clock matches the time entered.

This same procedure can be used to change the time or date at a later stage. Note that you can also use the up/down/left/right arrows to change the time and date; however, it's easier to use the numeric buttons. If necessary, you can set the time and date without a remote; see the 'Operating without a remote' section below.

If you want the clock to make daylight saving time (DST) changes automatically without a GPS module, you will also need to tell it which time zone you are in. This can be done before or after setting the time. Press the OK button on the remote control and then press the down button until the display shows 'SETTZ'. Press OK, then refer to Table 1 and choose the appropriate zone using the up/down. Press OK to confirm.

The default is 'NONE', in which case no time zone calculations are done. If a time zone is selected which has no DST rules (as per Table 1), this will not have any obvious effect, except that changing to a different time zone will then change the time to suit that location. If a time zone with daylight savings rules is selected, those rules will be obeyed and the clock will automatically change the displayed time when appropriate.

It's possible to override the DST rules, should they change after this article is published, or if an error is found; we explain how to do that later in this article.

Showing the date

Once set, the clock normally displays the time. The date can be shown with a quick press of either button on the clock itself or by pressing the show date button (usually mute) on the remote control. It will be displayed for five seconds with decimal points separating the day/month/year, then the unit will switch back to time display.

Display brightness

Hold down the volume+ or volume– buttons on the remote control to vary the display brightness. Auto-dimming continues to operate, if configured. For example, if you've set the brightness to 50% and the auto-dim is at 50% then the overall display brightness will be 25% of maximum.

Menu system

The time setting description above involved entering the menu to access the 'SETDA', 'SETTI' and 'SETTZ' options. The full menu tree is shown in Fig.9. The top level menu, shown in the blue boxes at the left, is accessed by pressing the OK button on the remote (or via the pushbuttons, as described later). Up and down scroll through the list.

Each additional 'level' of the menu is shown in a different colour and is accessed by pressing OK on its 'parent' entry. Similarly, pressing the escape button (normally the power on/ off button on the remote) will take you back up to the parent menu or back to the time

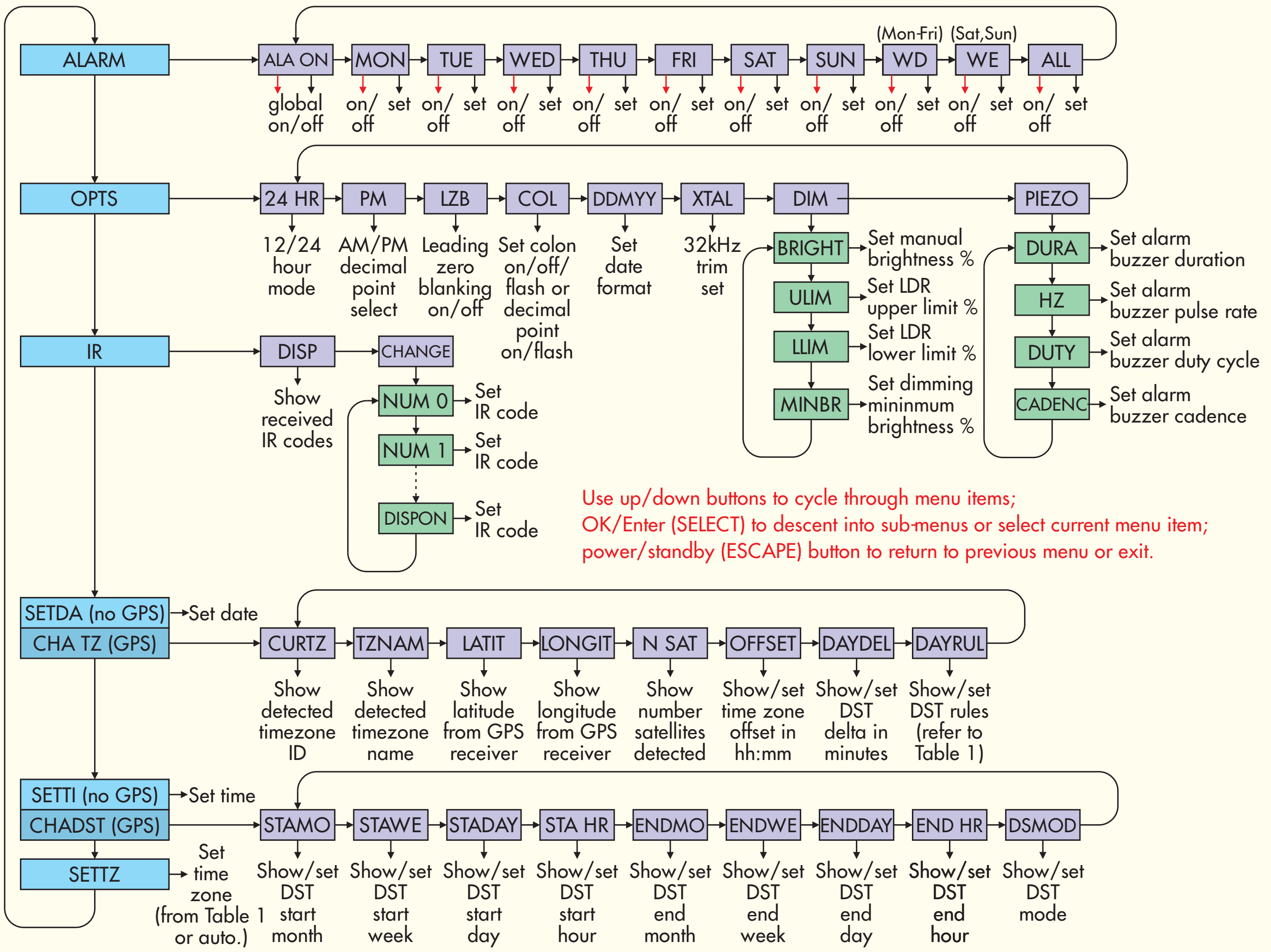


Fig.9: this shows the complete menu tree for the clock. The main menu is shown in blue on the left; two of the options vary depending on whether a GPS module has been detected or not. Sub-menu options are shown in mauve with their sub-menus shown in green. Pressing the OK/select button activates the function indicated for each menu item, allowing that parameter to be viewed or set. The escape (on/off) button goes out of the current menu and back to the parent, or in the case of the main menu, back to the regular time display.

display, if viewing the top level menu.

Below, we'll go through the remaining menu items and explain what they do, as well as detailing other clock functions accessed by different buttons on the remote.

Operating without a remote

The menu system can also be accessed without a remote, using the unit's pushbuttons. Hold down the right pushbutton for at least one second and release it to enter the menu. Pressing the left button is then equivalent to the up button on the remote; pressing the right button is equivalent to down. These then let you scroll through the menus.

To escape from a menu, hold down the left button for at least one second and release. To select an item, hold down the right pushbutton for at least one second and release. When you need to enter a numeric value (eg, setting the time), short presses of each button will increment or decrement the currently selected digit.

Holding down the right button for at least one second will cycle to the next digit. Holding down the left button for at least one second will save changes and return to the previous menu item. Holding down both buttons together and then releasing will abort changing that value.

In this manner, you can operate the menus without the remote. The buttons can also be used to show the date. However, note that many other functions are not available without a remote, such as timer modes and so on. Basically, the unit is designed to be used with a remote and the button functions are a fall-back, primarily intended for applications where it's used purely as a clock.

Setting the alarm

Normally, the right-most decimal point on the clock shows the global alarm status. If on, the alarm is set to go off at least once in the coming week. It's dim if there is no alarm set in the next 24 hours or bright if there is.

To set the alarm, enter the ALARM menu. You will see either 'ALA ON' or 'ALAOFF', indicating the global alarm on/off status. Press either OK or the record (ALA ON) button on the remote to toggle it. The ALA ON button will also work when the clock is showing the time, as a quick and easy way to enable or disable the alarm.

Cycle through the next seven menu entries to turn the alarm on or off for an individual day, or set the time for that day (in 24-hour format). The record button is used to toggle that day's on/off status, while select can be pressed

Fig.10(a-d): this series of images shows the complete global land mass coverage of the time zone data programmed into the clock. There are 128 separate shaded areas, mapped to 73 different time zones, each with different UTC/GMT offsets and daylight savings rules. Note that many zones overlap, which has been done to reduce the compressed size of the data set; see text for more details.

to set the alarm time, similarly to the way the clock's own time is set as described above.

You will also find menu entries for 'WD' (weekdays), 'WE' (weekend days) and 'ALL'. Changing the on/off status or time for any of these entries affects multiple alarms, ie, Monday-Friday for 'WD', Saturday-Sunday for 'WE' and Monday-Sunday for 'ALL'. They can still be individually changed after that. When finished setting alarm times, keep pressing on/off to exit the menus and return to the clock display.

When the alarm goes off, briefly press either pushbutton or the Escape button on the remote for a 5-minute snooze. A long (1s+) press of either pushbutton or a second press of the Escape button will cancel it altogether.

Using the clock as a timer

The clock can count time upwards starting at zero (eg, to measure how long something takes) or downwards to zero (eg, to alert you when a certain amount of time has passed). It also has stopwatch type functions such as a lap counter. It counts with 1/100th-second resolution for times less than one hour, 1/10th-second resolution up to 10 hours, one-second resolution for up to 100 hours and with further-reduced resolution up to 1000 days.

Since infrared commands normally take the same amount of time to transmit, receive and decode, the timing should be pretty accurate, to within a few hundredths of a second. However, since there's no guarantee an infrared command will be received without corruption, you will need to hold down the button to start the timer reliably, which could result in it sometimes being off by a fraction of a second.

There are three basic modes: count up with no limit, count up until a specific time is reached, or count down from a specific time to zero. When the limit is reached (either counting up or counting down), the piezo buzzer sounds, although this can be turned off if desired. Counting can be paused and the counter can have one minute added or subtracted while it's running.

Starting the timer

Press the channel+ button and the timer will start counting up from zero. You can tell the timer and not the clock is running since the colon LEDs switch off and the decimal points flash instead. Press the pause button to pause the timer; the display will freeze and flash. Press the play button to resume.

If you press the stop button, the display will freeze and flash but it will show the time for the last lap; ie, since the timer started for the first lap, or since the last time you pressed this button for subsequent laps. Press the play button to go back to the normal timer display. Pressing fast forward or rewind will add or subtract one minute from the displayed time.

Hold down the on/off button for a second or so to abort timer mode and go back to the normal clock display.

If you want to count up to a specific time, press one of the numeric buttons or up/down immediately after pressing channel+ (within a few seconds). Enter the time to count up to (in a similar manner to setting the time), with a maximum of 23 hours, 59 minutes and 59 seconds. Once you've entered the time, press select to start counting.

In this mode, the fast forward and rewind buttons change the target time by one minute; it will be briefly displayed when they are pressed, then it will go back to showing the timer. Also, when counting up to a target time, the last decimal point on the display indicates whether the buzzer will sound when the target is reached (by default, it's on). Press the record (alarm on/off) button on the remote to toggle it while in this mode.

Press the channel– (CNTDN) button to initiate counting down. The procedure is essentially identical to counting up, except that you are always prompted to set the initial time, using the same method as described above. Essentially, this mode is identical to counting up towards a target time, except for the fact that the timer starts at the set time instead and counts down to zero.

Changing options

There are a number of options which can be changed through the 'OPTS' menu. Once an option is displayed, use the OK button to change it. Numeric values can be changed using the up/down/left/right buttons or, in some cases, the numeric keypad on the remote. The options are as follows.

(1) 12/24-hour time

Display shows either '12 HRS' or '24 HRS'. Hours are shown as 01-12 in 12-hour mode or 00-23 in 24-hour mode.

(2) Leading-zero blanking

Display shows either 'LZB ON' or 'LZBOFF'. Press select to toggle between them. Applies only to the first digit on the display, ie, 3pm will be shown as

'3:00:00' with leading zero blanking enabled or '03:00:00' with it disabled. This would normally be disabled in 24-hour mode, but you can enable it.

(3) Hours/minutes/seconds separator in time display

There are five options: 'COLFLA' (colons flash at 1Hz; default), 'COL ON' (colons on permanently), 'COLOFF' (colons off permanently), 'DP ON', (decimal points on instead of colons) and 'DP FLA' (decimal points flash instead).

(4) Dimming sub-menu

Each entry allows you to set a value between 0% and 100%.

'BRIGHT' is the current manually displayed brightness setting. It also changes when the volume+ and volume– buttons are pressed.

'ULIM' is the percentage of ambient brightness where the display starts to dim automatically. For example, if set to the default of 75%, the display will be at full brightness between 75% and 100% ambient, but will dim below 75% ambient. Set it to 0% to disable auto-dimming.

'LLIM' is the percentage of ambient brightness where the display reaches minimum brightness. It will not dim further as the ambient light level falls below. The default is 10%.

'MINBR' is the display brightness achieved at the lower ambient limit. Setting this to zero means the display will turn off entirely at the lower ambient limit. The default is 25%.

(5) Piezo buzzer sub-menu

This determines the sound the piezo makes when the alarm goes off or the timer expires.

The duration setting is from 0-900 seconds (0 seconds = off, default = 10s). Hz indicates the frequency of the pulses from the piezo between 1 and 10Hz (default = 2Hz). Duty is the duty cycle from 1-100% (default = 50%). Each of these can be set by pressing select, then either up/down or using the numeric buttons to enter a value.

Cadence lets you enter three pairs of duration/pause values as a 6-digit number. The default is 100000, which gives an even series of pulses from the piezo at the selected frequency but, for example, a setting of 113200, in combination with a 2Hz frequency, would give a 0.5s beep, followed by a 0.5s pause, followed by a 1.5s beep, followed by a 1s pause, with this pattern repeating.

(6) Date format

This defaults to 'DDMYY' as is used in the UK. The other options are 'MDDYY' or 'YYMDD'; affects both date display and setting.

Changing infrared codes

The infrared menu, labelled 'IR' has two sub-menu options: 'DISP' and 'CHANGE'. If 'DISP' is selected, the unit shows the Philips RC5 or NEC code for any button pressed on the remote. Press either pushbutton on the clock itself to exit this mode.

If 'CHANGE' is selected, you can then select any of the remote button functions (as shown in Fig.8) using up and down and re-program it by pressing OK. The procedure is similar to that described in the initial setup above. Use the left pushbutton on the clock to abort and leave that code as it is, or the right pushbutton to de-assign the existing infrared code for that button and disable it (until a new code is set).

Time zone/daylight saving data

As mentioned last month, the clock incorporates geographic data, time zone data and daylight saving data, which allows it to determine the correct local time virtually anywhere on Earth's land mass with just the output of a GPS module. The geographic data is shown in Fig.10, plotted on top of the Earth's surface. Each coloured region represents a different time zone.

You may notice that many of the boundaries seem rather sloppy; this is done on purpose as borders defined with fewer points take up less flash memory. Basically, where two time zones meet (eg, at the border of two countries), we accurately define one border, which is often defined by a river or mountain range and thus has many wiggles – often requiring thousands of co-ordinates to define.

When we check whether your current location is within that time zone with the well-defined border, and the result is a negative, we don't need the border for the adjoining zone to be defined with such precision since we already know that if you are near the border, you are on the other side of it, by a process of exclusion.

As you can see, the data involved is substantial and it takes up about 150KB, even after a specially designed compression algorithm has been applied. If you're interested in more details, see the panel on pages 28 and 29 of the February 2016 issue of *EPE*.

Time zone data updates

We've made a substantial effort to provide up-to-date time zone geographical data and daylight savings rules in the firmware for the clock. However, the rules are very complex and vary drastically between different locations. They also change over time, so we decided there needed to be a way to keep the rules up-to-date, at least for the locations that constructors occupy.

Last-minute extras

(1) To calibrate the 32kHz crystal, set the XTAL menu option to between –512 (260ppm slower than default) and +511 (260ppm faster). This is adjusted automatically when a GPS module with a 1pps output is used.

(2) The unit can show the day of the week. Simply activate the date display function, then press the same button again.

(3) A new menu item, 'GPSLCK', has been added to the options menu. If set to 'IGNORE', the unit will use GPS time even if the satellite fix is not perfect. This will allow the unit to work in marginal signal areas, although time accuracy may not be quite as good.

(4) A new brightness menu item, 'CUR RD', shows the minimum/current/maximum raw LDR readings in 8-bit hexadecimal notation. The fourth digit decimal point lights when the data is going to be saved to Flash memory and goes out once it's saved. This can be used to troubleshoot the autodim function.

