THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

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DUAL TRACKING ±0V TO 19V POWER SUPPLY – PART 1

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- Voltage accuracy better than 1%
- Excellent load regulation, ripple and noise figures

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Using free power off grid to run lights

PLUS

INTERFACE, PIC N' MIX, NET WORK, CIRCUIT SURGERY, READOUT, TECHNO TALK

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JUNE 2012 PRINTED IN THE UK
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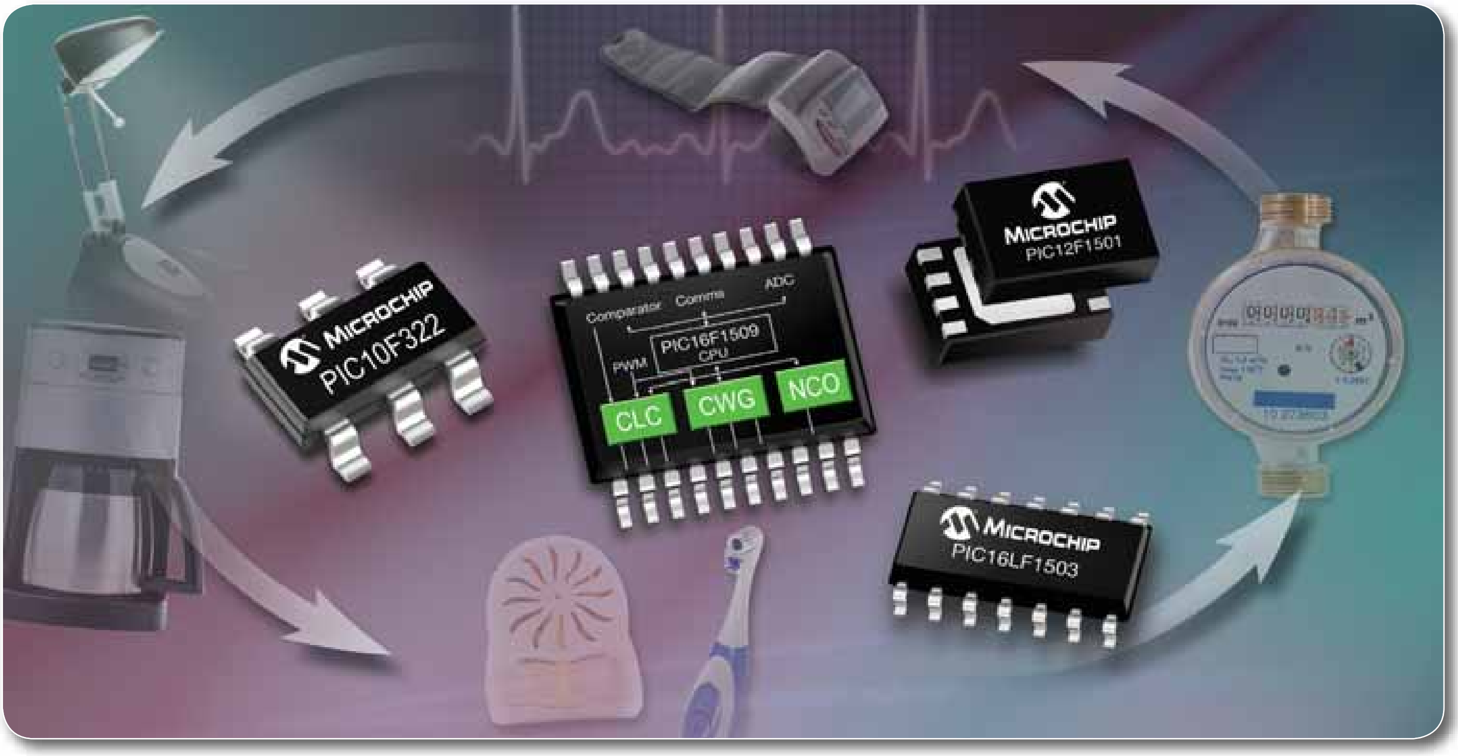
New 8-bit Microcontrollers with integrated configurable logic in 6- to 20-pin packages



Microchip's new PIC10F/LF32X and PIC12/16F/LF150X 8-bit microcontrollers (MCUs) let you add functionality, reduce size, and cut the cost and power consumption in your designs for low-cost or disposable products, with on-board Configurable Logic Cells (CLCs), Complementary Waveform Generator (CWG) and Numerically Controlled Oscillator (NCO).

The Configurable Logic Cells (CLCs) give you software control of combinational and sequential logic, to let you add functionality, cut your external component count and save code space. Then the Complementary Waveform Generator (CWG) helps you to improve switching efficiencies across multiple peripherals; whilst the Numerically Controlled Oscillator (NCO) provides linear frequency control and higher resolution for applications like tone generators and ballast control.

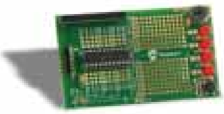
PIC10F/LF32X and PIC12/16F/LF150X MCUs combine low current consumption, with an on-board 16 MHz internal oscillator, ADC, temperature-indicator module, and up to four PWM peripherals. All packed into compact 6- to 20-pin packages.

Go to www.microchip.com/get/eunew8bit to find out more about low pin-count PIC® MCUs with next-generation peripherals

FAST-START DEVELOPMENT TOOLS

PICDEM ™ Lab Development Kit - DM163045

PIC16F193X 'F1' Evaluation Platform - DM164130-1



PICkit™ Low Pin Count Demo Board - DM164120-1

Free CLC Configuration Tool:
www.microchip.com/get/euclctool

MICROCHIP

Microcontrollers • Digital Signal Controllers • Analog • Memory • Wireless

ISSN 0262 3617
● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
● POPULAR FEATURES ●
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INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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Series and Features

Regulars and Services

Our July 2012 issue will be published on Thursday 7 June 2011, see page 80 for details.

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PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £24.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

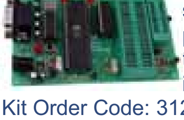
USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash/OTP PIC Programmer

USB PIC programmer for a wide range of Flash & OTP devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Supply: 16-18Vdc.
Assembled Order Code: AS3150 - **£49.95**
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

ATMEL 89xxxx Programmer

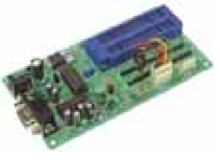


Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

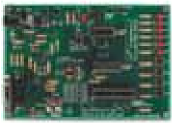
Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4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

PIC Programmer Board



Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board

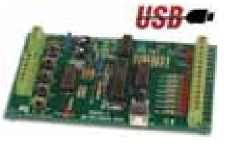


The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU303 £9.95

USB Experiment Interface Board



5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£39.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

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

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£24.95**
Assembled Order Code: AS3145 - **£31.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone

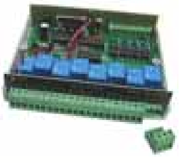
Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£14.95**

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

4-Ch DTMF Telephone Relay Switcher

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

8-Ch Serial Port Isolated I/O Relay Module

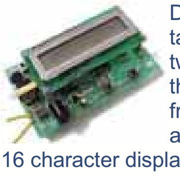


Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial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

Infrared RC 12–Channel Relay Board

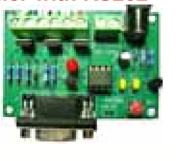
Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display

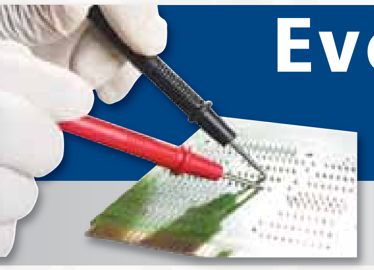


Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent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

3x5Amp RGB LED Controller with RS232



3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 3191KT - **£27.95**
Assembled Order Code: AS3191 - **£37.95**



Everyday Practical Electronics
FEATURED KITS
June 2012

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested Down Under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

SLA Battery Health Checker Kit

KC-5482 £29.00 plus postage & packing

The first versions of the battery zapper included a checker circuit. The Mk III battery zapper (KC-5479) has a separate checker circuit - and this is it. It checks the health of SLA batteries prior to charging or zapping with a simple LED condition indication of fair, poor, good etc.

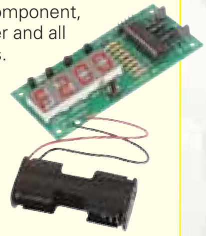
- Overlay PCB and electronic components
- Case with machined and silk-screened front panel
- PCB Dimensions: 185(L) x 101(W)mm

AUTOMOTIVE KITS

G-Force Meter Kit

KC-5504 £18.25 plus postage & packing

Measure the g-forces on your vehicle and it's occupants during your next lap around the race circuit, or use this kit to encourage smoother driving to save petrol and reduce wear & tear. Forces (+/- 2g) are displayed on the 4-digit LED display. Also use it to measure g-forces on a boat crashing over waves or on a theme park thrill ride. Kit includes PCB with pre-mounted SMD component, pre-programmed microcontroller and all onboard electronic components.



- Requires 2 x AA batteries
- PCB: 100(L) x 44(W)mm

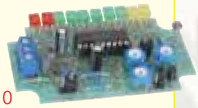
Note: We supply the PCB with the SMD component already mounted on the board to save time and frustration.

Featured in EPE November 2011

Voltage Monitor Kit

KC-5424 £8.50 plus postage & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.



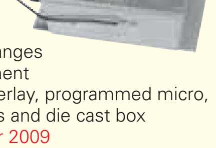
- PCB: 74(L) x 47(W)mm
- 12VDC
- Recommended box: UB5 use HB6015

Featured in EPE September 2010

Programmable High Energy Ignition Kit

KC-5442 £25.50 plus postage & packing

This advanced and versatile ignition system is suited for both two & four stroke engines. Used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing (available seperatley).



- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment
- Kit includes PCB with overlay, programmed micro, all electronic components and die cast box

Featured in EPE November 2009

Theremin Synthesiser Kit MkII

KC-5475 £27.25 plus postage & packing

The ever-popular Theremin is better than ever. It's easier to set up with extra test points for volume adjustment and power supply measurement and it now runs on AC to avoid the interference switchmode plugpacks can cause. It's also easier to build with PCB-mounted switches and pots to reduce wiring to just the hand plate, speaker and antenna and has the addition of a skew control to vary the audio tone from distorted to clean.

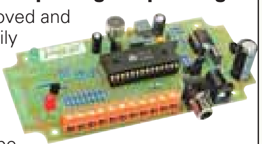
- Complete kit contains PCB with overlay, pre-machined case and all specified components

Featured in EPE March 2011

45 Second Voice Recorder Module

KC-5454 £12.75 plus postage & packing

This kit has been improved and can now be set up easily to record two, four or eight different messages for random access playback or a single message for 'tape mode' playback. Also, it now provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14VDC.



- Supplied with silk screened and solder masked PCB and all electronic components
- PCB: 120(L) x 58(W)mm

Featured in EPE December 2012

Class-T Digital Audio Amplifier Module

AA-0228 £11.00 plus postage & packing

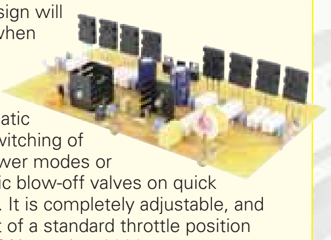
Ideal for any audio enthusiast that enjoys building and modifying speaker systems. The PCB is tiny which allows you to incorporate it into a wide variety of speaker systems.

- Regulated 12VDC 2000mA
- Size: 68(L) x 32(W)mm

Delta Throttle Timer Kit

KC-5373 £9.25 plus postage & packing

This brilliant design will trigger a relay when the accelerator is pressed or lifted quickly. Used for automatic transmission switching of economy to power modes or trigger electronic blow-off valves on quick throttle lifts etc. It is completely adjustable, and uses the output of a standard throttle position



Featured in EPE November 2006

Ultrasonic Antifouling for Boats

KC-5498 £90.50 plus postage & packing

Marine growth electronic antifouling systems can cost thousands. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in a sturdy polyurethane housings. By building it yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. The single transducer design of this kit is suitable for boats up to 10m (32ft); boats longer than about 14m will need two transducers and drivers. Basically all parts supplied in the project kit including wiring. (Price includes epoxies).

- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB: 104(L) x 78(W)mm

Featured in EPE March 2012

Now available Pre-built:

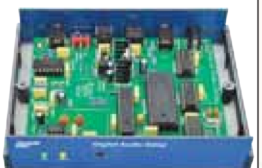
Dual output, suitable for vessels up to 14m (45ft) YS-5600 £309.25

Quad output, suitable for vessels up to 20m (65ft) YS-5602 £412.25

Digital Audio Delay Kit

KC-5506 £36.25 plus postage & packing

Corrects sound and picture synchronization ("lip sync") between your modern TV and home theatre system. Features an adjustable delay from 20 to 1500ms in 10ms steps, and handles Dolby Digital AC3, DTS and linear PCM audio with sampling rate of up to 48kHz. Connections include digital S/PDIF and optical Toslink connections, and digital processing means there is no audio degradation. Kit includes PCB with overlay and pre-soldered SMD IC, enclosure with machined panels, and electronic components.



- 9-12VDC
- Universal IR remote required - use AR-1729 £8.75
- PCB: 103(L) x 118(W)mm

Featured in EPE December 2011

Deluxe Motor Speed Controller Kit

KC-5478 £36.25 plus postage & packing

The deluxe motor speed controller kit allows the speed of a 240VAC motor to be controlled smoothly from near zero to full speed. The advanced design provides improved speed regulation & low speed operation. Also features soft-start, interferences suppression, fuse protection and over-current protection. Kit supplied with all parts including pre-cut metal case.

Note: Requires UK Mains socket or adaptor.

Featured in EPE May 2011

Jaycar Electronics

Freecall order: 0800 032 7241

Arduino - Simple to Advanced Projects

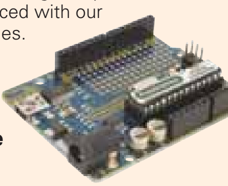
ARDUINO DEVELOPMENT KITS

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs (includes Jaycar stepper motors). Arduino projects can be stand-alone, or they can be communicated with software running on your computer. These Arduino development kits are 100% Arduino compatible. Designed in Australia and supported with tutorials, guides, a forum and more at www.freetronics.com. A very active worldwide community and resources are available with many projects, ideas and programs available to freely use.

"Eleven" Arduino-compatible development board

XC-4210 £14.50 plus postage & packing

An incredibly versatile programmable board for creating projects. Easily programmed using the free Arduino IDE development environment, and can be connected into your project using a variety of analog and digital inputs and outputs. Accepts expansion shields and can be interfaced with our wide range of sensor, actuator, light, and sound modules.



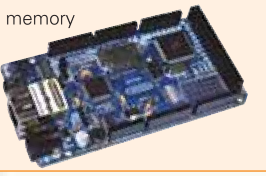
- ATmega328P MCU running at 16MHz
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs

EtherMega, Mega sized Arduino compatible with Ethernet

XC-4256 £43.25 plus postage & packing

The ultimate network-connected Arduino-compatible board: combining an ATmega2560 MCU, onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, Power-over-Ethernet support, and even an onboard switchmode voltage regulator so it can run on up to 28VDC without overheating.

MORE INFO AVAILABLE ONLINE

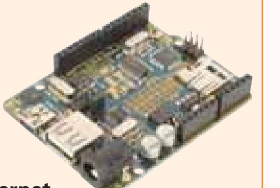


- ATmega2560 MCU running at 16MHz, large Flash memory
- 10/100base-T Ethernet built in
- 54 digital I/O lines
- 16 analog inputs
- MicroSD memory card slot
- Prototyping area
- Switchmode power supply

USB Droid, Arduino-compatible with USB-host support

XC-4222 £25.50 plus postage & packing

This special Arduino-compatible board supports the Android Open Accessory Development Kit, which is Google's official platform for designing Android accessories. Plugs straight into your Android device and communicates with it via USB. Includes a built-in phone charger.



- ATmega328P MCU running at 16MHz
- USB host controller chip
- Phone charging circuit built in
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs
- MicroSD memory card slot

EtherTen, Arduino-compatible with Ethernet

XC-4216 £25.50 plus postage & packing

This Arduino-compatible development board includes onboard Ethernet, a USB-serial converter, a microSD card slot for storing gigabytes of web server content or data, and even Power-over-Ethernet support.

- ATmega328P MCU running at 16MHz
- 10/100base-T Ethernet built in
- Used as a web server, remote monitoring and control, home automation projects
- 14 digital I/O lines (6 with PWM support)
- 8 analog inputs

Getting Started with Arduino

BM-7130 £7.25 plus postage & packing

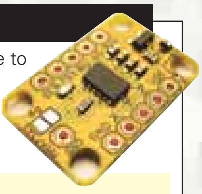
This book explains what Arduino is, how it works and what you can do with it. It also includes a project to build, complete with how to write the code to make it work.

- Softcover, 118 pages. 216 x 140mm

BOOK

Arduino Modules

We have a huge range of simple to advanced add-ons that provide input for your Arduino projects. Visit our website for our full range and more details.

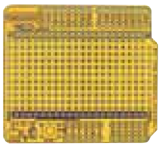


N-MOSFET Driver & Output Module	XC-4244	£2.75
Logic Level Converter Module	XC-4238	£2.75
Shift Register Expansion Module	XC-4240	£2.75
Light Sensor Module	XC-4228	£3.75
Sound & Buzzer	XC-4232	£3.75
Microphone Sound Input Module	XC-4236	£3.75
Hall Effect Magnetic & Proximity Sensor Module	XC-4242	£3.75
Full Colour RGB LED Module	XC-4234	£3.75
Temperature Sensor Module	XC-4230	£6.25
3-Axis Accelerometer Module	XC-4226	£7.25
Humidity & Temperature Sensor Module	XC-4246	£7.25

ProtoShield Basic

XC-4214 £1.75 plus postage & packing

A prototyping shield for the Eleven (XC-4210) and USBDroid (XC-4222) both featured above. Provides plenty of space to add parts to suit any project, keeping everything neat and self-contained. Includes dedicated space to fit a power LED and supply decoupling capacitor.



- Gold-plated surface

OLED Display Module for Arduino

XC-4270 £18.25 plus postage & packing

High resolution, full colour OLED display module! Perfect for graphics, gauges, graphs, even make your own video game or interactive display.

NEW

- 16,384 full colour RGB pixels in a 128 x 128 format
- Active display area 28.8 x 26.8 mm, (1.5 inch diagonal)

Light Sensor Module for Arduino

XC-4228 £3.75 plus postage & packing

This silicon light sensor outputs a voltage proportional to incoming light. Perfect for measuring light levels both indoors and out, security sensing and human feedback like waving a hand over the sensor.

NEW

- +/-60° field of view
- Supply voltage: 3.0 to 5.5VDC

ProtoShield Short

XC-4248 £2.00 plus postage & packing

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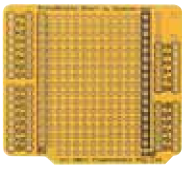

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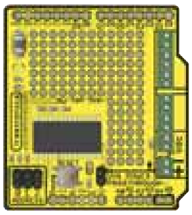

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NEW

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Keep your computer safe

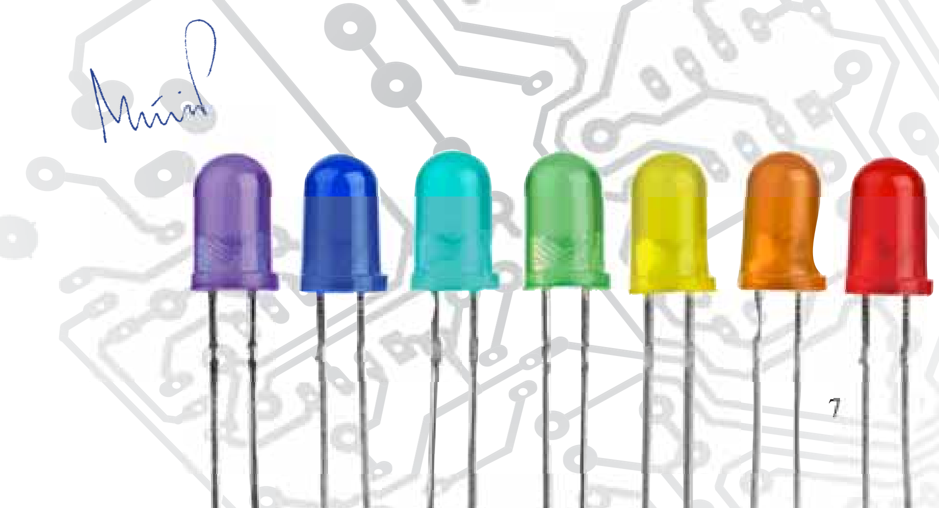
Well, it had to happen. In last month's *Readout*, I wrote a rather long and detailed explanation of why I thought Apple Mac computers were, on balance, safer from software nasties than Windows-based PCs. As luck would have it, within a week of publication the BBC ran a 'front-page' story entitled: 'Half a million Mac computers 'infected with malware'' You can read the article at: www.bbc.co.uk/news/science-environment-17623422. It was a salutary reminder that no computer – Macs included – are immune from malicious software, email attachments, websites and all the other unpleasant code that can catch out the unwary. Please do remember to keep your computer safe, whatever brand. Alan Winstanley's must-read *Net Work* column is the best place to get up to speed on safety. So, if you've been putting off protecting your computer, now is the time to follow his advice. Why not look back through past issues of *EPE* and adopt Alan's excellent recommendations.

There has been quite a bit of noise in the UK media recently about the teaching of ICT (information and communications technology). Promises to overhaul what most commentators agree is a stale and uninspiring curriculum are to be welcomed. Endless lessons in using the Internet, learning wordprocessing and how to give a PowerPoint presentation would kill the technological spirit in all but the most dedicated pupil.

There have been calls for a 'back-to-basics' approach to coding, and the recent launch of the Raspberry Pi computer is a welcome British innovation that should help this sensible proposal, but beyond that there is a depressing lack of ambition. Surely, a country with our proud heritage in electronics could aim higher than programming other country's computers? Who will design a future Raspberry Pi if all children are taught is how to use technology? Programming should be just part of the mix – I would like to hear a little more on 'how to make' technology.

Perhaps, the state of technological education is a reflection of the people we elect. I used Wikipedia to look at the university education of the coalition government cabinet – not one secretary of state had studied physics, chemistry, biology, medicine, mathematics or heaven forbid, any kind of engineering. And this isn't even a party political point; the Shadow Cabinet is equally ignorant of what makes the world go round – truly a depressing result.

But let's end on an upbeat note. This month's packed issue of *EPE* is full of engineering goodness. Robert Penfold has written a thorough, in-depth review of Pico Technology's Picoscope 6; the father and son Tooley team have built a fun 'Quiz Machine' for our new *Jump Start* series; and of course, we have a silicon-filled collection of fascinating projects and regular features to keep you busy.



NEWS

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

‘It’s good to talk’... for less... even better for free by Barry Fox

The price of unlocked smartphones and tablets is dropping dramatically – but they come with no help on how to use them online without signing a contract to pay at least £15 a month for a year or more. It pays to know some tips and tricks.

Wi-Fi comes free in any house or office with a broadband wireless router. Installing a Skype app lets the device work as a free phone for speech and video calls to and from other Skype users.

Buying Skype credit lets the device make low cost phone calls to ordinary phones and mobiles, and send SMS texts at low cost too. Receiving calls by Skype is impractical, so the trick is to use a pay as you go phone SIM for incoming calls.


Not just a pretty face – with a few apps, smartphones or tablets can cut your phone bill

Skype provides for automatic credit top-up using a pre-registered credit card; for example, users can add £10 when remaining credit drops below £1, which is useful for foreign travel.

Making use of hotspots

Wi-Fi ‘hotspots’ at upmarket hotels and airports still charge pounds per hour. But budget hotels and most cafes and bars now offer free Wi-Fi. The Olympics will see this spread to tube stations and streets around parts of London.

Although not yet clearly promoted, BT’s new BT Fon/Openzone service already provides free Wi-Fi roaming for anyone who has BT Broadband at home or in the office. The user’s password works with BT Wi-Fi signals coming from third-party home routers, BT callboxes and hotspots.