Table 1: Time zones and DST rules			
Display	Details	Offset	DST Rules
AU EAS	NSW, Vic, Tas	+1000	AUST
AU QLD	Queensland, PNG	+1000	-
AU SA	South Australia	+0930	AUST
AU NT	Northern Territory	+0930	-
AU WA	Western Australia	+0800	-
AU EUC	Eucla	+0845	AUST
AU LHI	Lord Howe Island	+1030	AUST (+30)
AU COC	Cocos Islands	+0630	-
AUMAC	Macquarie Island	+1100	-
NZ NZ	New Zealand	+1200	NZ
NZ CHA	Chatham Island	+1245	NZ
INTHAI	Indonesia/Thailand	+0700	-
JAPKOR	Japan/Korea/Palau	+0900	-
FIJI	Fiji	+1200	FIJI
USA HI	Hawaii	-1000	NTHAM
USA AK	Alaska	-0900	NTHAM
NA WE	USA/Canada West	-0800	NTHAM
NA MO	USA Mountain	-0700	NTHAM
ARIZON	Arizona	-0700	-
NA CEN	USA Central	-0600	NTHAM
NA EAS	USA Eastern	-0500	NTHAM
ASAMO	American Samoa	-1100	-
SA BOL	Bolivia, Eastern Quebec	-0400	-
CAN NL	Newfoundland	-0330	NTHAM
CAN NB	New Brunswick	-0400	NTHAM
PERU	Peru, Ecuador, etc	-0500	-
CAN SK	Saskatchewan	-0600	-
EUWES	Western Europe	+0100	EURO
EU IS	Iceland	+0000	-
EU UK	United Kingdom	+0000	EURO
EU EAS	Eastern Europe	+0200	EURO
EUMOS	Moscow	+0300	-
AS NKO	North Korea	+0830	-
AS BAN	Bangladesh	+0600	-
AS NEP	Nepal	+0545	-
RUWES	Western Russia	+0500	-
AFMOR	Morocco	+0000	MOROC
AF ALG	Algeria, Tunisia	+0100	-
AF LIB	Libya	+0200	-
AF EGY	Egypt	+0200	EGYPT
AFNAM	Namibia	+0100	NAMIB
AF AZO	Azores	-0100	EURO
AFMAU	Mauritius	+0400	-
IRAN	Iran	+0330	IRAN
AFGHAN	Afghanistan	+0430	-
ISRAEL	Israel	+0200	ISRAEL
GAZA S	Gaza Strip/West Bank	+0200	PALEST
JORLEB	Jordan, Lebanon	+0200	MIDEA
SA SEB	South-east Brazil	-0300	BRAZIL
SA NEB	North-east Brazil	-0300	-
SA PAR	Paraguay	-0400	PARAGU
BRAZIL	Rest of Brazil	-0400	BRAZIL
SA URA	Uruguay	-0300	URUGUA
SA VEN	Venezuela	-0430	-
MEXBJC	Baja California	-0800	MEXIC
MEX W	Western Mexico	-0700	MEXIC
MEX YU	Yucatan	-0500	MEXIC
MEX EA	Eastern Mexico	-0600	MEXIC
RU EAS	Eastern Russia	+1200	-
GEORGI	Georgia, Armenia	+0400	EURO
INDIAS	India, Sri Lanka	+0530	-
MONGO	Mongolia	+0800	MONGO
GRQAAN	Qaanaaq, Greenland	-0400	MEXIC
GREENL	Greenland	-0300	GRNLND
ATLSSI	S. Sandwich Islands	-0200	-
PA BAK	Baker Island	-1200	-
PASAM	Samoa	+1300	SAMOA
PA TON	Tonga, Tokelau	+1300	-
PA KIR	Kiribati, Line Islands	+1400	-
FR PON	French Polynesia	-1000	-
PAMAR	Marquesas Islands	-0930	-
PAGAM	Gambier Islands	-0900	-

As a result, the clock has the facility for you to change the rules for your current location. Updates are stored in the same section of Flash memory as the clock options are kept and override the built-in rules.

There are three basic parameters for each location that can be changed: offset from UTC (in hours and minutes), daylight savings time shift (+0, +30 or +60 minutes) and daylight savings rules. The menus that provide these options also offer some information regarding the currently detected time zone and GPS module status.

There are 19 different sets of daylight savings rules, listed in Table 1 under 'DST Rules'. Table 1 also shows which set of rules is used by default in each location. The time zone menu allows you to change the setting for your current location to one of the other rules, including disabling daylight saving for a zone which previously used it, or enabling it for one which did not.

To change these options for your location, go into the 'CHA TZ' menu (which appears when the unit has a GPS fix). The first five menu items simply show information; press OK to display that particular parameter and then escape (on/off) to go back to the menu.

Of the remaining three, 'OFFSET' allows you to change the difference in hours and minutes between UTC/GMT and your time zone. This can be set anywhere from 22 hours before UTC to 22 hours after UTC in 15 minute intervals, although few locations use offsets of more than 12 hours from UTC.

'DAYDEL' allows you to select how much the time changes when daylight saving starts and ends. This will almost always be one hour (60 minutes) although there is one location, Lord Howe Island, which has a half hour (30 minute) DST delta. To disable daylight saving in your location, you can either set this to zero or change the DST rule to 'NONE'.

'DAYRUL' allows you to select the DST rules for your location. These rules define which hour of which day DST starts and ends in a given year.

Changing DST rules

Since these rules can also change, there is a separate menu called 'CHADST' to change them. There are nine DST settings for each rule, represented by nine menu items, of which four define when it starts and four when it ends. The ninth determines how these are interpreted.

The most common mode, used by the vast majority of locations, is 'HDWM' which stands for 'hour, day, week of month'.

For example, in Australia at the time of writing, daylight saving starts at 2am on the first Sunday of October and ends at 2am (3am DST) on the first Sunday of April.

So in this case, the mode is HWDM and the following rules are used:

STAMO: 10 OCT	FINMO: 04 APR
STAWE: 1ST	FINWE: 1ST
STADAY: SUN	FINDAY: SUN
STAHR: 2	FINHR: 2

(In this menu, the hour values always refer to the time before daylight saving is applied, hence FINHR is 2, not 3).

The following countries use different modes. Iran uses 'EQUINO' where DST start/end dates are relative to the spring and autumn equinoxes. Brazil uses 'NOCARN' which is identical to HDWM except that DST changes are delayed by one week if they fall during Carnaval. Similarly, 'NORAM' delays DST changes if they fall during Ramadan and likewise 'NOROSH' delays DST changes if they fall during Rosh Hashana.

Meet the mighty Micromite

Part 1: Introduction

by Geoff Graham

The Micromite is an amazing device. A low-cost microcontroller programmed in a Microsoft-compatible version of BASIC with floating point, arrays and extensive string handling. The Micromite can interface to a variety of devices including touch-sensitive LCD panels and a host of sensors for temperature, humidity, GPS and more. Even better, the microcontroller only costs a couple of pounds and the BASIC interpreter is free. Available in a user-friendly 28-pin package, the Micromite makes a great controller for your heating system, lighting manager or whatever else your imagination can dream up.

Overview

The Micromite is based on the Microchip PIC32MX170 microcontroller. This is a powerful 32-bit device, which runs at 48MHz and has plenty of memory for programs and data. The Micromite firmware is free and the chip does not cost much (about £2) so the investment to get started is small. The firmware will run on two versions of the PIC32; a 28-pin dual-in-line package (DIP) which can be easily soldered or plugged into an IC socket, and a 44-pin package which is surface mount with a reasonably easy-to-solder pitch of 0.65mm.

Despite its low cost, the Micromite does not scrimp on features. The BASIC interpreter (called MMBasic) is Microsoft compatible with a number of modern extensions. Variables can be either single-precision floating point, 64-bit integers or strings up to 255 characters long. You can have arrays of these types with up to 8 dimensions, and with 50KB of RAM you have plenty of space to generate large arrays. The names of variables can be up to 32-characters long, so you can use meaningful names such as, 'TotalCount', 'ExternalTemp' and so on.

Your BASIC program is stored in the chip's Flash memory so it will never be lost, even after cycling the power. The space available is 60KB, and this will accommodate quite complex programs consisting of thousands of lines. The interpreter can be set to automatically run the program on power up so that the Micromite will act as an embedded intelligent controller.

What can you use the Micromite for?

Currently, there are thousands of Micromites being used for anything from controlling a fish tank's temperature to running an automated lathe. The chip itself costs just a couple of pounds, so you can treat it as a low-cost replacement for discrete circuitry, even if it is not doing anything important.

When coupled with a touch-sensitive LCD panel it becomes a sophisticated controller, and we are planning a series of articles based on this configuration. These include a garage parking assistant using an ultrasonic sensor and a boat computer which uses a GPS to display speed, heading and other parameters. Futher projects include a sophisticated appliance energy meter, a super-accurate clock and a synthesised 1Hz to 1MHz signal generator.

All these projects will cost very little to build because the Micromite and its peripheral devices are low cost and for the most part can be purchased direct from China via Internet sites such as eBay.

Input/output

The 28-pin Micromite has 19 I/O pins and the 44-pin chip has 33 I/O pins. Under program control these can be individually set to a digital input, digital output, analogue input, frequency measurement, pulse-width measurement and so on. MMBasic commands can also be used to generate pulses and transfer data in parallel. Interrupts can be used to notify your program when an input pin has changed state, so your program can react instantly without polling the I/O pins.

Up to five PWM or SERVO outputs can be used to create various sounds, control servos or generate computer-controlled voltages for driving equipment that uses an analogue input (eg, motor controllers).

One of the outstanding features of the Micromite is the range of communications protocols which it supports. There are two serial ports which support ordinary serial (TTL levels), RS232 or IEEE 485. The Micromite also supports I^2C, SPI and 1-wire communications, which are great for interfacing to a wide range of sensors including pressure, temperature, acceleration, light and more.

Incorporated within the Micromite's firmware is support for a number of special devices. This includes 3×4 and 4×4 keypads, 2- and 4-line LCD

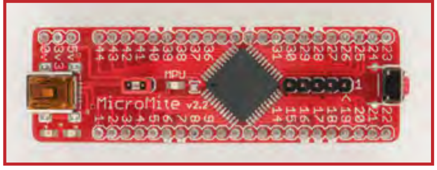


Fig.1. Top view of the Micromite showing its 44-pin surface-mount IC

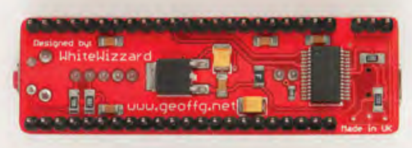


Fig.2. Underside of the Micromite

Fig.3. Examples of the graphics capability of the Micromite

displays, temperature and humidity sensors, battery-backed real-time clocks, distance measurement and servos. There is also support for NEC or Sony infrared remote-control protocols, which can be used to control the program running on the Micromite using an ordinary IR remote control.

LCD displays

The Micromite has built-in support for touch-sensitive colour LCD displays using the ILI9341 controller. These are manufactured in large numbers for use in common consumer products such as microwave ovens and washing machines. As a result, they are very cheap and can be purchased on eBay for under £5 (often including free freight).

The displays supported by the Micromite have 270 × 340 pixels with 65,000 colours and come in three sizes – 2.2-inch, 2.4-inch and 2.8-inch diagonal. Most also have a resistive touch controller built in and MMBasic will report the position of the touch in pixels so you can draw buttons and symbols on the screen and users can then select these by simply touching the screen.

There are a wide range of fonts that you can use, including large fonts for easy readability, fonts with special icons and specialty fonts such as seven segment fonts. Using the TEXT command you can position the text anywhere on the screen, select the colour and scale its size. As well as displaying text, you can draw extensive graphics on the LCD screen, including lines, boxes and circles.

Using these features you can display a lot of data on the screen, draw graphs and display on-screen touch-sensitive buttons and graphical objects. The photographs in Fig.3 show some typical displays. They are bright and easy to read and the touch sensitivity means that you often do not need any manual controls such as switches and knobs, the touch screen will do it all.

Console and editor

To communicate with the Micromite you use the console. This is a serial port on the Micromite over which you can issue commands, edit your program and observe error messages. Generally, the Micromite's console will connect to a serial port on your desktop computer or laptop. On this computer you run a terminal emulator, which provides a window where you can type and observe the Micromite's output.

The best method of making this connection is via a USB-to-serial converter. The USB end plugs into your computer and the serial end connects to the Micromite. To your desktop computer it presents a virtual serial port to which your terminal emulator will connect. We will have more to say on this subject later, when we will cover plugging in and connecting to the Micromite.

The Micromite includes its own built-in full-screen editor, which works over this serial interface. It enables you to enter a program, save it to the Micromite's memory and run it in quick sequence.

Micromite features

Fast 32-bit CPU with 256K of Flash and 64K RAM running a powerful BASIC interpreter. 60KB of non-volatile Flash memory is reserved for the program. 50KB of RAM is available for BASIC variables, arrays, buffers, etc. This is sufficient for quite large BASIC programs up to thousands of lines.

The BASIC interpreter is fully featured with floating point, 64-bit integer and string variables, long variable names, arrays of floats, integers or strings with multiple dimensions, extensive string handling and user-defined subroutines and functions. Typically, it will execute a program at 30,000 lines per second. MMBasic allows the embedding of compiled C programs for high-performance functions and the running program can be protected from being listed or modified by a PIN number.

19 input/output pins are available on the 28-pin chip and 33 on the 44-pin chip. These can be independently configured as digital input or output, analogue input, frequency or period measurement and counting. MMBasic commands will generate pulses and can be used to transfer data in parallel. Interrupts can be used to notify when an input pin has changed state. Up to five PWM or SERVO outputs can be used to create various sounds, control servos or generate computer-controlled voltages for driving equipment that uses an analogue input (eg, motor controllers).

Programming and control is done via a serial console (TTL voltage levels) at 38400 baud (configurable). Once the program has been written and debugged the Micromite can be instructed to automatically run the program on power up with no user intervention. Special software is not needed to develop programs.

Full-screen program editor is built into the Micromite, which only requires a VT100 terminal emulator and can edit a full program in one session. It includes advanced features such as search and copy, cut and paste to and from a clipboard.

Easy transfer of programs from another computer (Windows, Mac or Linux) using the XModem protocol or by streaming the program over the serial console input.

TFT LCD display panels using the ILI9341 and other controllers are supported allowing the BASIC program to display text and draw lines, circles or boxes in 65,535 colours. Resistive touch controllers on these panels are also supported, allowing them to be used as sophisticated input devices. These LCD panels typically cost US$7 and provide a low-cost, high-tech graphical user interface.

A comprehensive range of communications protocols are implemented, including I^{2}C, asynchronous serial, RS232, IEEE 485, SPI and 1-Wire. These can be used to communicate with many sensors (temperature, humidity, acceleration) as well as for sending data to test equipment.

The Micromite has built in commands to directly interface with infrared remote controls, including the DS18B20 temperature sensor, LCD display modules, battery-backed clocks, ultrasonic distance sensors and numeric keypads.

Special embedded controller features in MMBasic allow the clock speed to be varied to balance power consumption and speed. The CPU can be put to sleep with a standby current of approximately 100µA. While in sleep mode the program state and all variables are preserved. A watchdog feature will monitor the running program and can be used to restart the processor if the program fails with an error or is stuck in a loop. The running program can be protected by a PIN number, which will help prevent an intruder from listing or modifying the program or changing any features of MMBasic.

Because the editor is built into MMBasic you can easily modify a program running on the Micromite. You might have a Micromite controlling something (say your heating system) and you need to make a change. You can just connect to the console, interrupt the running program (with CTRL-C), run the editor to make the change and then set the program running again. Follow that with a disconnect from your laptop and in a matter of minutes your change is done.

BASIC interpreter

The BASIC interpreter running on the Micromite (called MMBasic) is Microsoft BASIC compatible, which means that the syntax was kept as close to Microsoft BASIC as possible and this makes it possible to download many programs from the Internet and run them with little modifications.

There are some functions not covered by Microsoft BASIC (eg, SELECT CASE) and in that case MMBasic relies on the ANSI Standard for Full BASIC (X3.113-1987) or ISO/IEC 10279:1991 for the appropriate syntax.

MMBasic is an interpreter, but it is optimised for speed. Most commands and functions are converted to single-byte tokens when a program is loaded, and that makes it possible for the interpreter to execute a command or function with little overhead. Similarly, caching is used for things such as user-defined functions, so that they can be instantly located when a call is made to them.

As a result, the Micromite will typically execute each command in 50µS or faster. This is plenty fast for most applications. Fast enough to respond to a high-revving engine and generate signals such as ignition triggers. And if that is not fast enough, you can embed compiled C functions in your BASIC program (explaineded later).

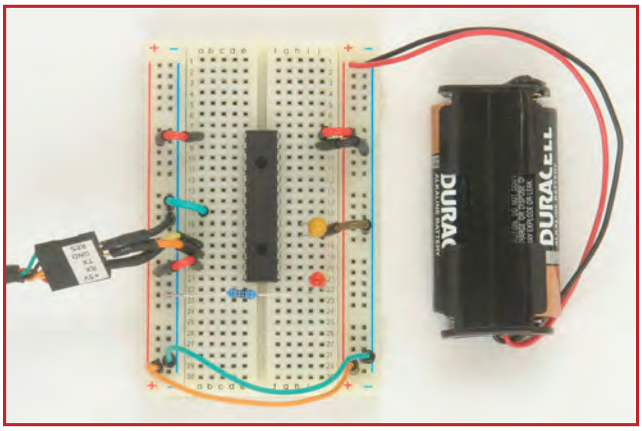


Fig.4. Solderless prototyping with the Micromite

Data types

MMBasic on the Micromite supports three data types – floating point, 64-bit integers and strings. Floating point allows you to use numbers with a decimal point; for example, 12.4. It also means that with general calculations (particularly involving division) you get the result that you would intuitively expect. So floating point is good for most applications and is the default used by MMBasic.

But the problem with floating point numbers is that they only store an approximation of the number when the number has more than six or seven significant digits. To avoid this issue, you can specify numbers as 64-bit signed integers. These can be used to accurately count and manipulate numbers up to nine million million million (or ±9223372036854775807 to be precise), which is a very large number indeed.

An illustration of where 64-bit integers come in handy is when you are dealing with latitude and longitude, which need to be stored with more than six digits of accuracy. There are many other cases where large and precise numbers are required, for instance, when working with frequency synthesisers.

The third data type – strings – is an often overlooked but important feature of MMBasic. A string is a sequence of ASCII characters and MMBasic has an extensive set of functions to pull them apart, search them and reassemble them in many ways. These powerful string functions come into their own when you are dealing with text displays, GPS data, serial interfaces and so on.

Before we leave data types we should remind you that you can define arrays of these data types with their size limited only by the amount of free memory.

Interrupts

Interrupts are another powerful feature of MMBasic. An interrupt is when MMBasic suspends the running of the main program to execute a subroutine when some signal is received.

Electrical characteristics

Power supply

Voltage range	2.3 to 3.6V (3.3V nominal). Absolute maximum 4.0V
Current at 48MHz	31mA typical (plus current draw from the I/O pins)
Current at 5MHz	6mA typical (plus current draw from the I/O pins)
Current in sleep	90µA to 100µA typical (plus current draw from the I/O pins)

Digital inputs

Logic low	0 to 0.65V
Logic high	2.5V to 3.3V on normal pins 2.5V to 5.5V on pins rated at 5V
Input impedance	>1MΩ. All digital inputs are Schmitt-trigger buffered
Freq response	Up to 200kHz (pulse width 20nS or more) on the counting inputs (pins 15 to 18)

Analogue inputs

Voltage range	0V to supply voltage, normally 3.3V
Accuracy	Analogue measurements are referenced to the supply voltage on pin 28 and the ground on pin 27. If the supply voltage is precisely 3.3V, the typical accuracy of readings will be ±1%.
Input impedance	>1MΩ (for accurate readings, source impedance should be <10kΩ)

Digital outputs

Current draw/sink	10mA (absolute max 15mA per pin or 200mA for whole chip)

Max open-collector voltage is 5.5V

PWM output

Frequency range	20Hz to 500kHz
Duty cycle	0-100%, 0.1% resolution below 25kHz

Communications speeds

Console serial	Default 38400 baud (range is 100 bps to 230400 bps at 40MHz)
COM1 serial	Default 9600 baud (range is 10 bps to 230400 bps at 40MHz)
COM2 serial	Default 9600 baud (range is 10 bps to 19200bps at 40MHz)
SPI	10Hz to 10MHz (at 40MHz), limited to 25% of clock speed
I²C	10kHz to 400kHz
1-Wire	Fixed at 15kHz

Timing accuracy

All timing functions (the timer, tick interrupts, PWM frequency, baud rate) are dependent on the internal fast RC oscillator, which has a specified tolerance of ±0.9%, but typically is within ±0.1% at 24°C.

Flash endurance

Over 20,000 erase/write cycles – every program save incurs one erase/write cycle. In a normal program development it is highly unlikely that more than a few hundred program saves would be required.

This signal can be a change of state on an I/O pin (for example a button press), it can be when data has been received on a communications port (serial or I^2C), or a keypress on the console, reception of a signal from an infrared remote control, and so on.

When you use interrupts you can write your main program to just take care of the main job, which might be something like monitoring a collection of sensors and generating the appropriate control signals. While the main program is doing that job, intermittent signals such as key presses and timing events can be handled in interrupt subroutines without disturbing the main program.

Embedded features

The Micromite is primarily intended as an embedded controller and therefore has a number of features to support this. These will be explained in more detail in a later article, but the following provides a short summary.

The Micromite can be configured to automatically start running its program on power up, so it will act as a dedicated 'intelligent' chip. The processor speed can be dynamically changed to provide speed when it is needed and conserve power when it is not. The sleep function results in even more power saving with the chip's current draw dropping to less than 100µA.

All errors can be trapped if necessary, and the watchdog feature will automatically restart the Micromite should the program fail for some reason. To prevent anyone from interfering with the running of the program, the break feature can be disabled and a PIN number can be set to restrict access to the command prompt.

Embedded C routines

MMBasic running on the Micromite is an interpreter. This means that your program is held in its original text format and the interpreter steps through it, interpreting each instruction as it is encountered. The alternative is a compiler, as used on the Arduino and other microcontroller systems that use the C or Python language. A compiled language like these requires a desktop type computer to do the translation of the program for the microcontroller.

This two-step process (compile/transfer/run) makes for a slow development process, but the benefit is that the resulting program runs much faster than an interpreted program. An interpreter like MMBasic has a very fast development cycle because you can jump from the editor to running the program in a fraction of a second and then, if an

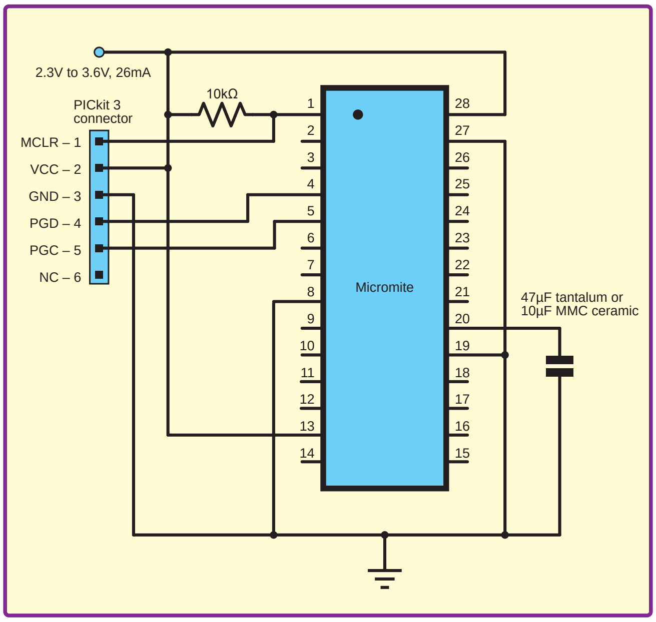


Fig.5. PICkit 3 connection to the Micromite

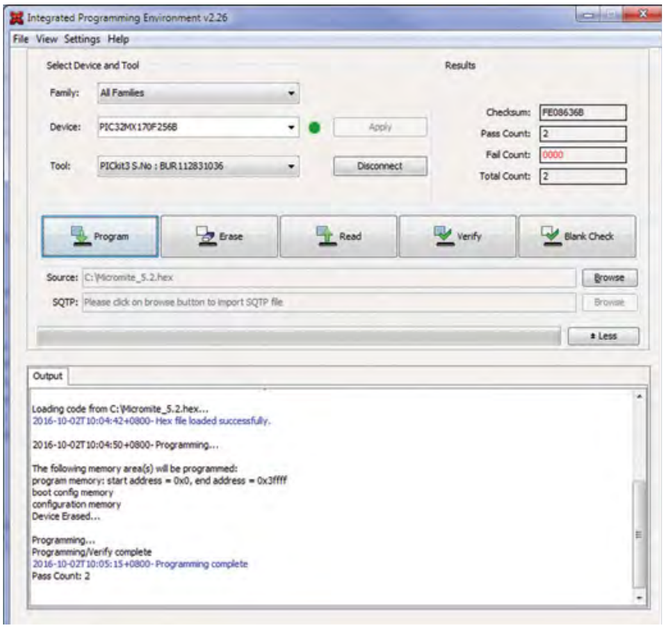


Fig.6. Using the IPE with the Micromite

Programming the chip

To program the Micromite firmware into the PIC32 chip you need a suitable programmer and arguably the best for the job is the Microchip PICkit 3. This can be purchased from Microchip and clones are available on eBay for as little as £10. We have tried a few of these clones and they worked just as well as the real thing, so the choice is yours.

To program the chip, you need to supply 3.3V power and connect the 47µF capacitor to pin 20 on the 28-pin chip or pin 7 on the 44-pin chip. In this tutorial we are going to concentrate on the 28-pin chip.

To drive the PICkit 3 you should load MPLAB IPE (Integrated Programming Environment) onto your desktop computer running Windows, Mac OS or Linux. This software is available from Microchip and is part of their MPLAB IDE programming environment. When you install the software you are given the option to load just the IPE component, you should select this as the full installation consumes a lot of disk space, which is not needed when you just want to program a chip.

To get started you must connect the PICkit 3 as shown in Fig.5. Then run the IPE software, which will display the screen shown in Fig.6. From then on the operation is reasonably intuitive: select the chip then select the programmer (PICkit 3). Next, click on the browse button to load the Micromite firmware. The firmware can be downloaded from the *EPE* website or from the author (**http://geoffg.net/micromite.html**). You need a file with the name **Micromite_x.x.hex** where **x.x** represents the current version number. The **.hex** suffix means that the data is in hexadecimal format, ready for the programmer.

The final step is to click on the Program button in the IPE window. IPE will first erase the chip, then program the hex data into the chip, followed by a verify stage, which reads back the programmed chip and compares it to the original hex data. This operation is fairly fool proof, so if IPE reports that the chip was successfully programmed you can be sure that it is OK.

However, that may not happen. A typical error message is 'Target Vdd not detected' which means that the programmer could not detect 3.3V on the Vdd pin (ie, the chip is not powered). Another error is 'Cannot read device ID'. The programmer could tell that you had connected to something (because Vdd was present) but it could not communicate with the chip. This usually means that something was interfering with the MCLR, PGD and/or PGC lines (ie, they were not connected or other components were loading down the signals).

Finally, assuming the chip was programmed correctly, you can disconnect the PICkit 3 and cycle the power. This will set the chip running the Micromite firmware. The next step is to connect a terminal emulator to the console, as described in the main text.

Table 1. Microcontrollers suitable for use as a Micromite

Version	Dimensions (mm)
PIC32MX170F256B-50I/SP	28-pin DIL package. Guaranteed to run at 48MHz
PIC32MX170F256B-50I/SO	28-pin SOIC package. Guaranteed to run at 48MHz
PIC32MX170F256D-50I/PT	44-pin surface-mount package. Guaranteed to run at 48MHz
PIC32MX170F256B-I/SP	28-pin DIL package. Guaranteed to run at 40MHz
PIC32MX170F256B-I/SO	28-pin SOIC package. Guaranteed to run at 40MHz
PIC32MX170F256DI/PT	44-pin surface-mount package. Guaranteed to run at 40MHz

Note: from testing, the chips rated at 40MHz also ran at 48MHz (at room temperatures), so they are a viable choice if you cannot find the higher speed versions.

error is discovered, quickly jump back into the editor.

With MMBasic running on the Micromite you can have the best of both worlds – an interpreter for fast and easy program development and embedded C functions for speed. The embedded C routines require a larger computer (Windows, Mac or Linux) to compile the routines and the resulting code is embedded in your BASIC program. MMBasic will extract this embedded code and add it to MMBasic so that it will act the same as a built-in command.

If you are fluent in the C programming language you can write your own embedded C routines. There is also a selection of embedded C routines included with the MMBasic firmware distribution, which includes drivers for alternative LCD display panels, additional communications ports (serial, I^{2}C and SPI), sorting routines and more.

Getting started

The Micromite firmware can be programmed into a range of chips as listed in Table 1. These cover a variety of package sizes and two speeds (40MHz or 50MHz). The Micromite will start up at 40MHz, so the firmware will run on any chip, but within your program you can step its speed up to 48MHz to take advantage of the faster chip speed available if you are using a 50MHz chip.

You can program the firmware into the chip yourself – see side box *Programming the chip* for details. You can also buy a pre-programmed chip and this will be much easier if you are just starting out with the Micromite and would like to avoid the added complication that programming the chip would entail. See the *Micromite sources* box for a list of where to obtain pre-programmed chips.

With a pre-programmed chip you can just plug it into a breadboard and start experimenting. However, note that the firmware is often updated with new features and bug fixes, so a programmer will be necessary if you want to take advantage of future updates.

Where is the development board?

Readers familiar with microcontroller evaluation products might ask, 'where is the printed circuit board with a display, I/O connectors, etc?'.

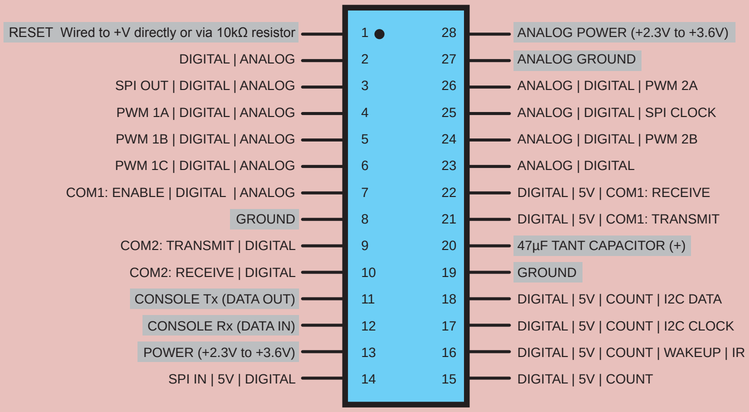
The answer is to not think of the Micromite as a complex system. It is a single-chip microcontroller, which you build into a circuit and program in place. If you want to experiment with the 28-pin chip you can plug it into a solderless breadboard, as illustrated in Fig.4.

The 44-pin version of the Micromite is a surface-mount chip and to make it easier for readers to use this you can purchase the 44-pin Micromite module from UK supplier **http://micromite.org**. This is shown in Fig.1 and Fig.2, and includes the Micromite chip and a USB-to-serial converter for the console. It is designed to plug into a solderless breadboard for testing so it can be used in a similar manner as the 28-pin version.

Using a solderless breadboard is invaluable when experimenting with the Micromite, but once you have the hang of how the chip works you would normally design a circuit around it and then continue to develop your program while it is in the circuit. This 'in-circuit development' is very productive because it allows you to develop and test small parts of the program as you go.

For example, if your project was a home brew controller you could develop and

28-pin Micromite connections



The above diagram shows the possible functions of each I/O pin on the Micromite. Note that the physical pins on the chip and the pin numbers used in MMBasic are the same. This means that nine pins are not available in MMBasic because they are dedicated to functions such as power and ground. These pins are shaded in grey in the diagram.

The notation is as follows (the mnemonic in brackets is the mode used in the SETPIN command):

ANALOG	These pins can be used to measure voltage (AIN).
DIGITAL	Can be used for digital I/O including digital input (DIN) and digital output (DOUT)
COUNT	Can measure frequency (FIN), period (PIN) or counting (CIN)
5V	These pins can be connected to 5V circuits. All other I/O pins are strictly 3.3V max
COM xxx	These are used for serial communications (see Appendix A)
I2C xxx	These are used for I^{2}C communications (see Appendix B)
SPI xxx	If SPI is enabled these pins are for SPI I/O (see Appendix D)
PWM xxx	PWM or SERVO output (see the PWM and SERVO commands)
IR	Can be used to receive signals from an infrared remote control (see the IR command)
WAKEUP	Can wake the CPU from sleep (see the CPU SLEEP command)

Pins 27 and 28 are the ground and power for analogue measurements. Normally, they are connected to the general ground and power (pins 8 and 13) but if you require noise-free and accurate analogue readings you should make sure that the power on pin 28 is regulated to 3.3V and well filtered. Also, your analogue inputs should be referenced to pin 27 (the analogue ground).

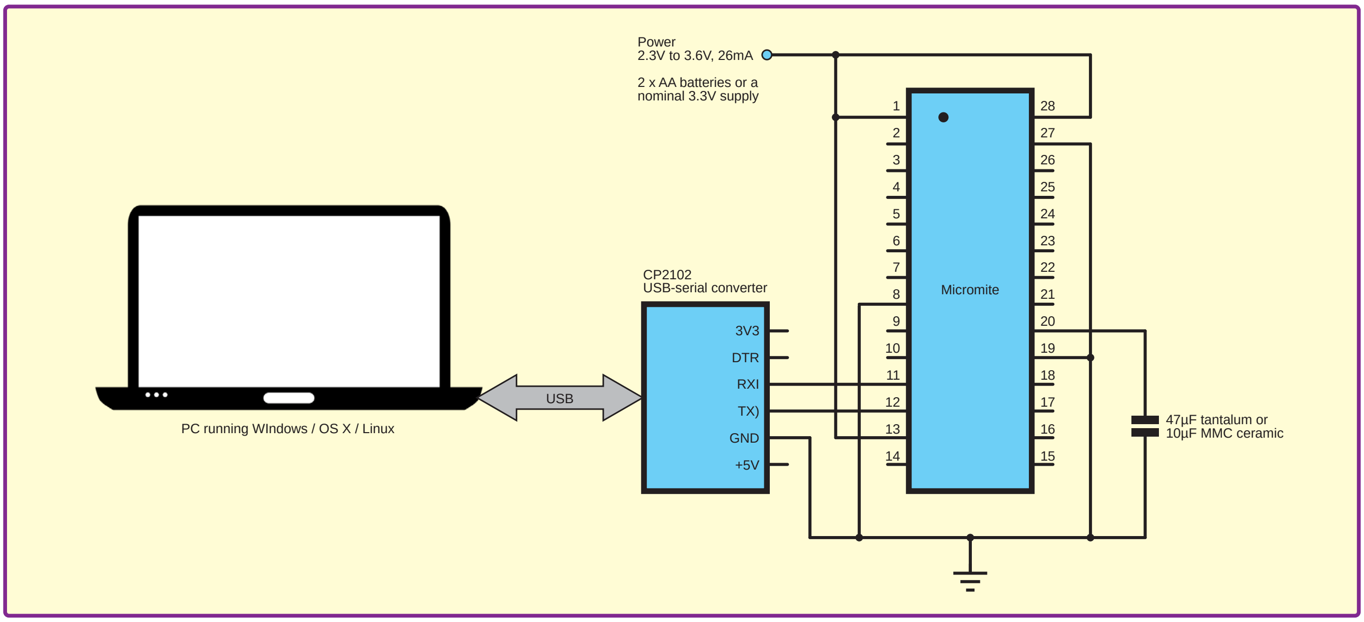


Fig.5. Using a CP2102 to enable console connection between the Micromite and a PC

test the temperature sensor first, then the power control and so on. The final program would just string these modules together.

Console connection

With the chip programmed, the next step is to connect a terminal emulator to the console. The console is a serial interface over which you can issue commands to configure the chip and edit/run programs. MMBasic also uses the console to display error messages.

A serial interface consists of two signals. One, often referred to as Tx (for transmit) sends a coded signal to the other device, and the second (called Rx) receives a signal. The data is sent with start and stop bits and uses ASCII coding for each character sent or received. The speed of transmission is referred to as 'baud rate', which is another way of saying bits per second. The Micromite starts up with its console serial port set to a baud rate of 38400.