A free BT Fon app for a mobile automatically finds a working BT hotspot and connects to it.

A 3G data connection is, of course, needed for Internet access ‘in the wild’. The SIM can slot into the mobile device, USB dongle or pocket hotspot like the Huawei Mi-Fi, which connect to a 3G data network and radiates the connection by Wi-Fi.

Pay as you go options

All the cellphone networks now sell pay-as-you-go (PAYG) SIMs for unlocked phones, but these are predominantly intended for speech and text, sometimes with a little data thrown in. For example, £3 a month buys a ‘bolt-on’ for an O2 PAYG phone SIM that delivers 100MB of ‘free’ data. Or £5 (paid online) buys 150MB with a Three PAYG SIM. This lasts three months before expiry, and is enough for checking email, googling a few facts and pulling down a few maps for GPS locating.

The new free Lebara PAYG SIMs, with minimum £5 speech top up, deliver 10MB a day either free, or for 50p a day, depending on which of Lebara’s puzzling and conflicting advice notes proves to be correct.

So far, no phone SIM will work in a USB dongle or Mi-Fi device. The sneaky way round this is to use a smartphone with a hotspot option, or install Joiku software. The phone then behaves like a Mi-Fi, which other devices can use to get a Wi-Fi connection.

To get a mobile broadband SIM intended for use in a dongle or Mi-Fi, it’s currently necessary to buy a new dongle or Mi-Fi, even though the user may already have one, which is a madness Ofcom will hopefully soon address. The PAYG cost is then around £10 per GB, with credit often expiring after a month.

Vodafone used to offer a PAYG mobile data dongle SIM with credit that never expired. But Vodafone withdrew the service and has been disconnecting.

Vodafone’s customer service in India explains why and how: ‘The reason that SIM card gets disconnected is explained as below (bit technical): When the number is not used for a particular amount of time, the SIM stays active but slowly and gradually it starts going down and becomes inert….’

Links

www.skype.com
www.btfon.com
www.lebara.co.uk
www.joiku.com

SEEING THE WORLD THROUGH GOOGLE'S GOGGLES

'Googlespex': a future man-machine interface?

Search engine giant Google has posted a video (www.youtube.com/watch?v=9c6W4CCU9M4) called 'One day…'. It demonstrates a pair of futuristic glasses that projects a head-up display on to the user's field of vision, with maps, augmented reality notes, video calls and reminders. It is also integrated with speech recognition and artificial intelligence, so you can talk to your glasses, dictate notes, ask questions and perhaps look a little odd as you walk down the street talking to yourself.

Google's press release states: 'We believe technology should work for you – to be there when you need it, and get out of your way when you don't. A team within our Google[x] group started Project Glass to build this kind of technology, one that helps you explore and share your world, putting you back in the moment.

Follow along with us at: http://g.co/projectglass as we share some of our ideas and stories. We'd love to hear yours, too. What would you like to see from Project Glass?'

Google has released very few technical details, so it's hard to be sure how much of the video is a real-time working presentation, and how much is wishful thinking. That said, Google is one of the few companies to have the financial clout and technical knowhow to pursue this kind of man-machine interface project.

Microchip simplifies C compiler line

Microchip has simplified its range of C compilers for all 900 PIC microcontrollers and dsPIC digital signal controllers. The MPLAB XC8, XC16 and XC32 compilers offer reduced complexity for 8-, 16- and 32-bit designers, with three cost-effective optimisation levels: free, standard and pro. In addition, MPLAB XC provides support for the Linux, Mac OS and Windows operating systems, enabling designers to use their platform of choice for embedded development.

Another important consideration for today's designers, is the ability to re-use their code and easily migrate to the level of microcontroller performance and features that best suits the needs of each project. These have always been strengths for Microchip, and MPLAB XC continues that tradition by making it easy to move code from any of Microchip's existing compilers. Additionally, MPLAB XC completes Microchip's toolchain of compatible compilers and debugger/programmers that operate seamlessly within the universal, cross-platform and open-source MPLAB XC integrated development environment, to reduce both learning curves and tool investments. MPLAB XC compilers are also compatible with the legacy MPLAB IDE.

Many designers need a free C compiler: the 8-, 16- and 32-bit free editions of Microchip's MPLAB XC compilers offer many optimisations, are fully functional and have no license restrictions for commercial use. For those who want to test their code with the pro optimisation levels, which are approximately 50% better than the free editions, Microchip also offers 60-day evaluation editions with pro optimisation, which revert to the free compilers after the evaluation period. Like the free editions, the evaluation editions are fully functional and have no license restrictions for commercial use.

To download free versions, or evaluate the increased code and speed optimisations available with paid-for options, PIC programmers should visit: www.microchip.com/get/E1C4

A compiler for every OS, PIC and wallet

Raspberry Pi ship dates

After a couple of hitches – a wrong component used and then questions about EMC – the Raspberry Pi organisation has announced (12 April) that 'RS Electronics and element14/Premier Farnell are preparing over the weekend to send out the first boards'.

In fact, according to a BBC report, some users have already received their boards. The first were school children in Leeds, in keeping with the stated purpose of the cheap, but powerful computer board – bringing low cost, powerful programming capability to Britain's next generation of computer scientists.

Raspberry Pi expects users to have received their boards by 20 April. For more details, see: www.raspberrypi.org

RIP power silicon?

Cloud computing and carbon emissions controls may see the extinction of the silicon semiconductor, as the power market demands superior products.

According to a new report by GBI Research, the substrate technologies used in the manufacturing of discrete power devices have been improved, offering better efficiency for the technology and power markets.

Silicon (Si) was the material originally used to make power semiconductors. However, this has evolved to include silicon carbide (SiC), gallium nitride on silicon (GaN-on-Si), gallium nitride (GaN), and gallium arsenide (GaAs), which offer improved performance. These new substrate technologies enable systems to use higher levels of power, wider bandwidth, and better efficiency compared to conventional silicon solutions.

Businesses with continuously running applications need infrastructure in the form of cloud computing or data centers. To enable more efficient and robust systems, data centers and UPS systems are built with high-performance semiconductor components, such as IGBTs and super-junction power MOSFETs. And, as datacenters grow, so too does the power semiconductor market.

Furthermore, at the 2008 G8 summit, member nations agreed to reduce global emissions by at least 50% before 2050. Electrically-operated vehicles will increase the demand for power discretes, and IGBTs and MOSFETs are the predominant power semiconductors used in this segment.

Digital Insulation Meter

By JIM ROWE

Think all your double-insulated power tools are safe, just because they <u>are</u> double insulated? As many have found to their ultimate cost, wear and tear on tools can mean that they become decidedly unsafe. Here's a meter that will give you back your peace-of-mind – on tools and many other electrical and electronic devices.

THIS is actually an improved version of the *Digital Megohm and Leakage Current Meter* we described in the September 2011 issue of *EPE*.

Our original design had a distinctly mixed reception from some of our readers. It could be summed up as 'OK but ….'

The first 'but' was that it would not deliver the nominal test voltage of 1000V or 500V DC into the minimum load resistance of one megohm, as specified in the relevant Australian Standard, ie, AS/NZS 3760:2003 – similar to the UK's IEE regulations.

The reason for this drawback was largely because we had set the internal current limit too low, and partly because the DC-DC converter could not deliver the current required, even if the current-limiting resistor had been removed.

Furthermore, some readers pointed out that the test voltage of 500V DC was too high for testing insulation of equipment with EMI suppression and MOVs (metal oxide varistors). These devices should be tested at no more than 250V DC.

Faced with that criticism, all we could do was to revise the design so that (a) the inbuilt DC-DC converter can deliver the full test voltage into a 1MΩ resistor, and (b) provide the additional test voltage of 250V DC. In fact, the new circuit can deliver the test voltage of 250V or 500V into a load of 100kΩ, if required, for the testing of portable RCDs (residual current devices).

Warning – read this first!

1) This is an educational project that lets you investigate electrical safety and insulation in portable equipment. It is NOT a substitute for a professionally built and certified 'PAT' tester.

2) It was designed for use in Australia / New Zealand. While their requirements are very similar to the those in the UK, you cannot assume they are identical.

3) If you are in any doubt about the safety of a piece of equipment then get it checked professionally.

4) This is not a beginner's project – only use it if you know what you are doing or are suitably supervised.

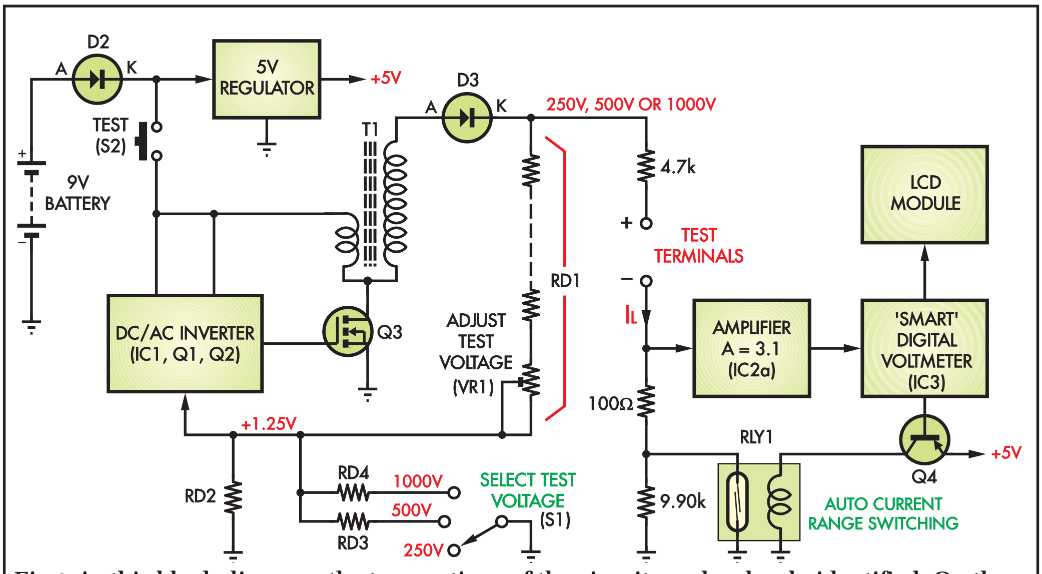


Fig.1: in this block diagram, the two sections of the circuit can be clearly identified. On the left is the power supply, consisting of a regulated 5V plus a high-voltage supply. On the right is the metering and display unit. These can be seen in the two separate PC boards below.

The physical presentation of the new meter is also quite similar to the original, except that it now has a 3-position switch to select from the test voltages of 250V, 500V or 1000V DC. Apart from the redesigned inverter section, the revised meter now has two current ranges instead of one, under the control of a PIC microcontroller.

As before, the *Digital Insulation Meter* is easy to build, with most of the major components mounted directly on two small PC boards. These fit snugly inside a compact UB1-size plastic box, along with a 6×AA batteryholder used to supply the meter's power.

It can be built up in a few hours and for an outlay much lower than commercially available electronic megohm meters.

To summarise, it can now test at 250V, 500V or 1000V, and can measure leakage currents from below 1µA to above 6mA. Also, it can measure insulation resistance from below 1MΩ up to 999MΩ.

How it works

The block diagram of Fig.1 shows the arrangement of the new meter with its somewhat more complex DC-to-DC converter. This is on the left-hand side.

The metering section, on the right side of the diagram, is used to measure any leakage current which flows between the test terminals, and from this it calculates the external resistance connected between them (knowing the test voltage in use).