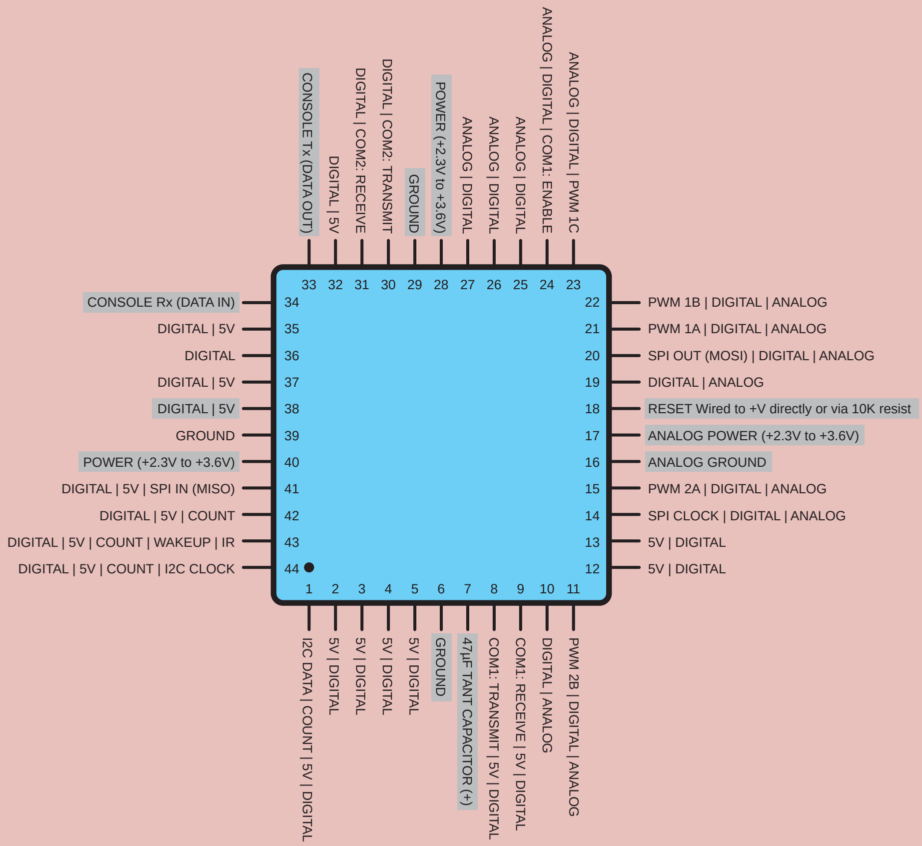
The signal level is TTL, which means that the signal swings between 0V and 3.3V. There are other signalling methods, notably RS232, which swings the voltage ±12 volts. The Micromite can accommodate RS232 too, but to get started you must ensure that your signalling levels are TTL.

The best method of accessing the serial console is to use a USB-to-serial converter, which will plug into a USB port on your desktop computer and at the other end connect to the Micromite's serial console. To your computer it will look like a serial port (via USB), while the connection to the Micromite Plus is a standard serial interface with TTL signals levels.

We recommend converters based on the CP2102 chip and they can be found cheaply on eBay (search for 'CP2102'). Fig.7 shows how such a converter can be connected to the 28-pin Micromite and a 44-pin Micromite module.

When the converter is plugged into your computer, and the correct driver is installed, it will appear as a serial port (ie, COM29 in Windows). You then

44-pin Micromite connections



The above diagram shows the possible functions of each I/O pin on the 44-pin Micromite. Note that the physical pins on the chip and the pin numbers used in MMBasic are the same. This means that 11 pins are not available in MMBasic (these pins are shaded in grey).

The notation is the same as described for the 28-pin version. Pins 16 and 17 are the ground and power for analogue measurements. Normally they are connected to the general ground and power (pins 29 and 28) but if you require noise-free and accurate analogue readings you should make sure that the power on pin 17 is regulated to 3.3V and well filtered. Also, your analogue inputs should be referenced to pin 16 (the analogue ground).

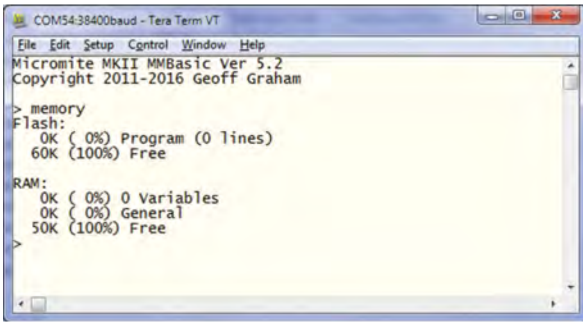


Fig.8. Micromite emulator command prompt

need to start a terminal emulator on your computer. For Windows we recommend Tera Term version 4.88, which can be downloaded for free from **http://tera-term.en.lo4d.com**. Set the interface speed to 38400 baud and connect to the serial port created by the USB-to-serial converter.

Macintosh and Linux computers have similar features and terminal emulators; however, the procedure for setting these up will vary.

After the console has been connected to a terminal emulator, apply power to the Micromite and you should see the Micromite's prompt (>), as shown in Fig.8. At this point, you can enter, edit and run programs using nothing more than the terminal emulator and a USB cable.

When your program has been tested and is running on the Micromite you do not necessarily need the console, so you could set the Micromite to automatically run its program on startup (OPTION AUTORUN). However, unless you got the programming perfectly correct the first time you will find yourself repeatedly reconnecting to make one tweak or another, so many people leave the USB to serial converter permanently connected (they do not cost much).

Trouble shooting

What if it does not work the first time? The first step is to check your power supply. Is it 3.3V and is it stable and free from electrical noise? If you have some doubts, you can use two fresh AA batteries in series as a power source for testing. Then check that 3.3V is on each pin, as specified in Fig.7 and that each ground pin is correctly connected to ground.

The next check is the 47µF capacitor connected to pin 20 on the 28-pin chip or pin 7 on the 44-pin chip. This capacitor is used to stabilise the internal 1.8V regulator within the PIC32 chip and without it you will not be able to program or use the chip. This capacitor must be a tantalum or a ceramic type – an electrolytic capacitor will not work.

Has the chip been properly programmed? If you programmed it yourself you should check that the programmer did report that the programming operation was successful. Check the current drawn by the chip – a draw of about 26mA means that the chip is working correctly and running the BASIC interpreter. A current of less than 10mA indicates that:

- Power or ground connection is faulty
- 47µF tantalum capacitor is faulty or not connected
- Chip not programmed correctly.

If you have a current draw of about 26mA the fault is most likely with the USB-to-serial converter or your terminal emulator. To check these two elements you can disconnect the serial connections from the Micromite and short the Tx and Rx pins of the converter together.

When you type something on the keyboard into the terminal emulator you should see the characters echoed on the screen. If not, you should diagnose and correct the error in your USB-to-serial converter and terminal emulator before proceeding.

If the above test is OK (ie, keystrokes echo on the screen) the only possible remaining fault is in your connection of the USB-to-serial converter to the Micromite. Check that the Tx pin on the converter goes to the Micromite's Rx pin and that Rx on the converter goes to the Micromite's Tx pin, as illustrated in Fig.7.

User manuals

The Micromite is quite a sophisticated device. After all, it is a full computer with a multitude of facilities. As a result, the *Micromite User Manual*, which describes it adds up to almost 100 pages.

This manual is the ultimate reference for the Micromite and covers everything from the I/O pins through to sophisticated functions that you might only need in specialised circumstances. It is in PDF format and available for free download from the *EPE* website and the authors website: **http://geoffg.net/micromite.html**

This series of articles will go through many aspects of the BASIC language but they will not cover everything. Many commands have additional features, so it would be worthwhile downloading the manual and having it handy as you read through this and following articles. That way, you can explore the full detail of a command that might interest you.

Short tutorial

Assuming that you have correctly connected a terminal emulator to the Micromite and have the command prompt (the 'greater than' symbol: >) you can enter a command followed by the enter key and it will be immediately run. For example, if you enter the command `PRINT 1/7` you should see this:

```
> PRINT 1/7
0.142857
>
```

This is called immediate mode and is useful for testing commands and their effects.

To enter a program you can use the `EDIT` command, which will be described later in this series. However, to get a quick feel for how it works, try this sequence (your terminal emulator must be VT100 compatible):

At the command prompt type `EDIT`, followed by the ENTER key. The editor should start up and you can enter this line:

```
PRINT "Hello World"
```

Press the F1 key in your terminal emulator (or `CTRL-Q`, which will do the same thing). This tells the editor to save your program and exit to the command prompt.

At the command prompt type `RUN`, followed by the ENTER key. You should see the message:

```
Hello World
```

Congratulations! You have just written and run your first program on the Micromite. If you type `EDIT` again you will be back in the editor, where you could change or add to your program.

Flashing an LED

Connect an LED with a suitable current-limiting resistor (say 470Ω) to pin 15 of

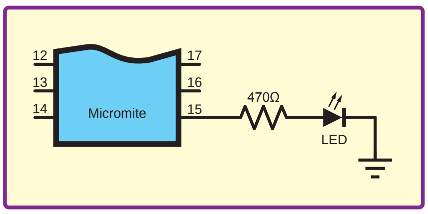


Fig.9. Schematic for a Micromite LED flasher circuit

Micromite sources

Programmed ICs, modules and kits

EPE online store
??? – tbd – ???

Micromite.org
http://micromite.org

Graeme Rixon (Rictech)
www.rictech.nz/pages/5/Products

CircuitGizmos
http://circuitgizmos.com

Mick Gulovsen
www.shop-dontronics.com/Micks-Mites

Unprogrammed (blank) chips

Microchip
www.microchipdirect.com

Element14
http://uk.farnell.com

RS Components
http://uk.rs-online.com/web

All suppliers will ship internationally the 28-pin Micromite, as shown in Fig.9. Then use the EDIT command to enter the following program:

```
SETPIN 15, DOUT
DO
  PIN(15) = 1
  PAUSE 300
  PIN(15) = 0
  PAUSE 300
LOOP
```

When you have saved and run this program you should be greeted by the LED flashing on and off. It is not a sophisticated program, but it does illustrate how your Micromite can interface to the physical world via your programming.

The chapter 'Using the I/O pins' later in the manual provides a full description of the I/O pins and how to control them.

Setting the AUTORUN option

You now have the Micromite doing something useful (if you can call flashing an LED useful). Assuming that this is all that you want the Micromite to do you can then instruct it to always run this program whenever power is applied.

To do this, you first need to regain the command prompt and you can do this by entering CTRL-C at the console. This will interrupt the running program and return you to the command prompt. Then enter the command:

```
OPTION AUTORUN ON
```

This will instruct MMBasic to automatically run your program whenever power is applied. To test this, you can remove the power and then reapply it. The Micromite should start up flashing the LED.

If this is all that you want to do you can disconnect the serial console and it will sit there flashing the LED on and off forever. If ever you wanted to change something (for example, the pause between on and off) you could reattach your terminal emulator to the console, interrupt the program with a CTRL-C and edit it as needed. This is the great benefit of the Micromite, it is very easy to write and change a program.

Next month

In Part 2 we will describe the editor, special device control and interfacing to touch sensitive LCD panels.

Keep up to date!

For updates to the Micromite firmware you can visit the author's website at: **http://geoffg.net/micromite.html**.

Another resource is The Back Shed forum where there are many Micromite users who are happy to help newcomers, see: **www.thebackshed.com/forum/Microcontrollers**

NET WORK

by Alan Winstanley

A Slice of Alexa Pi

IN RECENT editions of *Net Work*, I outlined Amazon UK's Echo, an anglicised version of their network-aware smart speaker that has stolen the lead over Google's Home smart device. In November, Amazon decided to celebrate 'Black Friday', America's latest export to Britain, by lopping 20% off the price and Echo is starting to appear in major British retail stores as well. Rather perversely, many bricks-and-mortar retail stores claimed they were nearly empty on Black Friday, because shoppers had gone online hunting for bargains instead. Even a DIY store checkout assistant whispered to me how she hates shopping in stores and much prefers using eBay and Amazon!

One motive behind Amazon's Echo is to make online shopping as painless and seamless as possible, removing every physical obstacle between wanting to buy something and actually completing Amazon's checkout process. Amazon's Echo will manage a shopping cart for you, as well as handling an increasing number of simple everyday tasks.

Amazon's Alexa is the product of Alexa Voice Service (AVS), Amazon's cloud-based voice recognition and control technology that understands spoken commands and responds accordingly. Echo's so-called 'skills' are app-like features designed for a particular task. Alexa's skillset is not confined to the smart Echo cylinders that are starting to populate our homes though: AVS offers developers of connected products the possibility of integrating Alexa into their devices, along with third-party skills using the Alexa Skills Kit (ASK). Interestingly, Amazon provides examples based on the Raspberry Pi, which gives rise to the prospect of a Pi responding Alexa-style to spoken queries. More details of AVS are at: **https://developer.amazon.com/alexa-voice-service/what-is-avs**. A sample Java app for Pi is offered on GitHub at: **https://github.com/alexa/alexa-avs-sample-app/wiki/Raspberry-Pi**, along with hardware requirements and an installer – ensuring a hassle-free Alexa setup within an hour... in theory.

It is still early days for Google Home, but already they are starting to leak out onto eBay (with US mains adaptor) for £125-£240 ($150-$300). In due course, it will be possible to customise your Google Home with a choice of fabric and metallic bases, but these are buried deep within the Google Play Store and are not yet available. Developments and refinements are a work in progress, so it's probably better to think of all these devices as 'a good start', with the best still to come.

Amazon's Alexa Voice Service (AVS) offers the prospect of adding Alexa's voice control to a Raspberry Pi for example

Content is king

Twenty years ago, when the web was first taking shape, a certain Bill Gates of Microsoft exclaimed that 'Content is king' and never has that been more true than today. With broadband services becoming ever more generic and indistinguishable, ISPs have fallen over themselves to add more value (make more profit) and lock customers into deals by bundling more services (mobile phones, data plans, VoIP) but the one thing major providers, portals, blogs and websites are desperate to supply is unique *content*. Satellite broadcaster Sky and British Telecom stumped up some £5 billion ($6.1 billion) on Premier League soccer rights between them, with BT Sport offering soccer, Australian cricket and tennis to its own subscribers.

Meanwhile, Amazon is pressing on with its Prime service, which offers free next-day delivery on many lines and is showing *The Grand Tour*, the re-incarnation of BBC TV's *Top Gear* motoring program, streamed in 4K HDR. Amazon claims the first programme in the series, streamed on 18 November, enjoyed the biggest ever premiere viewing figures on Prime, and the programme was widely acclaimed. *The Grand Tour* will be released to some 200 countries in December 2016, no doubt giving some viewers the excuse they crave to upgrade to the biggest and best 4K TV!

In order to convert an ordinary TV into a 'smart' one capable of receiving services such as catch-up TV, Netflix or Amazon Prime, Amazon's Fire Stick HDMI streaming media player also received the 'Black Friday' discount treatment, dropping to just £25, and I admit to finally succumbing to the appeal of the Fire Stick just before Christmas. Other streaming devices such as NowTV, Roku and Google's very versatile Chromecast dongle may also fit the bill. There has never been a more comprehensive but confusing choice for HDMI streaming media devices for your TV, and we can expect the major brands to continue to slug it out in the quest to conquer your home – offering more content than you can ever consume, of course.

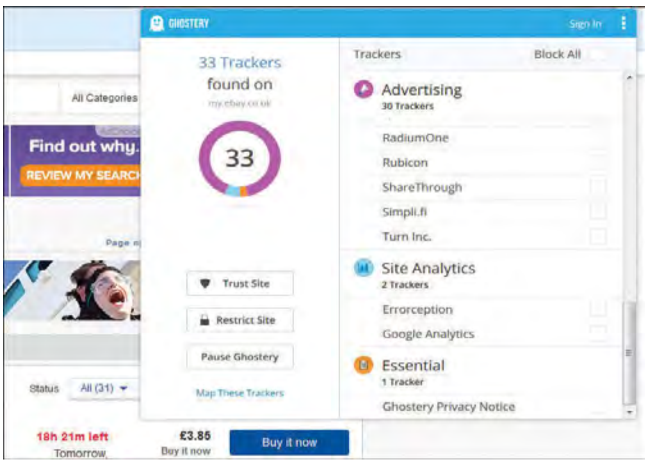
Up close and personal

Isn't it strange how many people have uneasy or irrational views when it comes to their privacy and anonymity? If a local town council was to rummage through everyone's wheelie bins one dark night when trying to 'profile' the residents, even if the bins were anonymised and contained no personally identifiable materials, people would still complain about being 'snooped on'. Paradoxically, the same citizens probably won't complain about surveillance cameras following them everywhere in a shopping mall, claiming that as they have nothing to hide they have nothing to fear. They would never, however, accept CCTV watching them at home in the lounge or anywhere else. So privacy *does* matter then, it's just that most people don't think about it objectively or rationally. This very human phenomenon was the subject of a thought-provoking TED Conference talk by Glenn Greenwald, entitled: *Why Privacy Matters*, viewable at: **www.ted.com/talks/glenn_greenwald_why_privacy_matters**

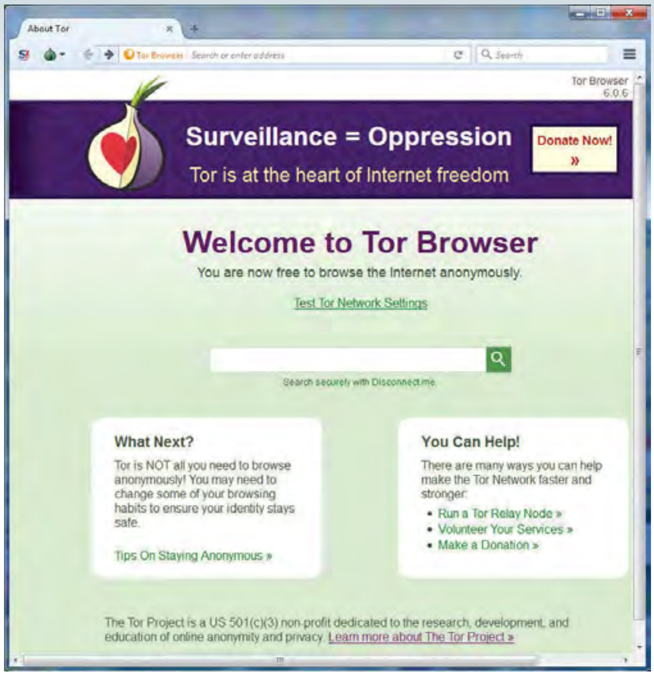
A user's online experience embraces some of the same confused rationale. I have written in the past about how some online operators seem to know almost everything about you except your name, and this intrusion starts with your IP address. The use of cookies, so-called 'trackers' and geo-location services all help the web industry to gather statistics and determine what websites your browser recently visited, what products you looked at recently, roughly where you are located and what your personal tastes and interests are likely to be. Marketers could even use so-called 'beacons' to track your progress walking up and down the shopping mall or around a store and target suitable adverts directly to your smartphone, which will become commonplace in the future.

To see the scale of this online snooping, try installing the Ghostery Extension for your web browser, downloadable from **www.ghostery.com**. A quick trip to the mobile site of eBay UK, for example, showed no less than 33 trackers, all keeping an eye on you. A *Daily Express* web page contained nearly 50 of them.

There is probably nothing in the world that technology companies like Google, Amazon, Facebook and eBay want more than to hone an artificial intelligence that gets inside users' minds, second-guessing what they want and what they might like to buy. Advertising opportunities abound and the name of the Internet game is 'monetisation', as industries scramble to profile you and grab a share of your disposable pounds, dollars and euros. If anyone is worried by how the Internet industry spies on web surfers then one solution is to use the Tor ('The Onion Router') web browser, which disguises your IP address and is downloadable



Ghostery is a browser plug-in that highlights the 'trackers' that are monitoring your surfing activities



Tor is a web browser designed from the ground up to protect your privacy

from **www.torproject.org**. Windows, Mac, Linux and Android versions are provided. After opening the Tor browser, you have to connect to the Tor network, which might take a minute or two. Using Tor to check our own *EPE* website hosted right here in Britain, the Tor 'circuit' (like Traceroute), displayed via the onion button, showed anonymous detours via several European countries.

That's all for this month's *Net Work*. You can contact the author at **alan@epemag.net** or send comments for possible inclusion in *Readout* to **editorial@wimborne.co.uk**

Darlington relay switch

NEW *EPE Chat Zone* user ***wolfie*** posted some questions about a circuit (see Fig.1) which uses a relay to switch a load depending on the light level sensed by a light-dependent resistor (LDR). He writes: 'Hi all. I am a newbie when it comes to electronics and I'm trying to teach myself from some books I have. The trouble with books is if you don't understand summat you can't ask it! In one of my books there's a little project at the end of each chapter. However, it doesn't have much explanation as to how it works. I don't need to actually build the project, but I want to understand what each part of it does. The first one looks very simple, but it leaves me with a number of questions. I understand that the LDR and the VR create a voltage divider that at some point turns the transistor on, which allows current to run through the relay and turn on whatever you want turning on. So, here's my questions:

1. What's the resistor doing, the 2.2kΩ one? What's its purpose?
2. Why two transistors, if they act as switches why do we need two switches?
3. What's that diode doing?

Thanks in advance.'

Wolfie's post was titled 'First silly questions', but the questions are far from silly, and as is often the case, produced helpful responses from other *Chat Zone* users. The basic answers are:

1) The 2.2kΩ resistor limits the base current into Q1 to a safe level.
2) A single transistor is unlikely to have sufficient current gain to switch the load from the current available for the LDR potential divider.
3) To prevent inductive kickback from damaging the transistor.

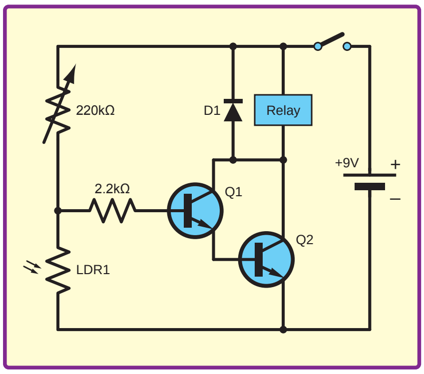


Fig.1. Chat Zone user wolfie's schematic

In this article we will look at the circuit in more detail and examine the issues raised by the questions, with particular focus on transistor switching operation.

In the *Chat Zone* thread, fellow *EPE* author Alan Winstanley pointed out the battery symbol is not correct – the symbol used represents a single cell (typically 1.2V to 1.5V, but it depends on the battery technology). A 9V battery contains multiple cells. A correct symbol is shown in Fig.2.

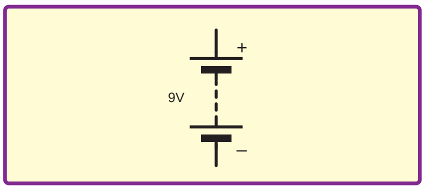


Fig.2. Correct 9V battery symbol

Circuit operation

The circuit operates as follows. First, as noted by ***wolfie***, the LDR and variable resistor form a potential divider connected across the supply. Consider the LDR and variable resistor on their own, initially. The voltage at the junction between them will depend on the relative resistance of the two devices, which in turn depends on the light level and the variable resistance setting. With the LDR in darkness, its resistance will be very high (typically several million ohms), probably at least ten times larger than the variable resistor value. Thus, the voltage at the junction will be close to the supply voltage. When the LDR is exposed to bright light its resistance will drop significantly (to typically several thousand ohms), probably at least ten times smaller than the variable resistor value. Now, the voltage at the junction will be close to zero.

If the light level changes from dark to light then the voltage will switch between something close to 9V to something close to 0V. For the transistors to conduct (and turn on the relay) their base-emitter voltages (V_{BE}) must both be greater than about 0.65V, so the voltage at the base of Q1 in the circuit in Fig.1 needs to be above about 1.3V. With the typical LDR dark and light values just discussed, the corresponding voltages will indeed be above and below 1.3V respectively. The variable resistor can be adjusted to set the exact light level at which the circuit switches.

In idealised circumstances these dark/light conditions provide a clear signal to switch the transistors (and hence the relay) on and off. That is, if transistors were perfect voltage controlled switches, which did not require any input current then the situation would be straightforward. However, transistors require an input (base) current when conducting, so we have to work out if enough current will be available from the potential divider.

Rough calculations

It is often worth performing approximate calculations to get a feel for the situation in a circuit. Here we need some idea of the ratio of current into Q1's base (the switch control input) to Q2's collector current (the current through the load). In addition to the original circuit in Fig.1, for comparison purposes, we will also consider a single transistor, as shown in Fig.3. This is simplified to show just a transistor and load; plus, the various currents and voltages have been labelled. For the circuit in Fig.3, current ratio relates to the base and collector currents of the single transistor Q1. The ratio of collector current to base current is called the 'current gain' of the transistor (symbol β) – we can apply this idea to the Q1/Q2 transistor pair as well as the single transistor.

The worst case for supplying current to the transistor(s) when the LDR is dark (transistor(s) on) is when the variable resistance is set to its maximum value of 220kΩ. With a supply of 9V, Ohm's law shows

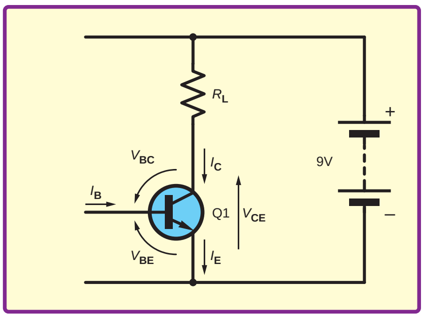


Fig.3. Single-transistor switch

that maximum current through a 220kΩ resistor is 9V/220k = 41μA. The actual voltage across it will be a little lower, but this will do for a rough idea. A typical 9V relay might have a coil resistance of 115Ω; so with 9V across it the current is 78mA. (This is a guess of course, as ***wolfie*** does not state what relay is used, but it is sufficient for illustrative purposes).

The ratio of controlled current to controlling current is 78mA/41μA, which is about 2000. Thus, a transistor switch needs a current gain of about 2000 in this situation. Single transistors typically have βs in the low hundreds, but the effective β is often much lower in switching applications (more on this later). This rough calculation indicates that a single transistor (as in Fig.3) would not have sufficient current gain – hence the use of two transistors in ***wolfie's*** circuit and the answer to the second question.

Darlington pair

The two transistors in Fig.1 are connected in what is known as a Darlington pair configuration. One transistor is used to directly drive another, resulting in a sort of 'super transistor' with a very high current gain. The Darlington configuration can be made from either two NPN transistors (as used in the circuit in Fig.1, also see Fig.4) or two PNP transistors (see Fig.4). Darlington configurations are use in power-switching applications (as in Fig.1), power amplifier output stages, voltage regulators and some types of sensing applications – particularly in optocouplers, where the Darlington arrangement can be used to increase the gain of a phototransistor. They can also be used in the input and gain stages of amplifiers.

The Darlington pair behaves like a single transistor which requires twice the value of base-emitter voltage (V_{BE}) of a single transistor to switch it on, and which has a current gain approximately equal to the product of the gains of the two individual transistors (so potentially up to tens or even hundreds of thousands). This indicates that a Darlington pair should be able to achieve the gain of around 2000 that we calculated above. Before looking at use of the Darlington pair in switching applications in more detail, it is worth looking at the characteristics of a single transistor

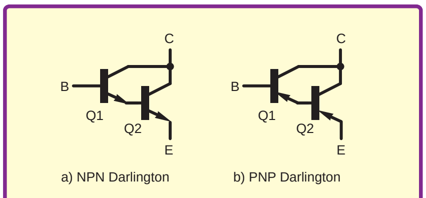


Fig.4. The Darlington Configuration

Table 1: Bipolar transistor regions of operation

Base-emitter junction bias	Base-collector junction bias	Region of operation	Comment
Forward	Forward	Saturation	Switch ON
Forward	Reverse	Reverse Active	Poor amplifier, specialist uses
Reverse	Forward	Forward Active	Good amplifier
Reverse	Reverse	Cut-off	Switch OFF

switch. We can also address the first question in this context.

Regions of operation

A bipolar junction transistor contains two diode (PN) junctions, this is true of both NPN and PNP transistors; the junctions are simply the opposite way round in the two types, requiring opposite voltages for the same operation. The two junctions can be either forward biased (on) or reverse biased (off) so there are actually four different regions of operation for the transistor. These are shown in table 1. When using transistors in circuits it is important to make sure they are in the appropriate region of operation. When a single transistor is used as a switch it is usually switched between the saturation and cut-off regions.

In the cut-off region both junctions in the transistor are reverse biased and no current flows through the transistor (except some leakage current). Thus, a transistor-based switch will be off. The very low current flow through the cut-off transistor ensures that very little power is dissipated in the transistor when the switch is off; however, care must be taken to ensure that the maximum collector-to-emitter voltage (V_{CEmax}) is not exceeded. In the case of circuits in Fig.1 and Fig.3, the maximum collector to emitter voltage is about 9V, which is not a demanding specification for a discrete switching transistor.

The saturation region is characterised by a small voltage drop between the collector and emitter (called V_{CEsat}), which is typically around 0.1 to 0.3V. In the saturation region both junctions are forward biased, so each junction will have about 0.6V across it. For example, we might see V_{BE} = 0.7V and V_{BC} = 0.50. The collector to emitter saturation voltage (V_{CEs}) is equal to the difference between V_{BE} and V_{BC} in saturation, in this case 0.2V.

High current

A single transistor-based switch is usually configured so that the transistor is saturated when the switch is on. The resulting low voltage drop from collector to emitter means that the power dissipation is not excessive, even for relatively high load currents. However, care must be taken to ensure that the maximum collector current (I_{Cmax}) is not exceeded. Again, the current of 78mA discussed above would not be a demanding specification for a discrete switching transistor. With a voltage drop of 0.2V the dissipation in the transistor due to the load current would only be about 16mW. In more demanding switching applications the current, voltage drop and power dissipation need careful consideration.

From Fig.1 and Fig.3 it is clear that most of the supply voltage will appear across the load if the transistor is saturated. In saturation, the collector-to-emitter voltage across a bipolar transistor does not vary much with varying collector current, so we apply a more or less constant voltage to the load, which is usually what we want.

The forward active region is used for amplifiers; where normally we would want to avoid saturation as it would probably imply clipping of the signal. The base-emitter junction will be forward biased with typically around 0.6 to 0.7V across it (V_{BE}); but slightly lower than in saturation case. The reverse active region is not commonly used, but does have some applications.

Junction characteristics

Fig.5 shows typical current-against-voltage characteristics for the base-emitter and collector-emitter junctions of a general-purpose switching transistor. The I_{BE} curve (red) is the base-emitter current and the I_{BC} (blue) is the base-collector current. Both curves show the standard diode 'switch on' characterises, where the current starts to increase very significantly when the applied voltage is increased about 0.6V to 0.7V.

The curves in Fig.5 are exponential, so the rate of increase rises as the applied voltage increases. Thus, small increases in applied voltage can result in very large current increase. These curves are the input currents, so the collector current will be larger still in most cases. The total current in the transistor is the sum of these junction currents plus the collector current.

The curves in Fig.5 indicate why the 2.2kΩ resistor is needed in the circuit in Fig.1 (and would be in the circuit in Fig.3 too). If the 2.2kΩ resistor was not present and the variable resistor was adjusted to its minimum value (effectively zero resistances) the 9V supply would be connected directly across the transistors' inputs. Ignoring the details of the Darlington pair for the moment, and just considering doing this with a single transistor (Fig.3) we see that the graph in Fig.5

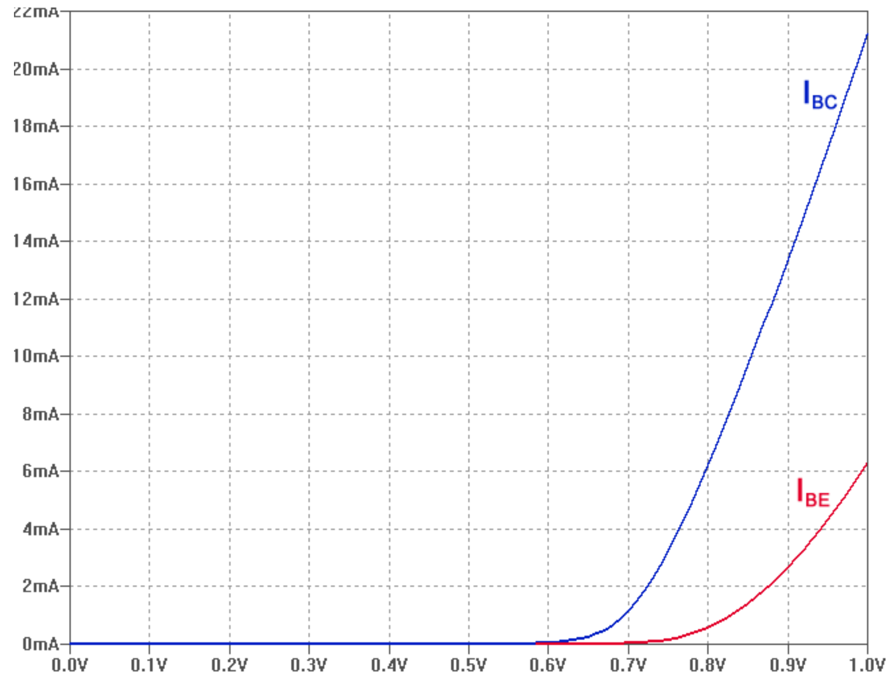


Fig.5. Plot of base-emitter (I_{BE}, red trace) and base-collector (I_{BC}, blue trace) junction characteristics (applied voltage vs. current). The base-collector junction conducts at a lower voltage than the base-emitter junction.

only covers voltages up to 1V. The steep increase even at 1V indicates that by V_{BE} = 9V the transistor's input current would be extremely large. In fact it would be so large that it would destroy the transistor due to excessive power dissipation. Note that this potential destruction is due to power dissipation from input current and voltage, not necessarily due to the load current, although that could play its part in the destructive scenario.

This situation does not change significantly for the Darlington pair. Although the individual junction voltages would be smaller, with a 9V input, with no base resistor the power dissipation would still be more than sufficient to destroy the transistors. The 2.2kΩ resistor limits the maximum current into the base. Again, using a rough figure, this cannot be more than 9V/2.2kΩ, about 4mA – less in practice, because the base-emitter voltage(s) mean that the full 9V would not be dropped across the resistor.

Forced beta

Going back to the single transistor scenario (Fig.3), we can use Fig.5 for reference, we see that a 4mA total input (base) current to the single transistor would imply that the transistor is saturated with almost all of the 4mA base current flowing into the base-collector junction. As far as the input is concerned, this is a safe level (the power dissipation due to the input current and voltage is not excessive). As long as the load current is low enough, the transistor will not burn out. Also, assuming the 115Ω discussed above, the ratio of collector to base current would be about 78/4, that is, approximately 20 – significantly lower than the 100 or 200 usually quoted as a typical transistor gain.

The properties of a transistor in saturation are different from those in the active region of operation and we need to be careful about making familiar assumptions about transistor operation which really relate to the forward-active operation. An important characteristic of the transistor in the forward-active region is the already mentioned current gain β, or strictly speaking the 'forward current gain' β_F. In the forward-active region the collector and base currents are related by the well know relationships:

$I_C = \beta_F I_B$ and $\quad I_B = I_C/\beta_F$

Values of β_F will be given on transistor data sheets and are typically in the range 100 to 200. However, as we have just seen, these 'standard' β values do not apply in the saturation region. For a transistor in saturation the base current is greater than I_C/β_F. In fact the base current exceeding I_C/β_F can be regarded as a condition for saturation. The value of I_C/I_B in saturation is called the 'forced beta'.