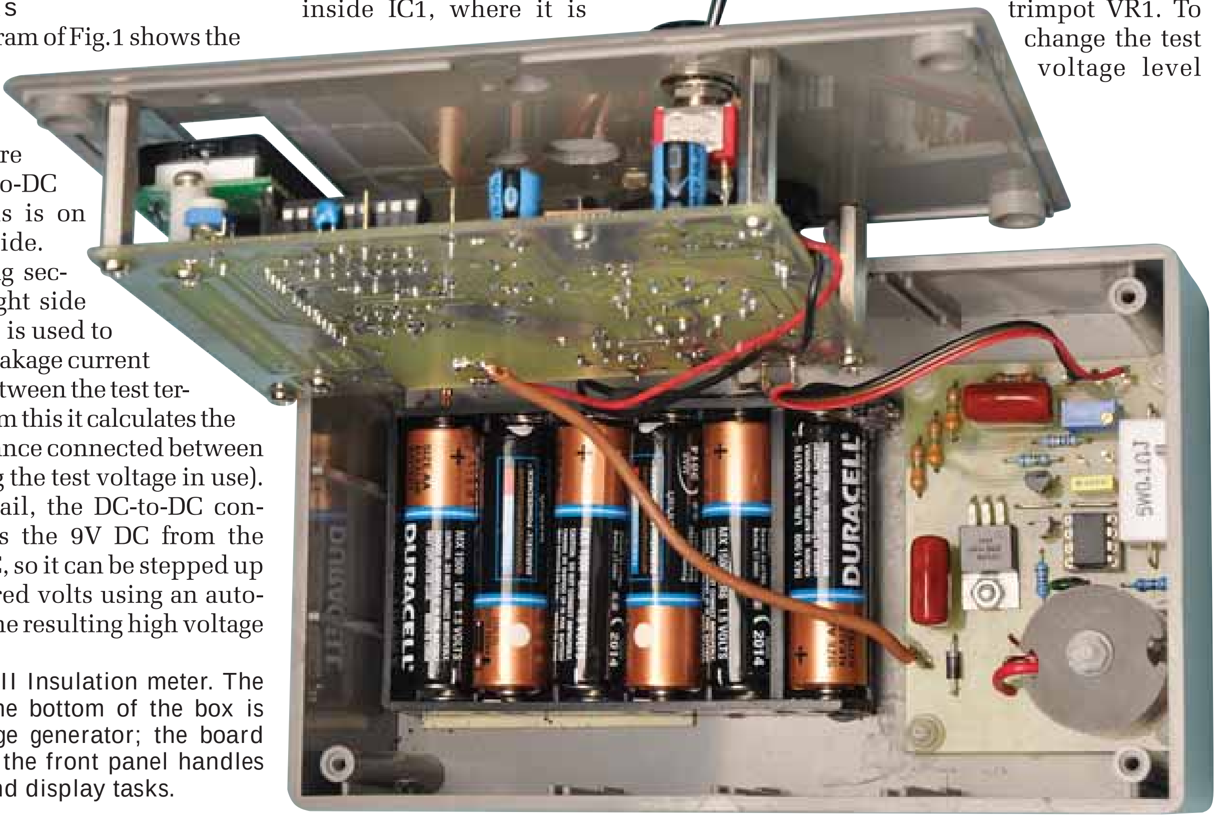
In more detail, the DC-to-DC converter converts the 9V DC from the battery into AC, so it can be stepped up to a few hundred volts using an autotransformer. The resulting high voltage AC is then rectified using ultra-fast diode D3 to produce the test voltage of 250V, 500V or 1000V DC.

Feedback divider

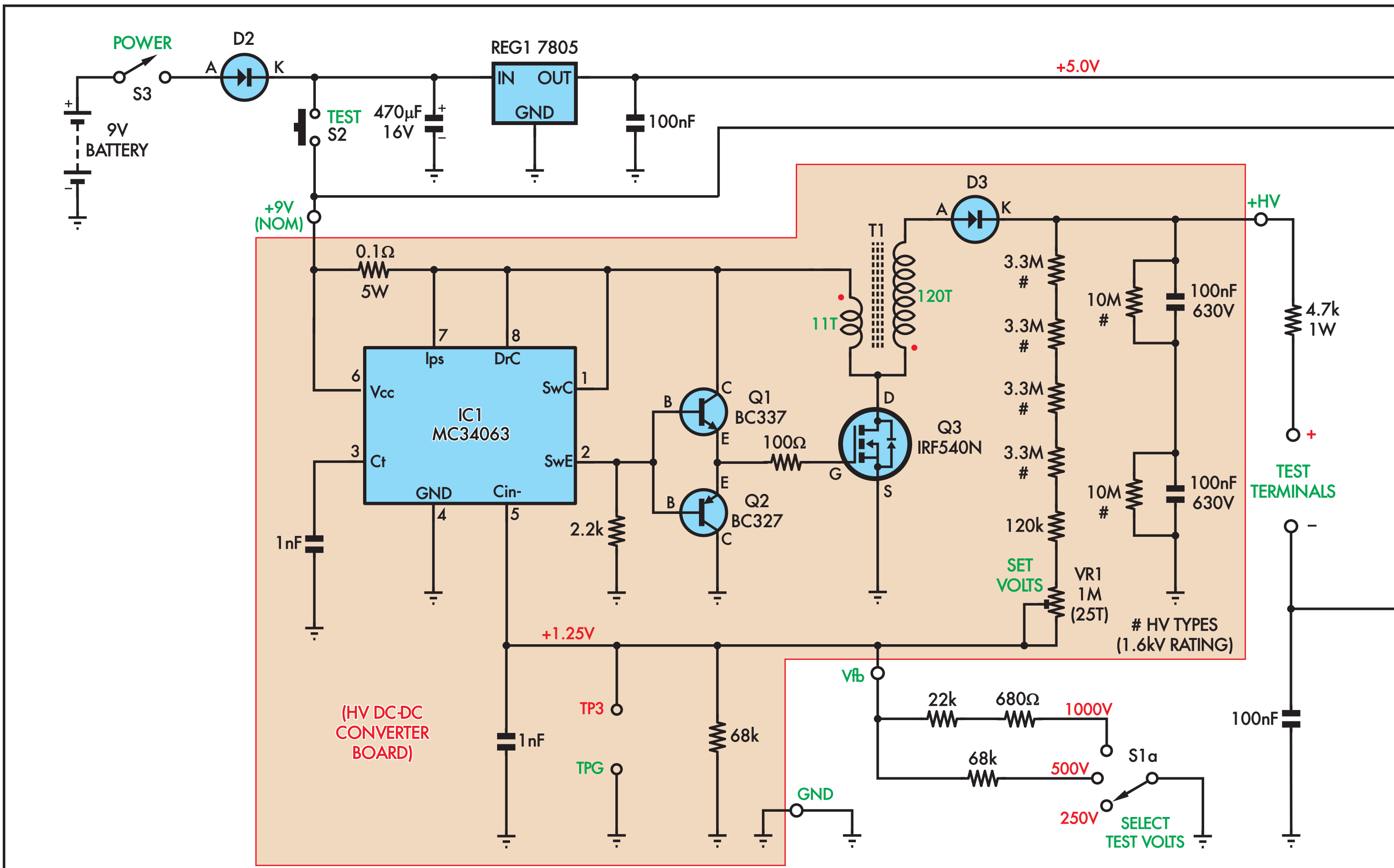
We use negative feedback to control the converter's operation and maintain its output voltage at the correct level. The feedback uses a voltage divider (RD1 and RD2) to feed a small proportion of the high voltage DC output back to one input of a comparator inside IC1, where it is compared with an internal 1.25V reference voltage.

The output of the comparator is then used to control the operation of the DC-to-DC converter, turning it on when the output voltage is below the correct level and turning it off again when the output voltage reaches the correct level.

The basic voltage divider using RD1 and RD2 alone is used to set the high voltage level to 250V, with multiturn trimpot VR1. To change the test voltage level



Inside our Mk II Insulation meter. The PC board in the bottom of the box is the high voltage generator; the board 'hanging' from the front panel handles the metering and display tasks.



DIGITAL INSULATION METER

Fig.2: the circuit is based around a PIC16F88 microprocessor, which measures the current between the test terminals (and therefore the device under test). The high voltage DC-to-DC converter supplies up to 1000V for these tests, in accordance with the relevant Australian/New Zealand standards. It can also supply lower voltages (250V and 500V) as required.

to 500V or 1000V, switch S1 is used to connect RD3 or RD4 in parallel with RD2, increasing the division ratio of the divider, and hence increasing the output voltage maintained by the feedback loop.

Note that the converter generates the test voltage only when TEST button switch S2 is pressed and held down. As soon as the button is released, the converter stops, and the high voltage leaks away via RD1 and RD2/RD3/RD4. This is both a safety feature and a simple way to achieve maximum battery life.

Meter section

Referring back to Fig.1, the meter section uses a shunt resistor connected between the negative test terminal and ground to sense any leakage current (I_L) that may flow between the test terminals. It is the voltage across this resistor which we measure, to determine the leakage current. The effective shunt resistance is switched between 100Ω and 10kΩ to give the meter two measurement ranges. The switching is done using relay RLY1, under the control of the PIC microcontroller (IC3) inside the metering circuit.

Initially, the shunt has a value of 100Ω, which means that a leakage current of 10mA produces a voltage drop of 1.00V. This provides the 'high current' measuring range. If and when the measured leakage current falls below 100µA, relay RLY1 is turned off to increase the effective shunt resistance to 10kΩ. This provides the 'low current' measuring range, where a leakage current of 100µA produces a voltage drop of 1.00V.

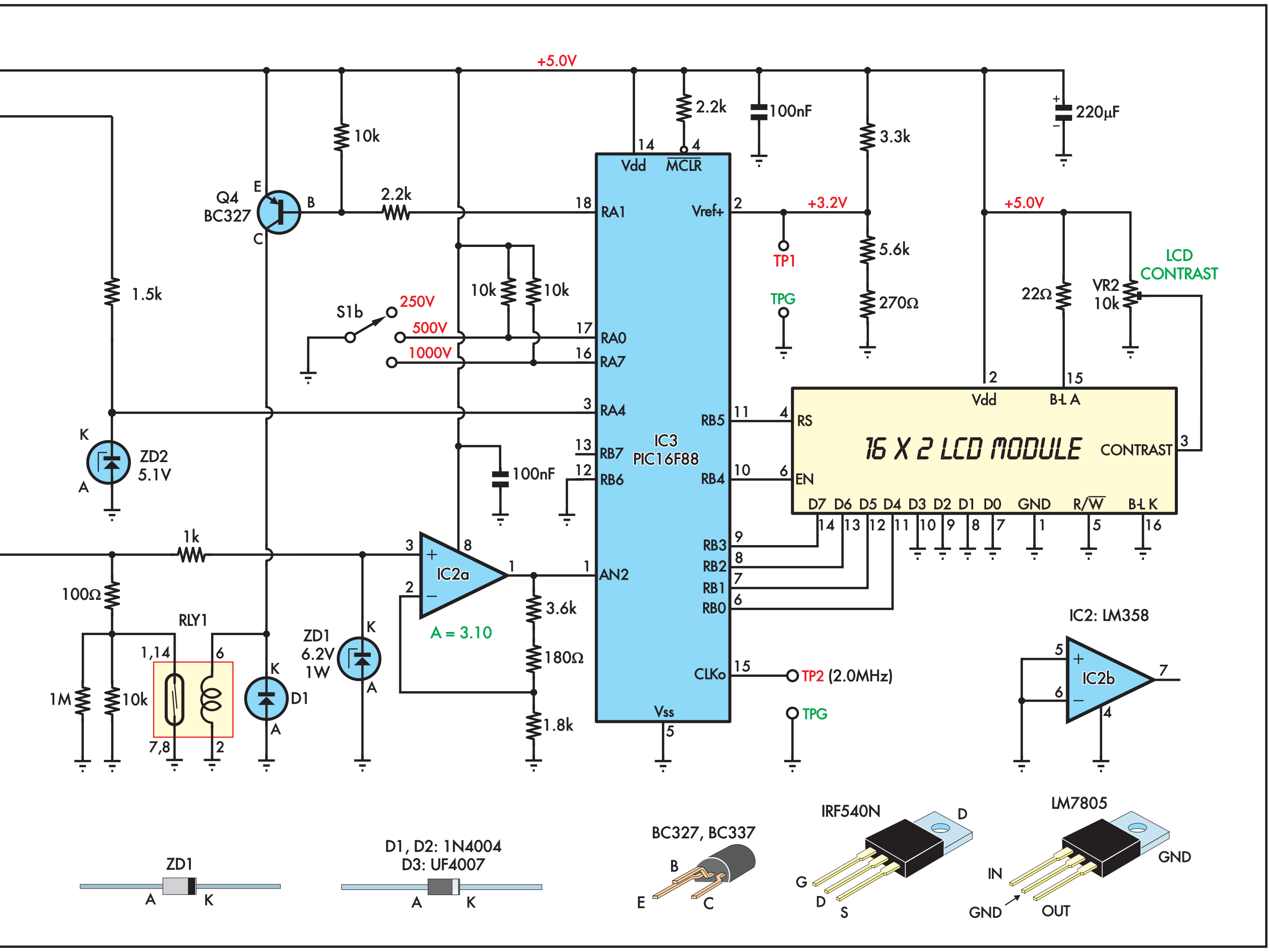
If this shunt resistance relay switching looks familiar, that's because we used a similar arrangement in the *Capacitor Leakage Meter* published in the Nov'11 issue, and in the *Capacitor Leakage Adaptor for DMMs* in the April 2012 issue.