Saturated Darlington

It would be easy to assume that when a Darlington pair is used as switch that both transistors are in saturation, but the real situation is more complex. Referring to Fig.1, assuming both transistors are on, then the base-emitter voltages of both transistors will be approximately 0.65V. If we assume Q1 is in saturation with a V_{CE} of about 0.2V then the voltage at the collector of Q2 must be equal to the V_{BE} of Q2 plus the V_{CE} of Q1, so it will be about 0.85V. This implies the V_{BC} of Q2 will be about –0.2, so the base-collector junction of Q2 will be reverse biased. Thus Q2 is not in saturation.

The previous figures were very approximate, a slightly more realistic set of values is:

Q1: V_{BE} = 0.65 V, V_{CE} = 0.19 V, I_B = 33 µA, I_C = 400 µA, β = 12
Q2: V_{BE} = 0.79 V, V_{CE} = 0.84 V, I_B = 433 µA, I_C = 71 mA, β = β_F 164.

These figures correspond with the graphs in Fig.5 and the input and load currents (33µA and 71mA) are close to our earlier estimate of 41µA and 78mA. The overall current gain of the transistor pair is 12×164, about 2000, which matches the requirement discussed above.

In general, a Darlington configuration prevents the second transistor from entering saturation, which helps keep the gain of the pair relatively high, but has the disadvantage that the voltage across the output transistor is larger than it would be for a single-transistor switch. This is important in power switching applications because it means greater dissipation due to the larger voltage drop across the device when it is on. However, for the circuit discussed here, the dissipation of about 60mW in Q2 is not likely to be of serious concern.

Darlington package

The Darlington configuration can be built using two individual transistors, but Darlington pairs in a single package are also available. A typical example is given in Fig.6, which shows the equivalent circuit of the TIP120. This devices includes a protection diode and a couple of resistors. The resistors act as pull-downs to make sure the transistor is off when required – this is particularly important if the drive circuit is high impedance when it is off.

Another disadvantage of the Darlington pair is that it can be rather slow in switching – this is not likely to be an issue for the circuit in Fig.1, but may be of concern in high performance applications. The problem is due to the fact that the first transistor cannot switch the second one off quickly – it goes open, circuit leaving charge in the base of the second transistor, which takes time to shift. This problem is alleviated by connecting a

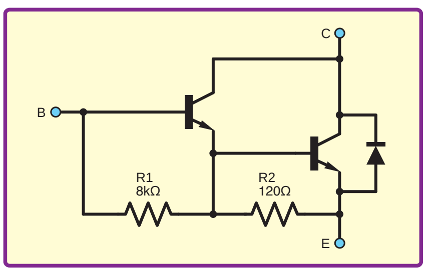


Fig.6. Example Darlington power transistor internal circuitry. This is the TIP120 from the Fairchild datasheet **(fairchildsemi.com)**

resistor from the base of the second transistor to ground (as R2 is in the circuit in Fig.6). Another issue with the Darlington pair is that any leakage current in the first transistor will be amplified by the second, meaning that total leakage effects may be quite large. Again, the R2 (Fig.6) base resistor helps – it is selected to ensure that its voltage drop when the first transistor's leakage current is flowing through it is such that the second transistor will not turn on.

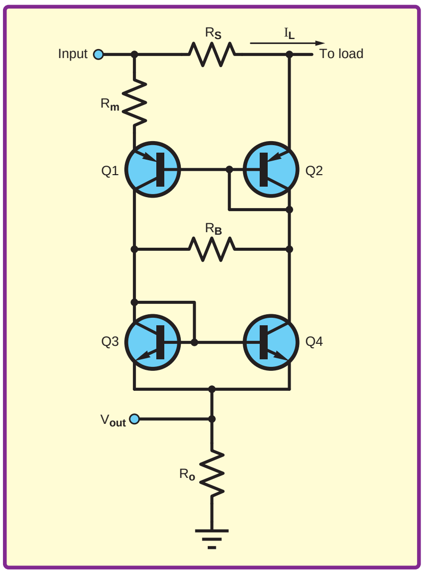
Protection diode

Finally, in relation to wolfie's third question, we should mention the need to protect the transistor from back emf from the relay coil. When current in an inductive load, such as a relay or solenoid coil is switched off, the magnetic field, which had been established by the supplied current collapses, inducing a voltage known as the 'back emf' or 'inductive kickback'. The inductor stores energy in a magnetic field while the current is flowing through it, but returns the energy to the circuit when the current is switched off.

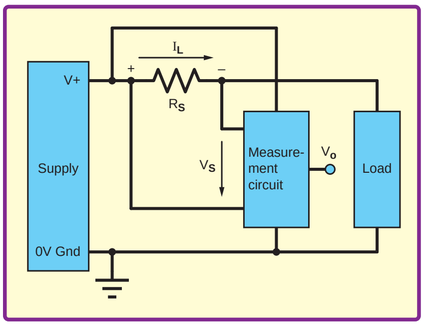
For the circuit in Fig.1, the back emf appears as a positive voltage spike at the collector of the transistor. This may result in voltages large enough to damage or destroy the transistor (possibly hundreds of volts). The more rapid the change in current as the inductor is switched off, and the larger the inductor value, the greater the back emf generated. The usual method of preventing the back emf from causing problems is to place a diode (variously called a 'freewheeling diode', 'flyback diode' or 'snubber diode') across the inductor, as shown in Fig.1. The term 'clamped inductive load' is also used in this situation. This diode is reverse biased when the power-switching device is on, but is forward biased by the back emf; so the diode dissipates the power or

Current mirrors for High-Side Current Measurement – errors in diagrams

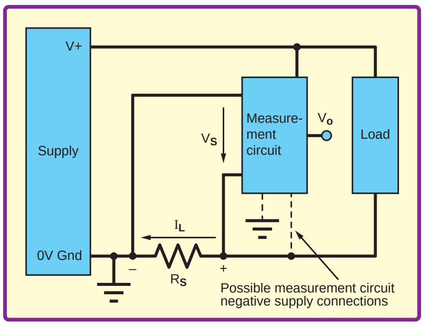
Unfortunately, some errors crept into a few of the figures in last month's *Circuit Surgery* on the use of current mirrors for high-side current measurement. The problems were spotted by *Chat Zone* users ***bowden_p*** and ***james*** – 'thank you' to them for pointing it out. My original diagrams were fine, but I did not notice the errors in the proof copies so they made it to press. The correct diagrams are printed here. Corrected Fig.1 includes the missing base wiring for Q3 and Q4. Corrected Fig.2 and Fig.3 show the correct voltage polarity and current direction respectively for the sense resistor R_S.



Corrected Fig.1. Ken Wood's high-side current monitor circuit



Corrected Fig.2. High-side supply current measurement. V_O is proportional to I_L



Corrected Fig.3. Low-side supply current measurement. V_O is proportional to I_L

AUDIO OUT

By Jake Rothman

Totally derailed: powering amplifiers – Part 3

Mains ground

The mains ground/earth is connected to the metalwork to prevent electric shock. It should also be connected to the amplifier earth. This has to be done via a ground-lift resistor to prevent an earth loop forming. This is typically a 1kΩ 0.5W device, with a 10nF ceramic RF bypass capacitor. It is convention to connect this to the input socket ground, since this is the defining point of 0V. In practice, it can be connected to the signal ground or dirty ground point with little difference in hum level. If there is any mains leakage current flowing, say from a high interwinding capacitance on the mains transformer, it would be best to connect it to the dirty ground. On amplifiers with a balanced input the earth plays no part in signal transmission and pin 1 is simply connected to the metalwork/mains earth.

Stereo wiring layout and hum loops

A stereo amplifier is just two mono amplifiers fed off the same power supply. However, there is an opportunity for an earth loop to occur (as shown in Fig.21a) because the two amplifier earths are joined at two points, the power supply and at the input. This loop can often give an earth buzz of 5 to 20mV on the speaker terminal. 5mV is enough to be heard with ones ear close to the speaker. The earths on the input sockets are normally connected together on the socket, pre-amplifier and signal source. Most stereo PCB-mount phono sockets have a single earth pin. The earth problem is avoided in professional amplifiers by the use of balanced inputs that don't need an earth to pass the signal. For unbalanced inputs, a common trick is to use 2.2Ω to 22Ω ground-lift resistors between the signal grounds and the main ground point on the power supply. This was devised Toby-Dinsdale (*Wireless World*, Jan 1965) and also used in the ground-breaking Quad 303 power amplifier in 1969. The input shared ground is then connected by a thick single connection to the main ground point (Fig.21b). There is the possibility this resistor may increase distortion since it may affect operation of the feedback loop, but I have not seen any evidence for this. Another technique is to use a mirror image layout with the centre earth rail for the both left and right channels signal earths (Fig.21c) connected to the shared supply earth. Using the same transformer core with two separate secondaries and rectifiers provides complete earth isolation (Fig.22). I once saw a guitar amplifier with an intractable earth hum. I had a look at the PCB and saw the earth track running continuously all the way round the outside of the board. With a deft application of the side cutters, breaking the loop instantly cured the hum.

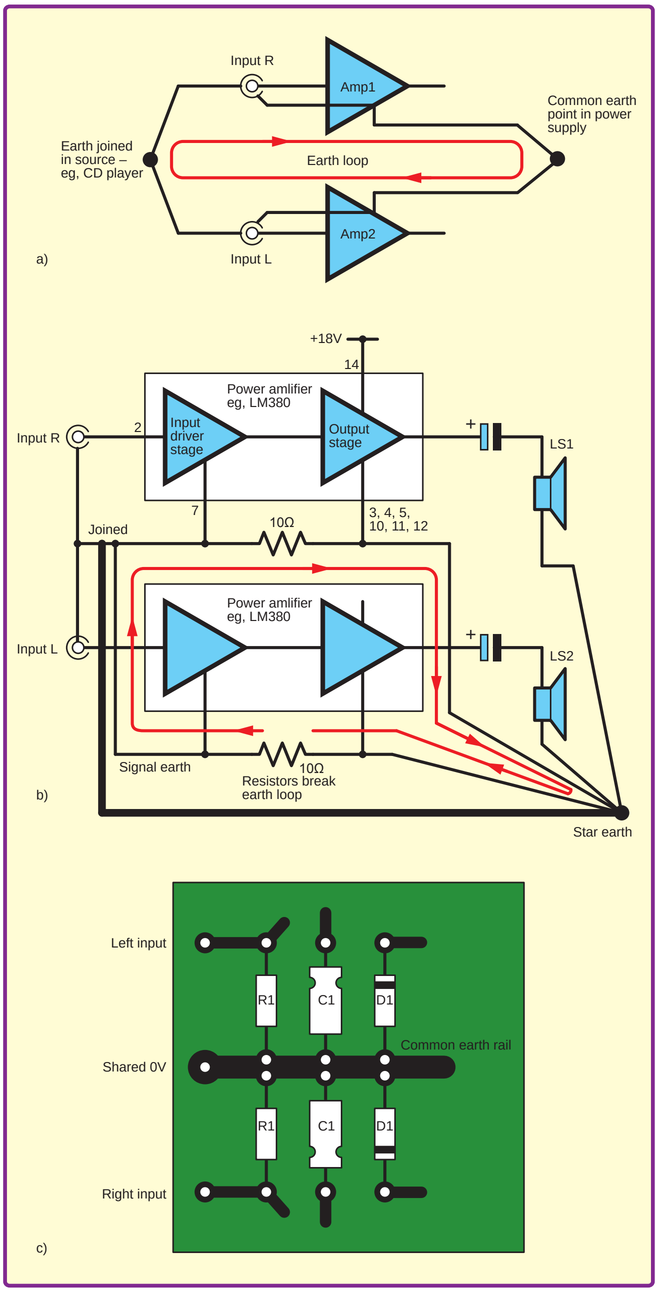


Fig.21 a) Wiring layout for a stereo amplifier, b) Using ground-lift resistors, c) alternative mirror image stereo amplifier layout (often used for PCBs)

Distorted rails

Another problem with class AB amplifiers is that the rectified audio rides on top of the sawtooth hum waveform on the unregulated power supply, as shown in Fig.23. This causes a degree of distorted crosstalk between both channels. Using the same secondary but separate rectifiers and smoothing caps provides some isolation of this signal – see Fig.24. Individual

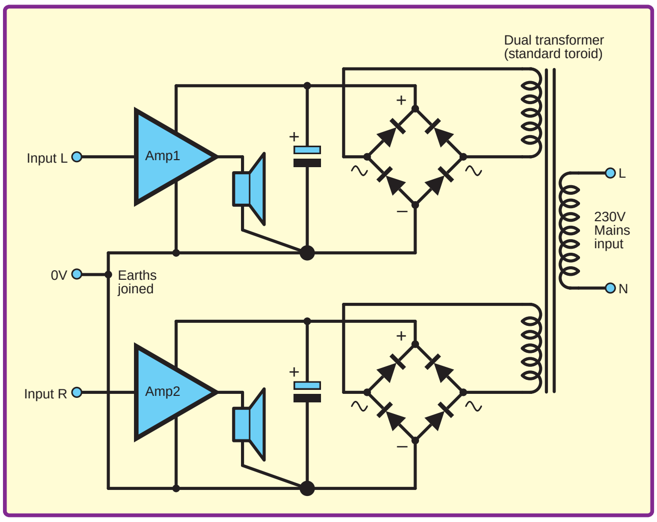


Fig.22. Inter-channel power rail and ground isolation provided by separate secondary windings on mains transformer.

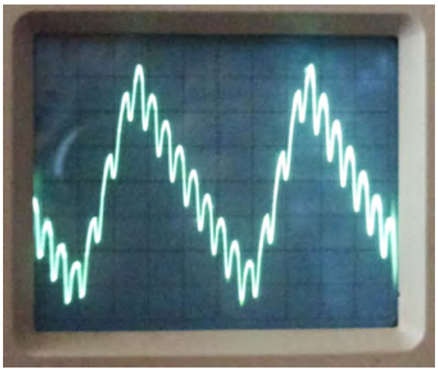


Fig.23. Oscillogram showing how audio superimposes itself onto the ripple waveform on the power supply.

decoupling capacitors for each amplifier fed by resistors from the main smoothing capacitor also helps. A single transformer with separate secondaries (Fig.22) provides almost total inter-channel isolation, apart from a bit of voltage sag due to the mutual primary resistance. If you are of the 'cost-no-object' fraternity, two separate mono amplifiers with individual power supplies, or monoblocks is the way to go.

A new test?

One test I always do on stereo/multi-channel amplifiers and active loudspeakers is to drive one output hard into a load resistor and listen to any resulting noise on the other outputs (Fig.25). I once sent an active speaker back because I could hear distorted bass harmonics in the tweeter output when the bass amplifier was clipped into a load resistor. A bit of track cutting and rerouting fixed it.

Fig.26 shows the layout of a stereo power amplifier using the circuit from *Audio Out* September 2016. 10Ω ground-lift resistors have been inserted by cutting the ground track from the driver stage. Notice the noding on the main smoothing capacitor in Fig.27. A normal bridge rectifier is used. If schottky diodes are used an additional volt is usually gained for a given transformer. These rectifiers have to be discrete since they are not available in high current bridge versions – see Fig.28.

Ripple current

One thing to watch out for, especially with class-A amplifiers, which draw a large continuous current, is the ripple current rating of the capacitor. It should be at least two times the DC current supplied. One way of measuring the ripple current is to put a clamp meter set to the 2A AC range on the capacitor lead. If you don't have a true RMS meter, an approximation allowing for the pulsed nature of the waveform is to multiply the current reading by two. If the rated current is exceeded, the capacitor warms up, which results in an increase in its ESR (equivalent series resistance) as it dries out. It then gets hotter and the process accelerates until the capacitor becomes an open circuit. If an old amplifier has developed a loud 100Hz hum it is usually the smoothing capacitors have dried out. It is convenient to check them in circuit by using an ESR meter, such as the peak ESR70, which I hope to review soon.

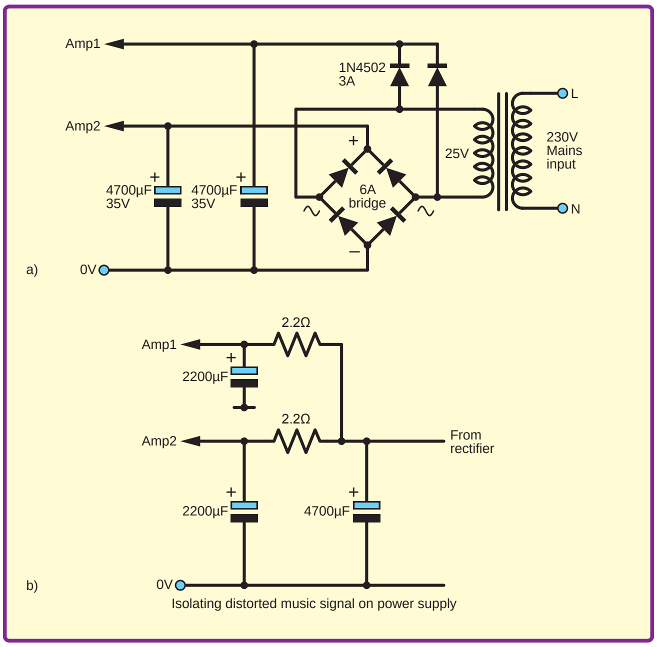


Fig.24. Providing separate rectifiers and smoothing capacitors gives effective isolation of audio on the supply rails.

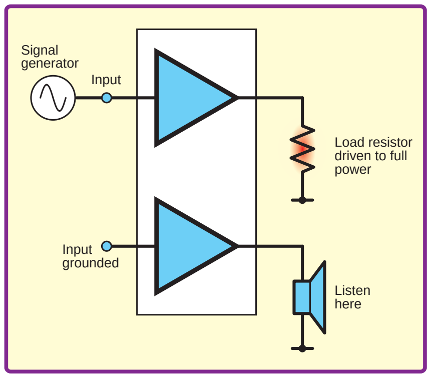


Fig.25. Testing dual-channel amplifiers to check for supply modulation.

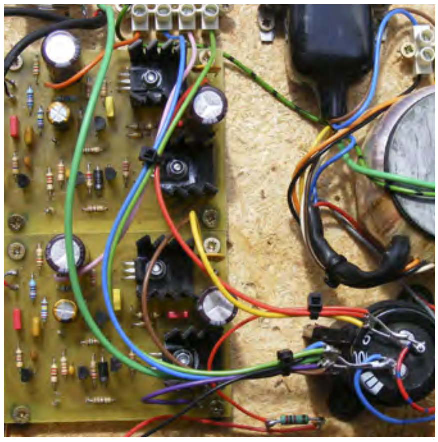


Fig.26. Prototype of stereo audio amplifier using Taylor-Rothman amplifier modules (EPE, Sep 2016). I included 10Ω ground-lift resistors, which eliminated a hum-loop that put 7mV on the output.

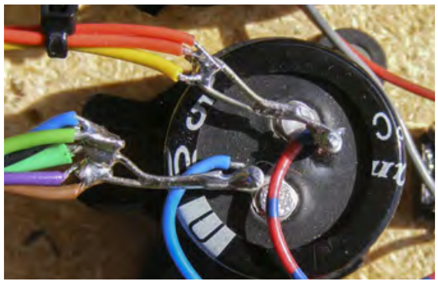


Fig.27. Noding on a power supply capacitor. The lower left cable cluster contains the ground cables/stub; the upper left contains the power cables/stub.

Fig.28. If you use a schottky bridge rectifier it will have to be made from individual diodes.

PIC n' Mix

Mike O'Keeffe

Our periodic column for PIC programming enlightenment

PICs and the PICkit 3: A beginner's guide – Part 9

LAST MONTH, we covered pulse-width modulation (PWM for short), which can be used for a wide range of applications from dimming LEDs to motor speed control. We briefly mentioned Timer0 and used it to set up the PWM module inside the PIC. This month, we come back to Timer0 and look at it in more detail. Lesson 9 of the *PICkit 3 Starter Kit User's Guide* covers a small example using Timer0. We're going to take a deeper look into the inner workings of these timers inside the PIC as well as look at the example code in Lesson 9.

Before moving onwards, I recommend having a read of the previous articles in the series. It's not necessary for this article, but you will gain 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**)

Time and clocks

Time is the great equaliser. It is the destroyer of mountains and the conqueror of worlds! Our lives revolve around time. This is also true inside the PIC. From the moment we apply power to the microcontroller, its clock starts to run. Imagine this clock as a miniature watch, that runs until power is removed. Just like us, this mini watch allows the microcontroller to keep track of where it is and what instruction to execute next.

Instead of hands on a watch, the clock inside the PIC is a digital signal. Fig.1 shows what this clock signal beside a data signal would actually look like if we were to capture it on an oscilloscope. The clock constantly toggles from a low to a high state. With the watch analogy, each high pulse would be like a single tick. One of the key things the clock actually does is 'latch' the data into memory on the rising edge of the clock. In other words, when the clock signal transitions from a low state to a high state (rising), the state of the data signal is stored in memory. In Fig.1, on the first rising edge, a '1' is stored, on the next rising edge, a '0' is stored and so on. The clock is what keeps things moving inside our microcontroller. So, inside the PIC, we have a clock, which runs freely. In fact, we have multiple clock modes to choose from:

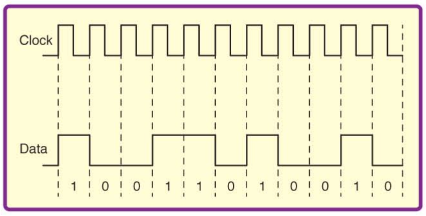


Fig.1. Diagram of clock and data signal

ECL	External Clock low-power mode
ECM	External Clock medium-power mode
ECH	External Clock high-power mode
LP	32kHz Low-Power crystal mode
XT	Medium-gain crystal or ceramic resonator oscillator mode
HS	High-gain crystal or ceramic resonator mode
RC	External resistor capacitor
INTOSC	Internal oscillator

Each option offers various advantages and disadvantages, balancing between lower power, greater speed and improved accuracy. For most applications, the internal oscillator is the easiest to setup using the `#pragma` directive and `FOSC=INTOSC` before the main loop in the code. The chosen oscillator is fixed when programming the PIC and cannot be modified during code execution. This ensures the timing inside the PIC doesn't get confused.

Once we've chosen which oscillator we want to use, we select the frequency of operation. This varies greatly between each of the options listed above. Considering just the internal oscillator, our frequency ranges from as low as 31kHz up to a high of 32MHz. This is the largest range of all the oscillators mentioned above, but it isn't the most accurate.

When we want to communicate with external devices over communication buses like I^{2}C, SPI or UART (serial bus), which are much faster and need better accuracy, it is preferable to use an external clock source like the Low-Power crystal mode (LP) and the medium-gain crystal (XT) mentioned above. These have better accuracy and are less sensitive to temperature drifts or fluctuations.

As well as latching our data, the clock is also used as a reference to derive multiple timers, which are used to time specific events. An event might be something like a button being pressed. There are two types of timers, the countdown and the stopwatch. The countdown timer starts at a number and counts down until it hits zero. The hourglass is a perfect example of a countdown timer, once the sand has passed from the top to the bottom, there is no more sand and the countdown has stopped. A stopwatch timer counts up from zero until it reaches a chosen point.

Much like the classic hourglass timer, in any digital system, we want to time specific events or count down until we want an event to occur. Unlike the hourglass timer, the digital timer is very accurate. We can read from the timer at any time. We can even write to that timer a specific time to start from or end at, just like adjusting the clock on your wall.

The timers

Timers are very important for nearly every project you create. They can be used by the PWM modules to dim LEDs, and by serial communications modules to communicate over a serial cable to your laptop/desktop. In the PIC16F1829 there are three main timers: Timer0, Timer1 and Timer2/4/6. Timer0 is an 8-bit timer or a counter. Timer1 is a 16-bit timer or counter, which is usually used for real-time clock circuits. Timer2/4/6 are three identical Timer2 modules and are 8-bit timer and period registers, which are commonly used by the PWM modules.

The timers are based on the clock oscillator chosen. As mentioned earlier, for most of the examples, we will be using the internal oscillator. There are three internal system clock sources, the 16MHz High-Frequency Internal Oscillator (HFINTSOC), the 500kHz (MFINTSOC) and the 32kHz Low-Frequency Internal Oscillator (LFINTSOC).

Consider the flowchart in Fig.2. We start the timer, increment the timer every time there's a rising edge on the clock and reset the timer once it's reached its maximum value. Now it's time to look at some code and see how this all comes together.

Timer0 example

Lesson 9 in the *PICkit 3 Starter Kit User's Guide* covers an example using Timer0. It takes directly from *Lesson 3: Rotate*, which we covered back in October. Instead of using a delay function like `__delay_ms(500)` to rotate around the four on-board LEDs, we will use Timer0. The problem with the delay function is that it uses a `while` loop for the entire time specified, and thus takes up *all* the processor's time and power. By using the Timer0 module, we are offloading this counting elsewhere, so the processor is free to perform other tasks.

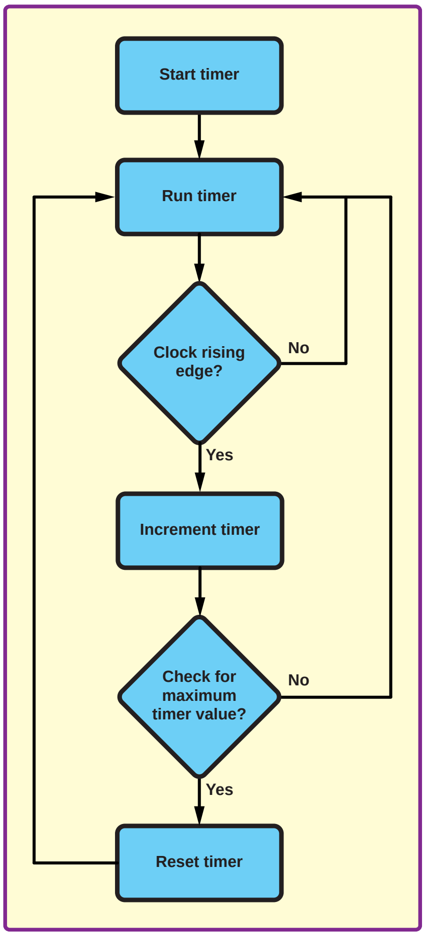


Fig.2. Timer operation flowchart

```
void main(void) {
      OSCCON = 0b00111000;
      TRISC = 0;
      LATC = 0;
      OPTION_REG = 0b00000111;
      LATCbits.LATC4 = 1;

      while (1) {
              while (!INTCONbits.TMR0IF) continue;
                      INTCONbits.T0IF = 0;
                      LATC >> = 1;
                      if (STATUSbits.C)
                              LATCbits.LATC3 = 1;
                      }
}
```

Fig.3 shows an accurate description of the code above. First we set the clock oscillator to 500kHz using the OSCCON special function register. Then we set Port C, which is connected to our LEDs, to outputs and set them to low output, ensuring they're off to start with. Then we set our Option Register using the `OPTION_REG` register. This sets our prescaler rate to 1:256. A prescaler is a method to reduce a high frequency to a lower frequency by integer division. We'll look at why shortly. In this case, the oscillator is 500kHz, the prescaler is 1:256, so Timer0 only increments once for each 256 rising edges of the clock. In effect, reducing our clock speed to 500,000 / 256 = 1953Hz. We'll come back to this in a moment.

In the `while` loop, we have a new control register `INTCON` and the Timer0 Overflow Interrupt Flag bit. The Interrupt Control Register (`INTCON`) controls various interrupts in the PIC. An interrupt is an event that is captured by the microcontroller, which 'interrupts' the current behaviour of the running code and does some task based on the event, before returning to normal operation. A button press is an example of an interrupt, which can be set up to turn on an LED every time the button is pressed. Instead of checking if the button is pressed, the interrupt controller will automatically check for you, which saves time and code.

In this example, the event is the Timer0 reaching its maximum value. Since it's an 8-bit timer, the maximum value it can hold is 2^8 = 256. As the prescaler is 1:256, the Timer0 will increment every 256 rising edges of the clock. Once the maximum value is reached in Timer0, the Timer0 Overflow Interrupt Flag bit (TMR0IF) is set to a '1'. Inside the while loop, we check to see if this flag is set and if it is, the flag gets reset. Then we right shift Port C, just like in *Lesson 3: Rotate*. Before the `while` loop is restarted we turn on the LED at Port C3 if the carry bit is set – `STATUSbits.C`

What we're really trying to do here is rotate the four LEDs, changing every half a second. The big question here is, how do get from a clock frequency of 500kHz to an LED flashing that we can actually see. This is where the prescaler comes into play.

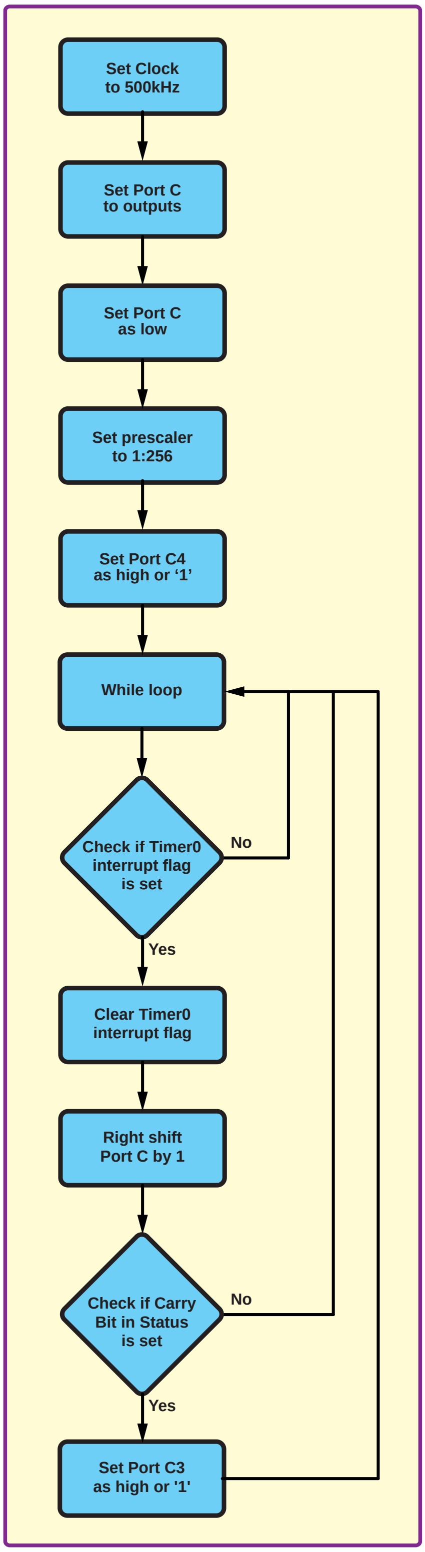


Fig.3. Timer0 example code flowchart!

When the prescaler is equal to 1, Timer0 will increment at the same speed as the clock oscillator. If the prescaler is 256 and the maximum Timer0 value is 256, then we need 256 × 256 = 65536 rising clock edges before the interrupt flag is set. The period of the clock oscillator is the reciprocal of the frequency, which is 1/500,000Hz = 2µs. If we multiply the number of clock edges we need (65536) by the period (2µs), we calculate how often our LED will change, 65536 × 0.000002s = 0.131s, which is still faster than we want.

We're missing one final piece of the puzzle. We want the LED to change every half a second or 500ms. The code above is correct; however, we didn't take into account the length of time for an instruction cycle. This is sometimes called a fetch-decode-execute cycle, which is a fundamental aspect of the internal workings of the PIC microcontroller. When we write our code, the microcontroller must decode it to understand what it needs to do. First, the PIC fetches the next command from program memory (eg, `LATCbits.LATC3 = 1`), then it must determine what this instruction means, and then execute the required actions.

According to the datasheet, for the PIC16F1829, an instruction cycle clock is equal to `FOSC/4`. Thus, an instruction cycle (or period) is the reciprocal of the clock, which means the clock oscillator, which is 500kHz, is divided by four to handle each instruction inside the PIC. With this in mind, the effective clock oscillator period is now (1 / (500,000 / 4) = 8µs. Therefore the LEDs will rotate at 65536 × 0.000008s = 0.524s, which is close enough to half a second.

The watchdog timer

I said there are only three timers inside the PIC; however, I should add the watchdog timer. This is a separate timer, with a very useful function. When enabled, this timer must be reset periodically or it will reset the PIC microcontroller. It's a safety mechanism to help if your software or hardware has gone awry and it can't fix itself. I highly recommend implementing a watchdog timer into any code you write and let the PIC save itself.

Next month

We've covered a few important and detailed topics in the last few months, including PWM, timers and debounce. Next month, I'd like to take a break and build a little project using our newfound skills. The project won't involve the Low Pin Count Demo Board this time, but we'll stick with the PIC16F1829 and use some Veroboard.

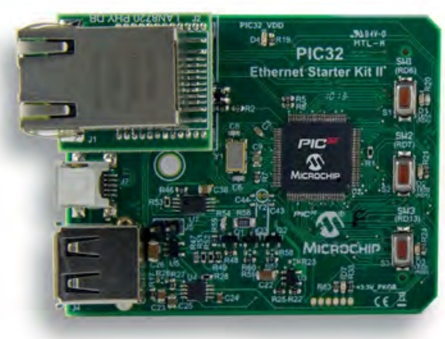
Not all of Mike's technology tinkering and discussion makes it to print.

You can follow the rest of it on Twitter at *@MikePOKeeffe*, up on *EPE Chat Zone* as *mikepokeeffe* and from his blog at *mikepokeeffe.blogspot.com*

MICROCHIP

Development Tool of the Month!

PIC32 Ethernet Starter Kit II



Part Number
DM320004-2

Overview:

The PIC32 Ethernet Starter Kit II provides the easiest and lowest-cost method to experience 10/100 Ethernet development with PIC32 microcontrollers. Combined with Microchip's free TCP/IP software, this kit gets your project running quickly. The PIC32 microcontroller has an available CAN 2.0b peripheral and USB host/device/OTG. This starter kit features a socket that can accommodate various 10/100 Ethernet transceiver (RJ-45) PHY Daughter Boards for prototyping and development and an expansion connector that enables the addition of Microchip's PIC32 expansion boards or the creation of your own board.

Key Features:

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- Includes 10/100 Fast Ethernet LAN8740 PHY Daughter Board
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- Standard A to mini-B cable for debugger
- Standard A to micro-B cable for USB application development
- PIC32 running at 80 MHz with 512K Flash, 128K RAM, 8 channel DMA + 8 channel DMA dedicated to Ethernet, CAN and USB

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MICROCHIP

Max's Cool Beans

By Max The Magnificent

Fig.1. Yours truly (left), Mike Mittlebeeler (right), and Caveman Diorama (center).

Having fun with Stone Age LEDs

As you may recall – probably for longer than you care to recall – I've been waffling on about creating a caveman diorama. This all started several years ago when I found and refurbished an old wooden television cabinet and decided I wanted to create a diorama inside it. I tried making the cave out of chicken wire and papier mâché, but all I ended up with was tangling myself up in chicken wire and covered in papier mâché.