The voltage drop across the shunt resistance is fed through op amp IC2a, which has a voltage gain of 3.1 times. IC2a drives IC3, a PIC16F88 microcontroller, which is used as a 'smart' digital voltmeter.

The amplified voltage from IC2a is fed to one input of the ADC (analogue-to-digital converter) module inside IC3, where it is compared with a reference voltage of 3.2V. The digital output of the ADC is then mathematically scaled, to calculate the level of the leakage current in milliamps or microamps.

IC3 is then able to use this calculated current level to work out the insulation resistance, because it can sense the position of switch S1 and hence 'knows' whether the test voltage being used is 250V, 500V or 1000V.

So, all it has to do is calculate the total resistance which will draw that level of leakage current from the known



test voltage, and then subtract the 'internal' 4.7kΩ and 100Ω/10kΩ resistors from this total value to find the external resistance between the test terminals. The calculated leakage current and insulation resistance values are then displayed on the LCD, along with the test voltage being used.

In case you're wondering about the purpose of the 4.7kΩ resistor connected between the high voltage generation circuit and the positive test terminal (ie, inside the meter), it's mainly to limit the maximum current that can be drawn from the DC-to-DC converter – even in the event of a short circuit between the test terminals.

This should make the meter relatively safe to use, especially as it won't be too easy to connect yourself between the two test terminals while simultaneously holding down the Test button.

Of course, if you're really determined to give yourself a shock it can be done, but we wouldn't recommend it!

Incidentally, if you do deliberately short circuit the output terminals while pressing the test switch (S2), you will burn out the 4.7kΩ 1W current-limiting resistor; it can be regarded as a fusible resistor. You will then have to replace the resistor. but at least the rest of the circuit will have been protected.

If you suspect that you have blown the 4.7kΩ resistor by shorting the output, test the output voltage of the unit with your DMM on a high DC 'volts' range. If there is voltage, it's still working!

Circuit details

Now let's look at the full circuit diagram of the *Digital Insulation Meter* (Fig.2). The DC-to-DC converter is based on IC1, an MC34063 converter/controller that drives MOSFET Q3 via driver transistors Q1 and Q2. When the inverter is operating, the transistors switch Q3 on for a brief time (about 50µs), which allows current to flow from the +9V supply through the primary winding of transformer T1.

As a result, energy is stored in T1's magnetic field. Then Q3 is switched off again, causing the magnetic field to collapse. This causes a high 'back-EMF' voltage to be generated in both windings of T1, which are connected in auto-transformer fashion, so that the total voltage applied to the anode (A) of diode D3 is equal to the sum of the back-EMF in both windings, plus the 9V supply voltage.

Diode D3 then conducts to charge up the series-connected 100nF/630V capacitors to this high voltage. Both of these capacitors have a 1.6kV-rated 10MΩ shunt resistor included to ensure that the converter's high output voltage is shared equally between them. This is only important when the test

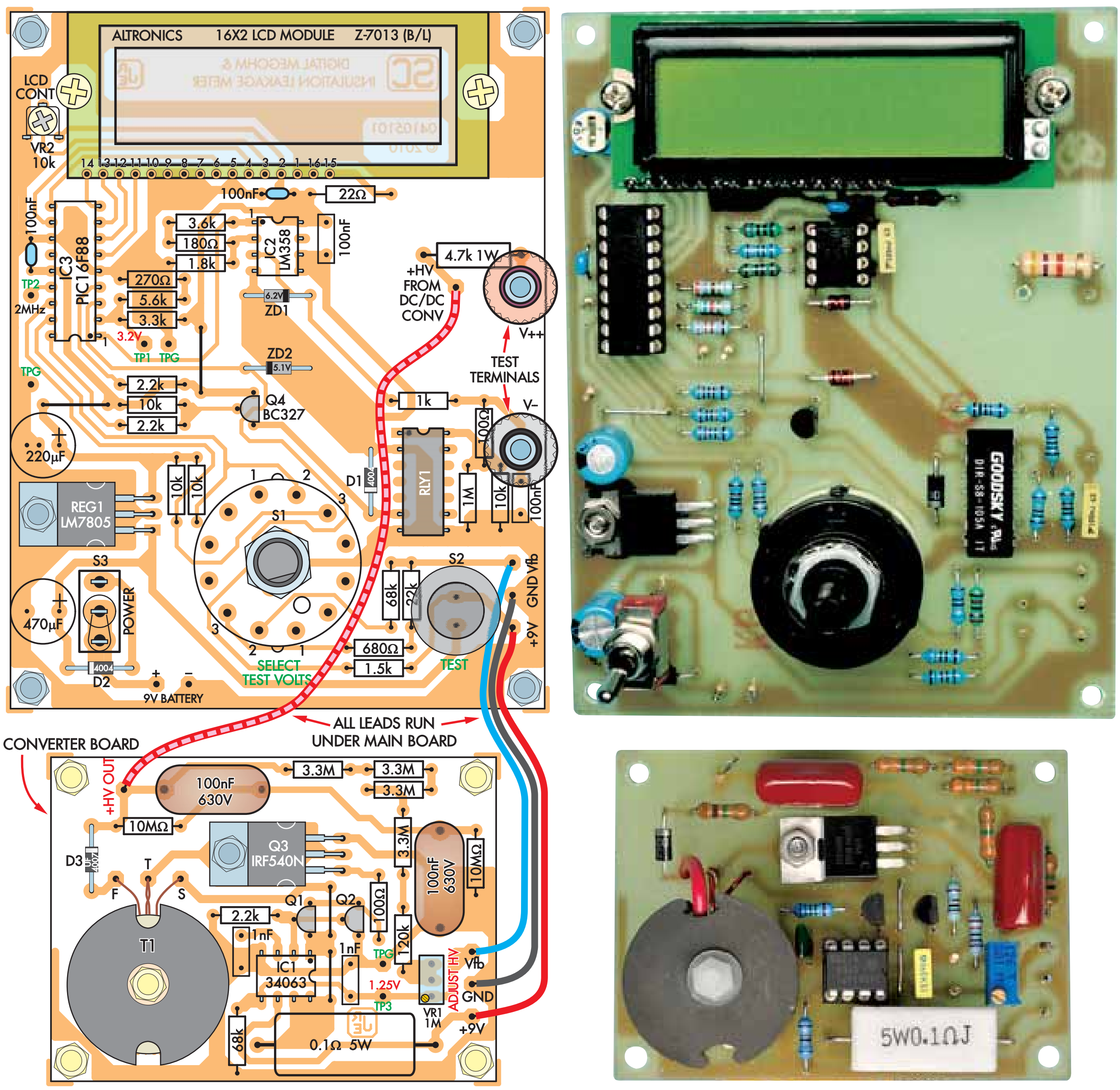


Fig.3: component layouts for both the main (measurement/display) PC board (top) and the high voltage DC-to-DC converter PC board (bottom), along with matching photographs alongside. Follow these diagrams exactly, not only to ensure your unit works perfectly, but also to minimise the risk of you getting a 'bite'. (It probably won't do any damage, but why risk it!)

voltage setting is 1000V – we want to ensure that neither capacitor has its 630V rating exceeded.

The four 3.3MΩ high-voltage resistors, together with the 120kΩ resistor and trimpot VR1, correspond to the upper divider resistor RD1 in Fig.1. The 68kΩ resistor connected between pin 5 of IC1 and ground corresponds to RD2, the fixed lower leg of the feedback divider, which provides the converter's 250V output voltage. The other 68kΩ resistor switched by S1a corresponds to RD3, while the 22kΩ and 680Ω resistors connected in series correspond to RD4.

Providing S2 is on, the converter will continue to run until the high voltage output reaches the correct level. That's because until this level is reached, the proportion of the output voltage fed back to the comparator input (pin 5) of IC1 will not reach the +1.25V reference level inside IC1. However, as soon as the high voltage output does reach the correct level, the proportion fed back to pin 5 will rise just above 1.25V, and IC1 will stop turning Q3 on – stopping the converter even if S2 is still being held down.

The converter gets its power directly from power switch S3 (via S2 and D2), so it is supplied with the full battery voltage, less the drop in D2. All of the remaining circuitry in the meter operates from a regulated +5V supply line, derived from the battery via REG1, an LM7805 3-terminal regulator.

Smart metering

The metering side of the circuit is fairly straightforward, thanks to the use of a PIC16F88 micro (IC3). As noted before, the signal from op amp IC2a is fed to pin 1 of IC3, which is configured as ADC input channel AN2, and the

PARTS LIST – DIGITAL INSULATION METER

*1 PC board, code 849 (Main/Dis), 109mm × 84mm
*1 PC board, code 850 (DC-DC Conv), 70mm × 51mm
1 UB1-size plastic box, 157mm × 95mm × 53mm
1 LCD module, 2 lines × 16 characters with LED back-lighting (Altronics Z-7013, Jaycar QP-5512 or equivalent)
1 Ferrite pot-core pair, 26mm OD, with bobbin to suit
1 500mm length of 0.7mm diameter enamelled copper wire
1 8m length of 0.25mm diameter enamelled copper wire
1 100mm length 0.7mm diameter tinned copper wire
1 10× AA batteryholder (flat), cut down to 6×
1 2-pole rotary switch, PC board mounting, with 16mm knob (S1)
1 SPST pushbutton switch, panel mounting (S2)
1 SPDT mini toggle switch, panel mounting (S3)
1 Mini DIL reed relay, SPST with 5V coil
2 Binding post/banana jacks (1 red, 1 black)
2 4mm solder lugs
1 16-pin length of SIL socket strip
1 16-pin length of SIL pin strip
1 18-pin IC socket
2 8-pin IC sockets
4 25mm M3 tapped metal spacers
2 12mm M3 tapped nylon spacers
11 6mm M3 machine screws, pan head
4 6mm M3 machine screws, csk head
3 M3 hex nuts, metal
4 12mm M3 machine screws, nylon
1 25mm M3 machine screw, nylon
9 M3 hex nuts, nylon
6 M3 flat washers, nylon
12 1mm diameter PC board terminal pins

* Available as a pair from the *EPE PCB Service*

Software

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

WE DO NOT SUPPLY READY-PROGRAMMED MICROCONTROLLERS

Semiconductors
1 MC34063A converter controller (IC1)
1 LM358 dual op amp (IC2)
1 PIC16F88 programmed microcontroller (IC3)
1 LM7805 5V regulator (REG1)
1 BC337 *NPN* transistor (Q1)
2 BC327 *PNP* transistor (Q2,Q4)
1 IRF540N 100V *N*-channel MOSFET (Q3)
1 6.2V 1W Zener diode (ZD1)
1 5.1V 1W Zener diode (ZD2)
2 1N4004 1A diode (D1,D2)
1 UF4007 ultra-fast 1000V diode (D3)

Capacitors
1 470uF 16V radial electrolytic
1 220uF 10V radial electrolytic
2 100nF 630V metallised polyester
2 100nF 100V MKT metallised polyester
2 100nF multilayer monolithic ceramic
2 1nF 100V MKT metallised polyester

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Resistors (0.5W 1% metal film unless specified)

2 10MΩ HV*		4 3.3MΩ HV*		* HV (1.6kV rated)
1 1MΩ	1 120kΩ	2 68kΩ	1 22kΩ	eg MH25 series
4 10kΩ	1 5.6kΩ	1 4.7kΩ1W	1 3.6kΩ	Farnell 110-0295
1 3.3kΩ	3 2.2kΩ	1 1.8kΩ	1 1.5kΩ	(10MΩ) and Farnell
1 1kΩ	1 680Ω	1 270Ω	1 180Ω	110-0288 (3.3MΩ)
2 100Ω	1 22Ω	1 0.1Ω 5W wirewound		

1 1MΩ mini 25T vertical trimpot (VR1)
1 10kΩ mini horizontal trimpot (VR2)

microcontroller then makes its calculations to drive the LCD.