Then my wife introduced me to Mike Mittlebeeler, an ex-Apache helicopter pilot whose hobby is making model railways and military dioramas. For more than a year now, Mike and I have been meeting up in my office on Saturday mornings to work on the caveman diorama. A few weeks ago, although it's not yet finished, we decided to enter it in a local modeling competition as a work in progress. When we arrived at the competition, we established a base station in the corner of the exhibition area, as seen in Fig.1.

As an aside, the large image of the caveman holding the stone bowling ball in the background was created by CG artist Jeroen Cloosterman (**http://bit.ly/2dUNlJP**). Jeroen kindly gave us permission to use this image – the full-size version is truly spectacular

Fig.2. Home sweet home... ca. 10,0000 BC

Fig.3. It's all done with mirrors... well, LEDs actually

(**http://bit.ly/2eNHRC5**). My chums Bruce and Bob from Out of the Box Exhibits (**http://bit.ly/2eNCYsQ**) added the rays of coloured light coming out of the ball to reflect the light effects in our cave, and they also created the stone-look picture frame and pillar.

Where does the space go?

We're working at a 1:32 scale, which means that a six-foot-tall man would be 2.25-inches in height in our diorama. One thing we've discovered is that it's incredibly easy to fill up a cave with 'stuff.' We don't have the room to show close-up images of everything here, but I've included some highlights.

Let's start by considering the cave as a whole – See Fig.2. Towards the back of the scene we see the entrance to the cave. The mountains and sky are being presented on a flat-screen computer monitor about six inches behind the entrance. Currently this is just a still image, but in the fullness of time we intend to model the outside world using 3D software and generate this scene on the fly. This will allow us to do all sorts of things, like having a volcano erupt at noon each day, and having the weather in the diorama match the weather in the real world outside my office.

In the middle of the cave in the foreground we have our fire (Fig.3). We're really rather proud of this. At the bottom are 19 tri-coloured LEDs. Then we have a cone of crunched glass bound with clear epoxy, which provides myriad internal reflections and refractions. Twigs that have been burnt at the ends surround this. The whole effect is extremely realistic when the LEDs are randomly flickering away.

On the left-hand side of the cave is a pool (of clear epoxy) with tiny fish in it. There's also a small wooden rack with drying fish hanging from it. This is probably a good point to note that we have tri-coloured LEDs hidden all over the place, including about 30 at the bottom of the pool, which allow us to introduce a nice ripple effect.

On the floor at the foot of the entrance we find a pile of logs. It was only after we'd glued these down that a friend pointed out that the ends were too smooth to have been cut with stone axes, and instead they appeared to have been cut with a chain saw. Fortunately, we have a time portal (Fig.4) to explain my presence sitting around the fire with the cavemen (when we get around to adding the figures as discussed below), so we added a chainsaw to the scene. Also, note the three wooden ladders – one located behind the logs and the other two near the floodlights. These are tied with white

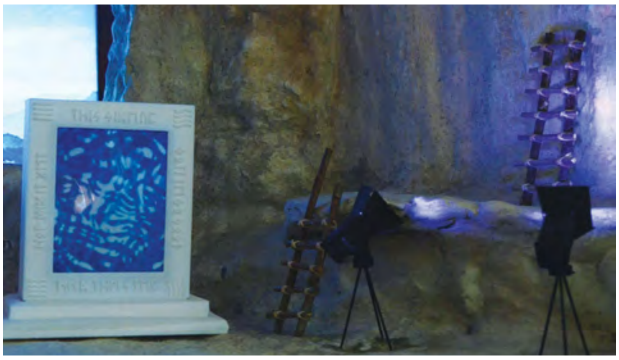

Fig.4. Max's time portal

cotton thread that was dyed in tea (each of these knots took me about seven minutes to tie).

We also have a bunch of tri-coloured LEDs at the back of the tunnel located half way up the left-hand wall, along with another 155 of the little scamps hidden in the ceiling (Fig.5). In the fullness of time, we'll have a waterfall coming out of the tunnel and splashing down onto the rocks in the center of the pool below.

Returning to the floodlights and the time portal at the right-hand side of the cave. In the case of the floodlights, which will be used to illuminate a caveman standing on a ladder creating a cave painting, we're running the power, ground, and control signals up their legs. The 3D print files for these were created by my chum, Steve Manley, in the UK (you can access a ZIP file containing the 3D floodlight files here **http://bit.ly/2fwWsWa**; and the 3D time portal files here **http://bit.ly/2erJmoR**). Meanwhile, another chum, Daniel Whiteley, has been working on the code to transition the images being displayed on the time portal's screen, but this part of the diorama is still a work in progress (hence the fact that we didn't have time to paint the portal or mount the screen for the competition), so I'll share all that in a future column.

Fig.5. More LEDs in the tunnel and the sky is generated by a PC monitor

So much fun stuff to do...

…and so little time to do it all in. We've still got to get the time portal up and running and add the waterfall, plus a lot of other little fiddly details, but the main thing is to add the figures. We're now thinking of modeling these using a program called Daz 3D (**http://bit.ly/2f9SK0t**) and then 3D printing them, which means that we now need to learn how to use Daz 3D. I tell you… there simply aren't enough hours in the day! Until next time, have a good one!

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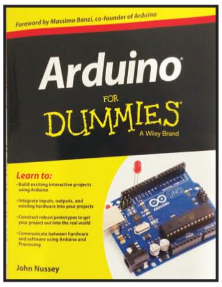

ARDUINO FOR DUMMIES
John Nussey

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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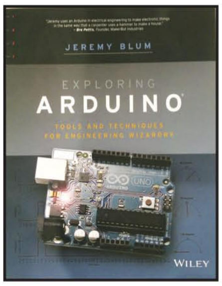

EXPLORING ARDUINO
Jeremy Blum

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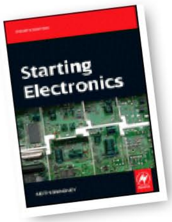

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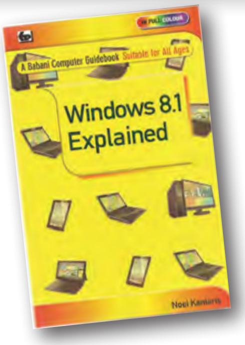

WINDOWS 8.1 EXPLAINED

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

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

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

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

KINDLE FIRE HDX EXPLAINED

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

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

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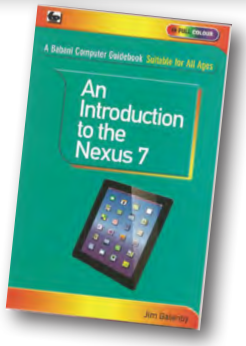
118 Pages **Order code BP743** **£8.99**



AN INTRODUCTION TO THE NEXUS 7

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

Among the many useful topics covered are: An overview of the main features of the Nexus 7; setting up the Nexus 7; charging the battery; connecting to the Internet and signing up for Gmail; touch-screen operation and navigating around the various screens; installing Apps from the Google Play Store; setting a password and other precautions to keep your files safe; connecting accessories such as a USB Drive, mouse and keyboard; enjoying entertainment such as eBooks, games, music and videos; searching the Internet, including speaking in keywords; using e-mail, Skype and social networking; installing the free Google Drive app to save your documents in the cloud; using Google Docs free word processing and spreadsheet software; printing a document using Google Cloud Print, Exporting Nexus 7 files to laptop and desktop computers; and much more besides….

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

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ALAN WINSTANLEY

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Also ideal for those approaching electronics from other industries, the Basic Soldering Guide Handbook is the best resource of its type, and thanks to its excellent colour photography and crystal clear text, the art of soldering can now be learned by everyone!

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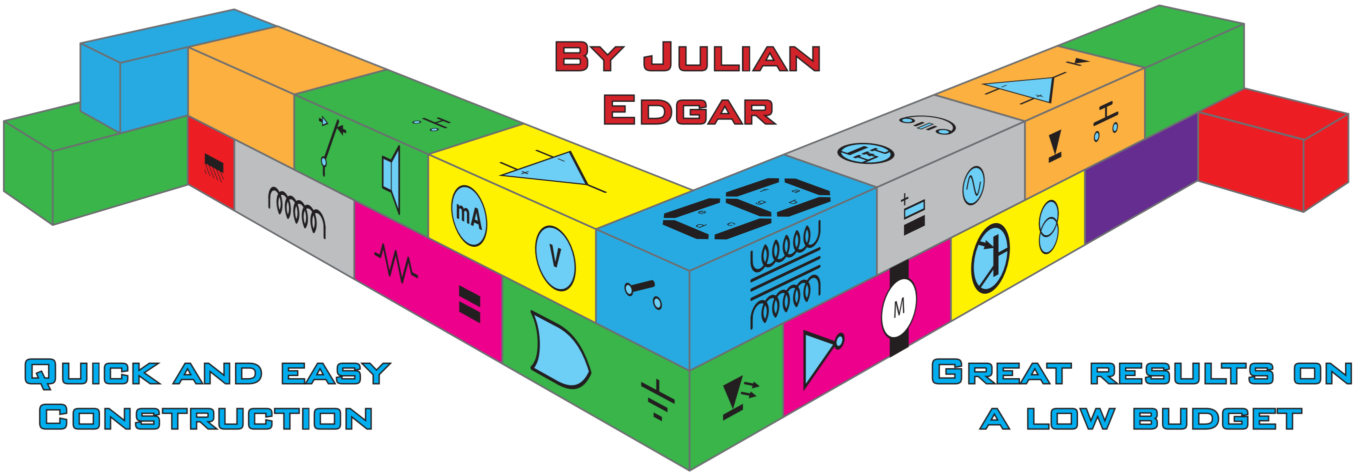
Electronic Building Blocks



By Julian Edgar

Quick and easy construction

Great results on a low budget

Four-Channel Car Sound Amplifier

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!

Here's a four-channel, car sound amplifier with a maximum output of 68W per channel. That's more than enough – even with relatively inefficient car speakers – to give you plenty of volume and punchy bass. Even better, if you're happy to do some of your own metalwork and you already have some hardware like fasteners and spacers, the cost is very low. Quality? Far better than the vast majority of similar car power amplifiers!

Starting points

The heart of the amplifier comprises four LM3886 ICs. This venerable audio amplifier IC is an oldie – but a goody. Each is capable of 68W into 4Ω at a maximum distortion of 0.1%.

This view shows the six switching transistors used by the power supply module. The eBay module is supplied complete with the insulating washers and pads for heatsink mounting. However, you need to supply your own board-mounting stand-offs.

However, rather than start with the bare ICs, we use two prebuilt, two-channel modules from eBay. Note that the selected modules require a ±28V DC supply, rather than the AC transformer supply that most of these modules are configured for. Therefore, when sourcing these modules, ensure they are *exactly* as pictured.

You'll pay about £10 for each of the two required modules. To find them, search under 'Assembled LM3886TF Dual channel Stereo Audio Amplifier Board 68W+68W 4Ω 50W*2 8Ω'. (At the time of writing, look for eBay item 172274154282.)

The completed four-channel, 12V amplifier – the power supply module is on the left, and the two 2-channel amplifier modules on the right. When the lid is placed on top, it locates the fan above the amplifier modules. (A similar-sized vent hole to the fan is located under the power supply module.)

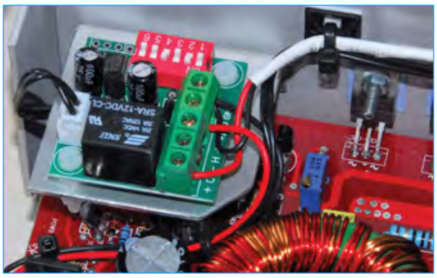
Next up, you'll need a power supply capable of driving these modules. Previously, developing such a supply would have been expensive and time consuming – but now one is available off the shelf. It's called '1PC Switching boost Power Supply board 350W DC12V to Dual ±20-32V for auto' and costs only about £18, including delivery. (At the time of writing, look for eBay item 321406996228.)

While the output of the power supply is ±32V as it arrives (the on-board pot allows adjustment), the LM3886 is happy with up to ±42V, so that's fine.

I also chose to use a fan for heatsink cooling and triggered it via another eBay module. This module is called '20-90^{o}C DC 12V Thermostat Digital Temperature Control Switch Temp Controller New', and costs a mere £2. (At the time of writing, look for eBay item 152234681961.)

Wiring

The electronics aspect of building the amp is dead easy. The power supply board input GND, K and 12V terminals are connected as follows – GND to chassis ground, and the 12V terminal directly to the positive of the car battery. Use a high-current fuse in this battery supply – eg, 20A. The K terminal requires 12V to switch on the power supply – normally it's connected to the 'power aerial' output of the head unit.



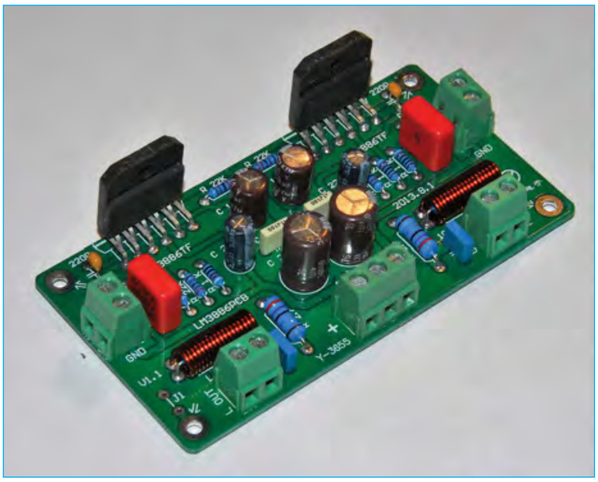
This tiny module triggers the cooling fan on the basis of the temperature selected with the DIP switches. In this case, the temperature for fan activation was set at 40°C. The remote temp probe is located between two of the LM3886 amplifier ICs on one of the heatsinks.

Only recently released, this power supply module generates ±32V DC from 12V DC and can be directly connected to the amplifier modules.

(Or, if you don't have this, you could connect it to any ignition-switched 12V supply.)

The power supply board's output terminals (VCC+, GND and VCC–) are, respectively, connected to the (+), GND and (–) terminals of the two amplifier modules.

The line level inputs from the head unit are connected to the IN amplifier module terminal blocks (observe correct polarity), and the speakers connected to the OUT terminal blocks (again observe correct polarity). And that's it for wiring!



This prebuilt stereo amplifier module is available on eBay for just £10, with two of the modules needed for this amplifier. The module requires at least ± 28V DC to run and, in use, plenty of cooling capacity (good heatsinks and/or fan) is also required.

Building

You need to provide plenty of heatsink capacity – either by the use of substantial heatsinks, or by using smaller heatsinks but adding a fan. The majority of heat is generated by the four LM3886 modules – despite appearances, the power supply module heatsink requirements are more modest.

I wanted a compact box, so I made one from aluminium sheet specifically to suit the required dimensions. The overall dimensions of the box were about 250 x 140 x 75mm. Using 8mm-thick aluminium plate for two walls of the box formed the heatsinks. A salvaged 12V fan was placed in the top panel (and there is a matching size hole in the bottom panel). The temperature-sensing module, set to turn on at 40°C, triggers the fan.

The power supply module comes with the required insulating washers and collars for mounting the transistors to the heatsink, while the amplifier modules uses plastic encapsulated ICs and so do not require any extra insulation. To mount the boards, you'll need to provide the insulated standoffs and screws, washers and nuts.

Rather than place connectors for the inputs and speakers on the box, I chose to directly wire these connections to the boards. These leads were run through rubber grommets that slide up appropriate channels when the lid is screwed into place.

Obviously the type of housing you place the components in is up to you – you could even use a discarded car sound amplifier enclosure that incorporates its own heatsink. But remember, whatever approach you take, you'll need either quite substantial heatsinks, or a fan – quite possibly both.

Results

The only financial outlay I had was for the eBay amplifier and power supply modules – so, £38. And for that money, this is an unbeatable amplifier. The sound is excellent – better than commercial car sound amplifiers costing two or three times much, and so much better than the typical four-channel amplifier built into a head unit that it's not even funny!

Note – this amplifier is also appropriate for anywhere you need quality four-channel sound and you're limited to a 12V supply. That includes, boats, caravans and houses working off a low-voltage solar system.

Next month

In March's issue we have something a little different – Five eBay essentials to stock up on. Intrigued? – then you definitely do not want to miss the next super *Electronic Building Block* article!

One of the requirements was that the amplifier be reasonably compact and light. The final item has a mass of 1.75kg and dimensions of 250 x 140 x 75mm.

PCB SERVICE

CHECK US OUT ON THE WEB

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

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

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

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Next Month

Content may be subject to change

Speech Timer For Contests & Debates

If you are involved in school or university debating contests you will be aware of the importance of a speech timer. It keeps meetings and events on time and also prevents individual speakers from droning on past their allotted time. This *Timer* has a large 3-digit display and a buzzer. Plus, it has a tiny infrared remote control.

Solar MPPT Charger & Lighting Controller – Part 2

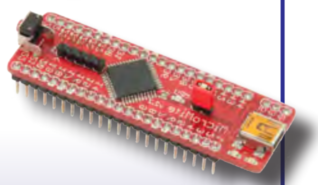
Our new *Solar MPPT Charger/Lighting Controller* uses solar panels to charge a 12V or 24V battery and then works with LDR/PIR sensors to run 12V DC lighting or an inverter. Next month, we'll show you how to build it and describe the setting-up procedure.

Arduino-Based Fridge Monitor and Data Logger

Keep tabs on your fridge with this temperature and humidity *Monitor* – the *Data Logger* will even let you know about midnight raids!

Meet the mighty Micromite – Part 2

The Micromite is an amazing device. A low-cost microcontroller programmed in a Microsoft-compatible version of BASIC with floating point, arrays and extensive string handling. In Part 2 we examine its powerful and flexible input/output and interfacing abilities.



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

MARCH '17 ISSUE ON SALE 2 FEBRUARY 2017

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