Once it has measured and calculated the leakage current in this way, the micro can then calculate the effective leakage resistance. This is because it is able to sense the position of test voltage selector switch S1, via the contacts of S1b which are connected to input pin 17 (RA0) and pin 16 (RA7). So, knowing the test voltage in use, it can calculate the total resistance connected between the test terminals. Finally, it then works out the external resistance between the terminals by subtracting the 4.8kΩ or 14.7kΩ internal resistance.

Both of the calculated current and resistance values are then displayed on the LCD module, along with the test voltage being used.

IC3 is using its internal clock oscillator, running at very close to 8MHz. This gives an instruction cycle time of 2MHz, which may be monitored using a scope or frequency counter at test point TP2.

Trimpot VR2 allows the LCD module's contrast to be adjusted for optimum visibility, while the 22Ω resistor connected to pin 15 sets the current level for the module's inbuilt LED back-lighting. This was chosen for the best compromise between display brightness and battery life, as the LED back-lighting is a major component of total battery current.

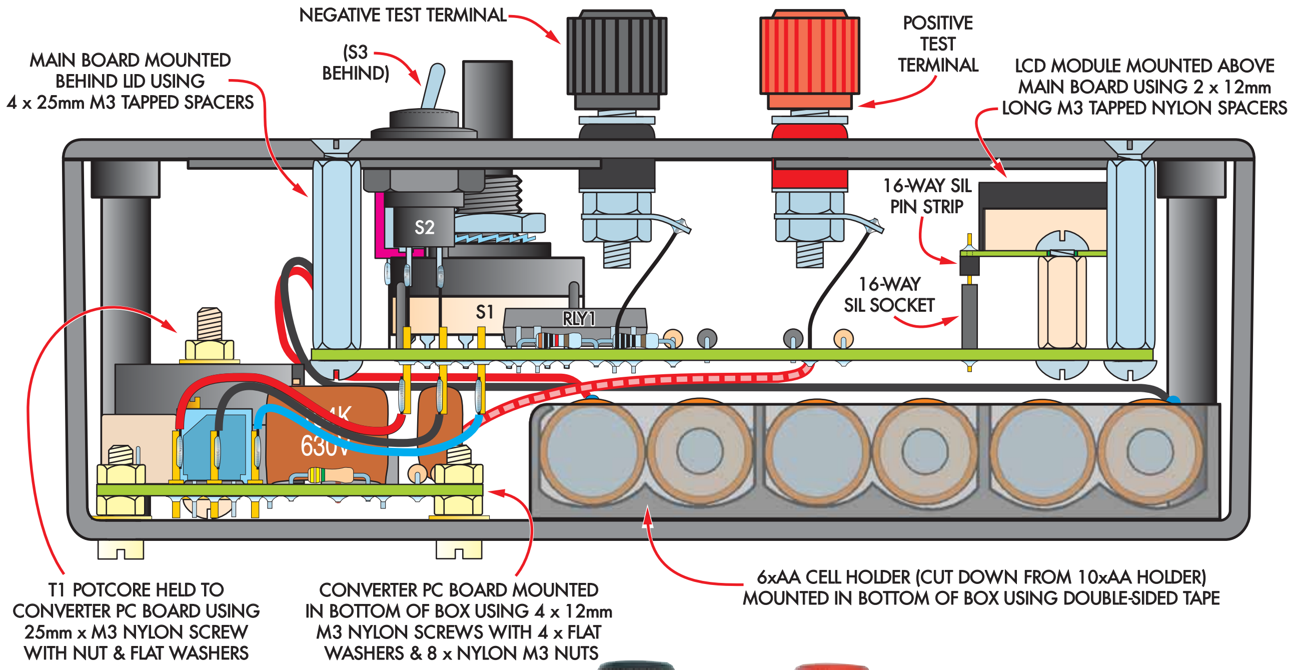
Construction

As you can see from the photos and diagrams, most of the components used in the new Digital Insulation Meter are mounted directly on two small PC boards.

The high voltage converter parts all mount on the smaller of the two boards, which measures 70mm × 51mm and is coded 850 (DC-DC Conv). This board sits in the bottom of the plastic box, at the front of the 6×AA cell batteryholder.

Most of the remaining components mount on the larger board, which measures 109mm × 94mm and is coded 849 (Mains/Dis). This board attaches to the underside of the box lid/front panel via four 25mm-long M3 tapped spacers.

The only components not mounted on either board are the test terminals, pushbutton switch S2 and power switch S3; these all mount directly on the box lid/front panel.



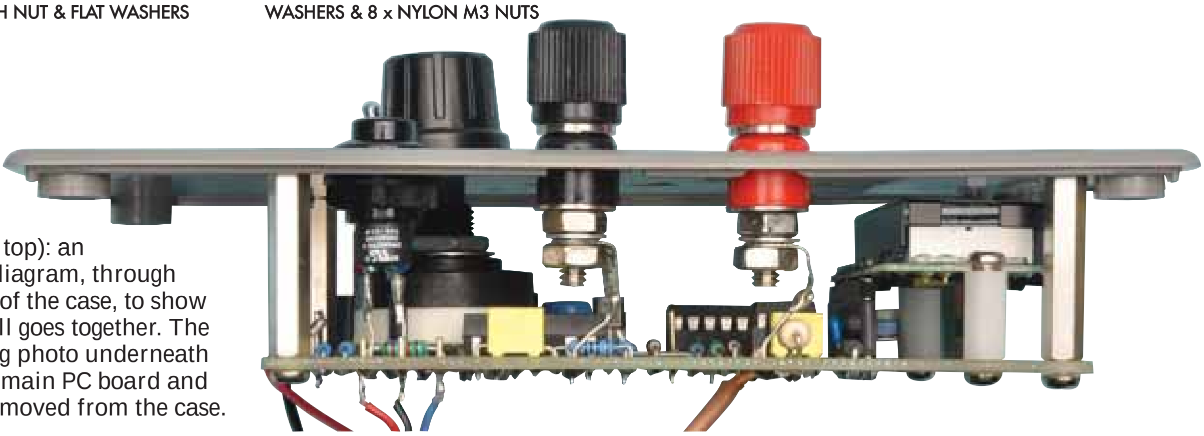


Fig.4 (at top): an 'X-ray' diagram, through the side of the case, to show how it all goes together. The matching photo underneath is of the main PC board and panel removed from the case.

The location of all of the components mounted on both boards, along with their correct orientation, should be clear from the overlay diagram, Fig.3.

There are only two wire links to be fitted to each board, so these are best soldered first so they won't be forgotten. After both pairs of links are in place, you can fit the terminal pins on the larger board: test points TP1 and TP2 and their reference grounds, plus those for the 9V battery connections (at lower left) and the three at lower right for the interconnections to the converter board.

There are a further six terminal pins to fit on the smaller board: for TP3 and its ground, the three interconnection wires to the larger board (at lower right) and finally for the high voltage output (upper left). Once the terminal pins have been fitted, you can fit the sockets for IC1 (on the smaller converter board), IC2 and IC3.

Next, come all of the fixed resistors, taking particular care to fit each value in its correct position. Follow these with the two trimpots, making sure you fit these with the orientation shown in Fig.3.

The capacitors are next, starting with the lower value ceramic and metallised polyester caps and following these with the 1nF (on the converter board) and the two polarised electrolytics on the main board – again matching their orientation to that shown in Fig.3. The 100nF 630V polyester caps can be fitted also at this stage.

After the capacitors, you can fit diodes D1 and D2 on the main board, and D3 (UF4007) on the converter board, taking care to orient them as shown in Fig.3. These diodes can then be followed by Zener diodes ZD1 and ZD2, which both go just above the centre of the main board. Note that these are oriented in opposite ways, as shown in Fig.3, and also that the 6.2V Zener is ZD1 while the 5.1V Zener is ZD2.

Now you can solder transistors Q1 and Q2 to the converter board, making sure that you fit the BC337 device as Q1. You can also fit the remaining BC327 transistor (Q4) on to the main board.

After the transistors, you can fit reed relay RLY1, making sure you position it with the 'notch' end uppermost, as indicated in Fig.3. Then comes the rotary switch (S1), after first cutting its spindle to a length of about 15mm from the threaded mounting sleeve, and filing off any burrs.

Mount the switch in the board so that it is oriented with the locating spigot in the '5 o'clock' position, and push the switch pins through the board holes as far as they'll go before soldering to the pads underneath.

Once the switch is fitted, you should remove its main nut/lockwasher/position stopwasher combination and turn the spindle by hand to make sure it's at the fully anticlockwise limit. Then refit the position stopwasher, making sure that its stop pin goes down into the hole between the moulded '3' and '4' digits.

After this, refit the lockwasher and nut to hold it down securely, allowing you to check that the switch is now 'programmed' for the correct three positions – simply by clicking it through them by hand.

Next, fit the LM7805 regulator (REG1) on the main board. This is in a TO-220 package and mounts flat against the top of the board, with its leads bent down by 90° about 6mm from its body, so that they pass down through the board holes. The regulator is then attached to the board using a 6mm-long M3 screw and nut, passing through the hole in its tab. The screw and nut should be tightened to secure the regulator in position *before* its leads are soldered to the pads underneath.

MOSFET Q3, also in a TO-220 package, is mounted on the smaller converter board in exactly the same way.

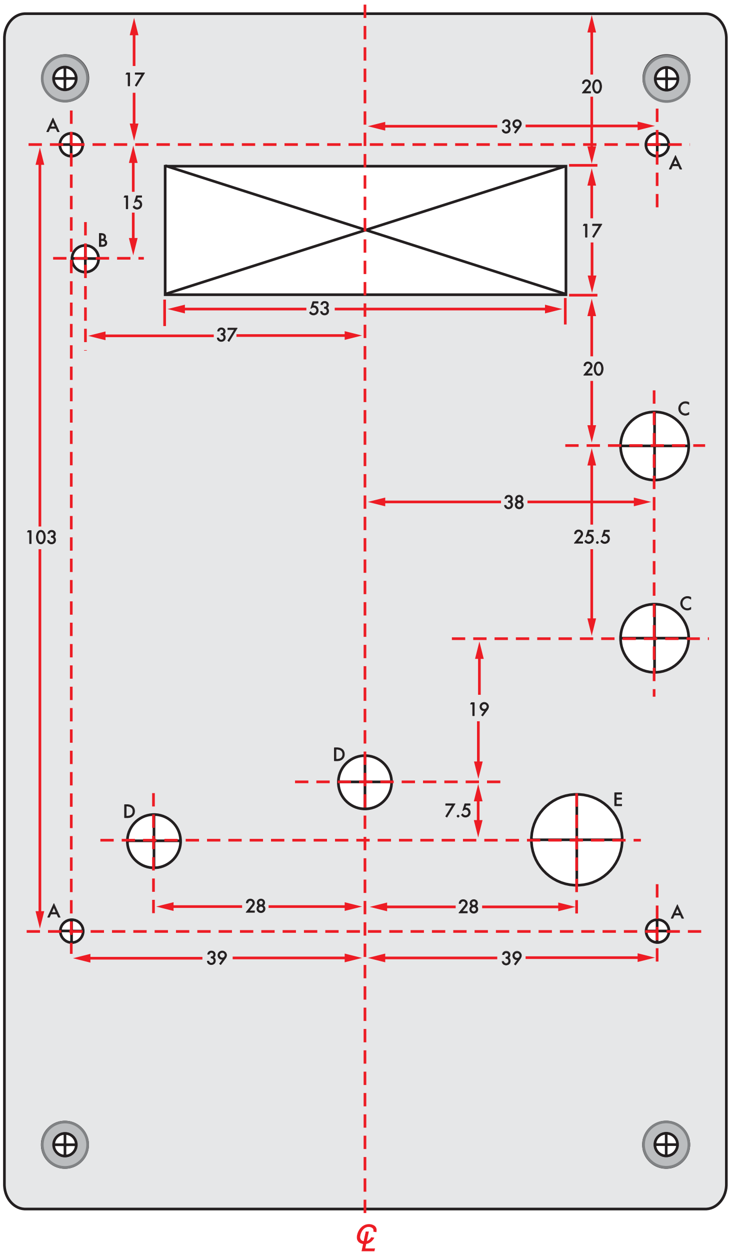


Fig.5: drilling diagram for the UB-1 box lid, which becomes the front panel. All dimensions are in mm.

Display module

The final component to be mounted directly on the main board is the 16-way length of SIL (single in-line) socket strip used for the 'socket' for the LCD module connections. Once this has been fitted and its pins soldered to the pads underneath, you'll be almost ready to mount the LCD module itself.

However, before this can be done, fasten two 12mm-long M3 tapped nylon spacers to the board in the module mounting positions (one at each end) using a 6mm M3 screw passing up through the board from underneath. Then 'plug' a 16-way length of SIL pin strip into the socket strip you have just fitted to the board. Make sure the longer ends of the pin strip pins are mating with the socket, leaving the shorter ends uppermost to mate with the holes in the LCD module.

Next, remove the LCD module from its protective bag, taking care to hold it between the two ends so you don't touch the board copper. Then lower it carefully onto the main board, so the holes along its lower front edge mate with the pins of the pin strip, allowing the module to rest on the tops of the two 12mm-long nylon spacers.

Then you can fit another 6mm M3 screw to each end of the module, passing through the slots in the module and mating with the spacers. When the screws are tightened (but not over tightened) the module should be securely mounted in position.

The final step is then to use a fine-tipped soldering iron to carefully solder each of the 16 pins of the pin strip to the pads on the module, to complete its connections.

The final component to mount on the converter board is step-up transformer T1, which needs to be wound first. This may sound daunting, but there are only 131 turns of wire in all. You'll find all of the information on winding the transformer and mounting it on the converter board in the box panel opposite.

After this has been accomplished, you can plug the three ICs into their respective sockets – IC1 on the converter board, and IC2 and IC3 on the main board – making sure to orient them all as shown in Fig.3.

At this stage, both of your PC board assemblies should be nearly complete. All that remains is to attach one of the 25mm-long mounting spacers to the top of the main board in each corner, using 6mm-long M3 screws. Then the board assemblies can be placed aside while you prepare the case and its lid.

Preparing the case

There are only four holes to be drilled in the lower part of the case, to take the mounting screws for the converter board. These should be 3mm in diameter and with their centres marked out using the converter board itself as a 'template', by sitting it temporarily

Winding the transformer

Step-up autotransformer T1 has a primary winding comprising 11 turns of 0.7mm enamelled copper wire (one layer), followed by a secondary winding of 120 turns (4 × 30-turn layers) of 0.25mm enamelled copper wire. As shown in the assembly diagram at right, all five layers are wound on a small nylon bobbin, which fits inside a two-piece ferrite pot-core measuring 26mm in diameter.

First wind on the 11-turn primary using the 0.7mm diameter wire. You'll find that this will neatly take up the full width of the bobbin, providing you wind the turns closely and evenly. Then cover this first layer with a 9mm-wide strip of plastic insulating tape or thin 'gaffer' tape, to hold it down.

Leave about 50mm of wire free of the bobbin at the 'start' end, and cut any surplus wire off about 40mm from the 'finish/tap' end (taking it out via one of the 'slots').

Next, take one end of the 0.25mm wire and twist it around the 'finish/tap' end of the primary winding to anchor it while you wind the first layer of the secondary. This must be wound on the bobbin in the same direction as the primary, as if it is a continuation of the first layer. If you wind them closely and evenly you should find that you will be able to fit 30 turns across the bobbin.

Once you have wound on the 30 turns, cover this second layer (the first secondary layer) with a 9mm-wide strip of plastic insulating tape to hold it in place. Then you can wind the third layer in exactly the same way, covering it with a strip of tape as before.

The remaining wire can then be used to wind the two further 30-turn layers, again making sure that you wind them in the same direction as you wound the earlier layers, and covering each layer with a strip of tape.

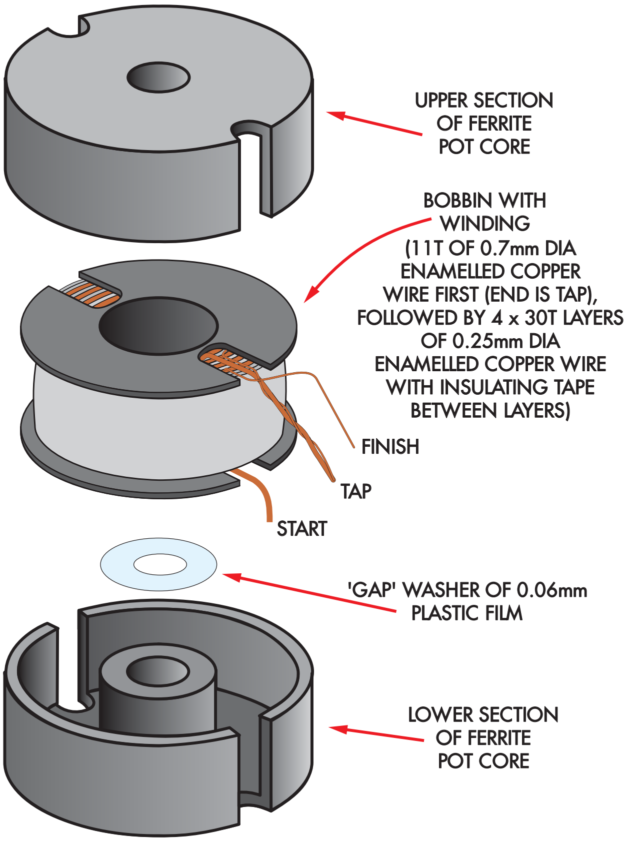
With the fifth and final layer wound and taped, the 'finish' end of the wire can be brought out of the bobbin via one of the slots (on the same side as the start and tap leads), and your wound transformer bobbin should now be ready to fit inside the two halves of the ferrite pot-core.

Just before you fit the bobbin inside the bottom half of the pot-core, though, there's a small plastic washer to prepare. This is to provide a thin magnetic 'gap' in the pot-core when it's assembled, to prevent the pot-core from saturating (magnetically) when it's operating.

The washer is very easy to cut from a piece of the thin clear plastic that's used for packaging electronic components, like resistors and capacitors. This plastic is very close to 0.06mm thick, which is just what we need here. So, the idea is to punch a 3mm to 4mm diameter hole in a piece of this plastic using a leather punch (or something similar to cut a clean hole) and then use a small pair of scissors to cut around the hole in a circle, with a diameter of 10mm.

Your 'gap' washer will then be ready to place inside the lower half of the pot-core, over the centre hole.

Once the gap washer is in position, you can lower the wound bobbin into the pot-core around it, and then fit the top half of the pot-core. The autotransformer should now be ready for mounting on the converter PC board. To begin this step, place a nylon flat washer on the 25mm-long M3 nylon screw that will be used to hold it down on the board.



(ASSEMBLY HELD TOGETHER & SECURED TO CONVERTER PC BOARD USING 25mm x M3 NYLON SCREW & NUT)

Then pass the screw up through the 3mm hole in the PC board corresponding to the centre of the transformer, and lower the assembled pot-core down over the nylon screw, holding it together with your fingers (with the bobbin and gap washer inside) and with the 'leads' towards diode D3.

When the pot-core assembly is resting on the top of the converter board, keep holding it and the board together with the nylon screw so you can apply the second M3 nylon flat washer and M3 nut to the upper end of the screw. Tighten the nut so that the pot core is not only held together, but also secured to the top of the PC board.

Once this has been done, all that remains as far as the transformer is concerned is to cut the start, tap and finish leads to a suitable length, scrape the enamel off their ends so they can be solder-tinned, and then pass the ends down through their matching holes in the board, so they can be soldered to the appropriate pads.

Make especially sure that you scrape, tin and solder BOTH wires which form the 'tap' lead – ie, the finish of the primary winding and the start of the secondary. If this isn't done, the transformer won't produce any output.

It's also a good idea to fit a 25mm length of insulating sleeving over the exposed 'finish' lead, between the transformer winding and the PC board. This will help prevent any 'flashover' when the transformer is producing 1000V pulses.

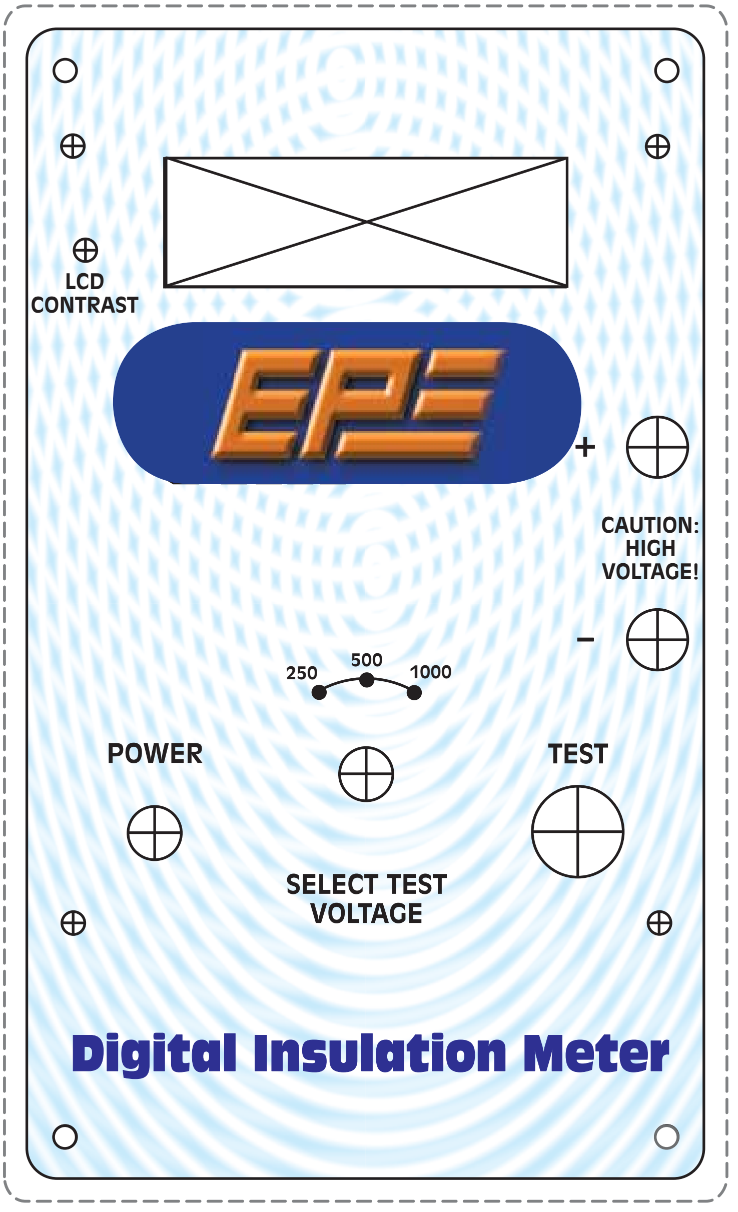


Fig.5: same-size front panel artwork which can be photocopied and glued to the panel. For protection, it should first be laminated or sealed with self-adhesive clear plastic.

Insulation testing

Testing the insulation of mains-powered equipment and cables is an important step in ensuring that they are safe to use and don't pose a shock hazard.

According to the Australian and New Zealand standards for safety inspection and testing of electrical equipment (AS/NZS 3760:2003), tests on the insulation of 'domestic' cables and equipment operating from 230V AC should be carried out with a testing voltage of 500V DC.

However, where the equipment includes MOV surge protection devices, the testing can be carried out with a voltage of 250V DC.

The recommended testing voltage for insulation tests on industrial equipment such as ovens, motors and power converters operating from three-phase 400V AC is 1000V DC.

Insulation tests on domestic 230V equipment can be performed by measuring either the leakage current or the insulation resistance.

For Class I (earthed) equipment with accessible earthed metal parts, the leakage current should be no greater than 5mA, except for portable RCDs (residual current devices) where it should not be greater than 2.5mA. The insulation resistance for these devices should be not less than 1MΩ or not less than 100kΩ for a portable RCD.

For Class II (double-insulated) equipment, the insulation resistance with the power switch 'on' measured between the live supply conductors (connected together) and external unearthed metal parts should again be not less than 1MΩ.

The same insulation resistance figure of 1MΩ applies to extension cables and power boards (between the live conductors and the earth conductor), to power packs (between the live input pins and both output connections), portable isolation transformers (between the primary winding and external earthed or unearthed metal parts, between primary and secondary windings, and also between the secondary winding and external earthed or unearthed metal parts).

inside the box spaced only about 1mm from the front.

Once these four holes are drilled and de-burred, you can mount the converter board inside the box using four 12mm-long M3 *nylon* screws, with a *nylon* flat washer and *nylon* nut fitted to each screw first to act as board mounting pillars or 'standoffs'. The converter board can now be slipped down over the screws, and another M3 nylon nut placed on each screw to hold the board in place.

You don't need mounting holes for the batteryholder, because it can be held securely in place using two strips of 'industrial' double-sided adhesive foam tape. However, before it can be fitted into the case, it must be cut down to accommodate only six cells.

This involves cutting off the last four cell positions (at the 'negative lead' end), and then drilling a 2.5mm hole in the end of the sixth cell position, at the negative spring end. The end of the spring is then carefully bent inwards and around in a circle, so that it can be held in place using a 6mm-long M3 machine screw and nut, which will also attach the negative lead connection lug on the outside.

The converted batteryholder can now be fitted inside the main section of the box behind the converter board, with the connection lead side to the left. Mount it using double-sided adhesive foam as mentioned earlier.

The box lid needs several holes drilled, plus a rectangular cutout near the upper end for the LCD. The location and dimensions of all these holes are shown in Fig.5, which can also be used (or a photocopy of it) as a drilling template. The 12mm hole for S2 and the 9mm holes for the test terminals are easily made by drilling them first with a 7mm twist drill and then enlarging them to size carefully using a tapered reamer.

The easiest way to make the rectangular LCD window is to drill a series of closely-spaced 3mm holes just inside the hole outline and then cut between

The three LCD screens which should greet you when you turn the Digital Insulation Tester on. The one on the left is self explanatory. It changes automatically to the middle one, which tells you what to do (it's not rocket science). The right screen shows the test voltage (as set by S1), the leakage current (in this case zero – bewdy!) and the measured resistance.

the holes using a sharp chisel or hobby knife. Then the sides of the hole can be smoothed using small needle files.

We have prepared an artwork for the front panel, which can be photocopied from the magazine (Fig.5). The resulting copy can be attached to the front of the lid and then covered with self-adhesive clear film for protection. A more robust alternative is to hot-laminate the paper panel in a clear pouch, cut it to size and then attach it using thin double-sided tape.

You might also like to attach a 60mm × 30mm rectangle of 1mm to 2mm thick clear plastic behind the LCD viewing window, to protect the LCD from dirt and physical damage. The 'window pane' can be attached to the rear of the lid using either adhesive tape or epoxy cement.

Once your lid/front panel is finished, you can mount switches S2 and S3 on it using the nuts and washers supplied with them. These can be followed by the binding posts used as the meter's test terminals. Tighten the binding post mounting nuts quite firmly, to make sure that they don't come loose with use. Then use each post's second nut to attach a 4mm solder lug, together with a 4mm lockwasher to make sure these don't work loose either.

Now you can turn the lid assembly over and solder 'extension wires' to the connection lugs of the three switches, and also to the solder lugs fitted to the rear of the binding posts. These wires should all be about 30mm long and cut from tinned copper wire (about 0.7mm diameter).

Once all of the wires are attached, they should be dressed vertical to the lid/panel so they'll mate with the corresponding holes in the main PC board when the two are combined.

You should now be ready for the only slightly fiddly part of the assembly operation: attaching the main PC board assembly to the rear of the lid/front panel.

This is only fiddly because you have to line up the extension wires from switches S2, S3 and the two test terminals with their matching holes in the PC board, as you bring the lid and board together. This is not too difficult though, so just take your time and the lid will soon be resting on the tops of the board mounting spacers. Then you can secure the two together using four 6mm-long machine screws.

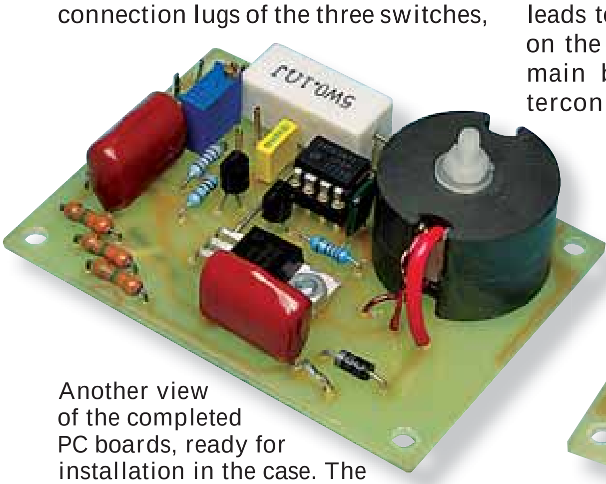
Turn the complete assembly over and solder each of the switch and terminal extension wires to their board copper pads. Once done, you can clip off the excess wire with side-cutters.

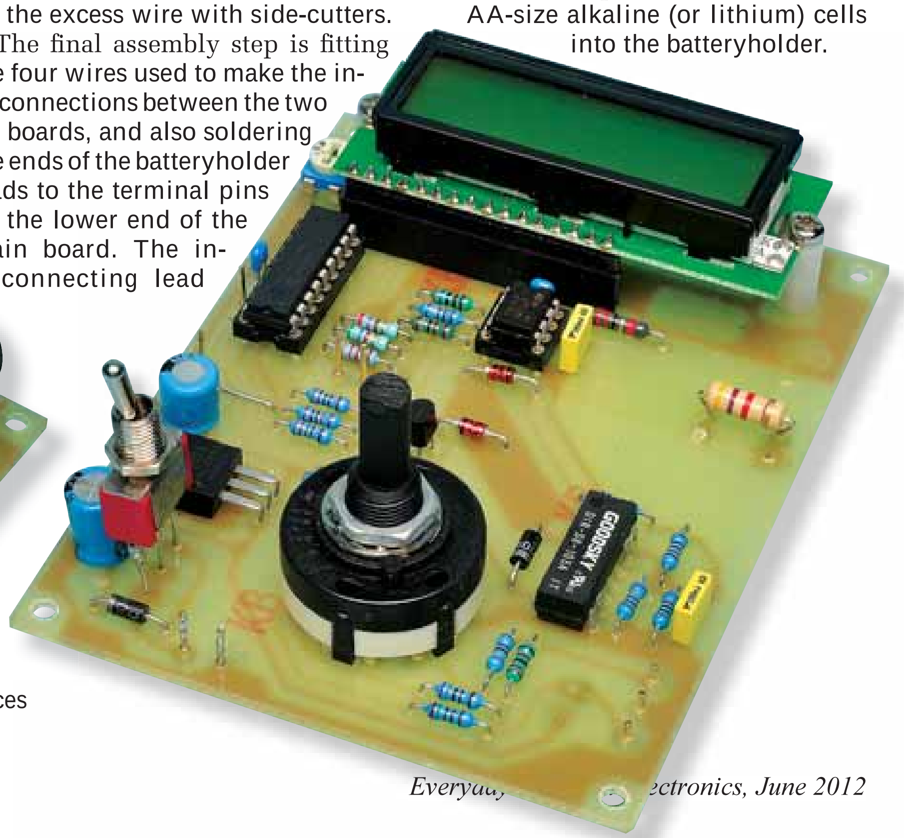
The final assembly step is fitting the four wires used to make the interconnections between the two PC boards, and also soldering the ends of the batteryholder leads to the terminal pins on the lower end of the main board. The interconnecting lead connections are shown clearly in Fig.3, but there are two points which should be stressed. One is that while light-duty insulated hookup wire (even rainbow cable, which we used) is fine for the three low voltage leads (+9V, GND and Vb), you *must* use wire with mains-rated insulation for the high voltage lead.

The second point is that although this is not shown in Fig.3 for clarity, all four of the interconnecting leads are run underneath the main board, and connect to it on the copper side.

Note too, that although the high voltage lead connects to a terminal pin on the converter board, it solders directly to the board copper at the main board end. A terminal pin can't be used here, because it would protrude down too far when everything is assembled (and risk flashover to one of the cells in the batteryholder).

Once the interconnecting leads and battery leads have been fitted, your new *Digital Insulation Meter* is almost ready for its initial checkout. All that remains is to make sure power switch S3 is in the Off position, and then fit six AA-size alkaline (or lithium) cells into the batteryholder.





Another view of the completed PC boards, ready for installation in the case. The smaller board (above) is actually an early prototype – there are a few differences **in the final version (shown in the overlay).**

What the PIC firmware does...

When power is turned on via S3, the PIC firmware 'starts work' by turning on relay RLY1 via Q4, to ensure that the metering circuit is set for the higher current range. It also initialises the LCD module, and then displays an initial greeting message on it to show that the meter is 'active'.

After pausing a few seconds, it then displays a second message, advising the user to first set the test voltage (via S1) and then press the Test button (S2) to start testing.

As soon as it senses (via RA4) that the Test button has been pressed, it first checks the test voltage you have selected using S1. (It does this by checking the logic levels on RA0 and RA7.) Then it directs the PIC's ADC module to make a sequence of 10 measurements of the voltage applied to the AN2 input (which is the voltage across the 100Ω leakage current shunt, amplified by IC2a).

After taking the 10 measurements, it then works out the average of these measurements by calculating their sum and then dividing by 10. This averaging is done to give more steady readings, because the individual measurements tend to vary as a result of 'ripple' on the output of the DC-to-DC converter.

This average of the 10 measurements is then checked to see if it is a 'full scale' reading, and if so, the firmware checks to determine the meter's current range setting.

If it isn't set for the higher current range, the meter is switched to the higher current range and the firmware loops back to take another sequence of 10 measurements, and work out their average.

If the average reading was not a full-scale one, or if it is already set for the higher current range, the firmware then does another check to see if the reading is below 10% of full scale. If this is so, it checks to see if the meter is switched to the lower current range.

If not, the meter is switched to the lower current range and the firmware loops back once again to take another sequence of 10 measurements and work out their average.

By doing this automatic range changing, the firmware finally achieves an average reading with the best resolution it is able to provide.

This reading is then processed by the firmware and its 24-bit floating point maths routines to calculate both the leakage current (in mA or μA) and the equivalent leakage resistance in megohms.

These calculated values are then displayed on the LCD screen, along with the test voltage being used.

One further little job done by the firmware is to check the values being displayed for current and leakage resistance, and if there are any 'leading zeroes' they are changed into blanks. This is another improvement over the firmware in the first version.

Initial checkout

When you turn power switch S3 on, a reassuring glow should appear from the LCD display window – from the LCD module's back-lighting You may also be able to see the Meter's initial greeting 'screen', as shown in one of the display photos shown earlier.

If not, adjust contrast trimpot VR2 with a screwdriver until you get a clearly visible display. (VR2 is adjusted through the small hole just to the left of the LCD window.)

After a few seconds, the display should change to the Meter's measurement guide 'screen', where it reminds you to first set the test voltage using S1, and then press button S2 to perform the test.

As soon as you do press the test button, the display should change into the Meter's test result 'screen', where it displays the test voltage plus the measured leakage current and resistance. At this stage, it will show a leakage current of 0μA and a resistance of 999MΩ because you haven't connected anything between the two test terminals to draw any current.

Now try switching voltage selector switch S1 to the other positions. When you then press and hold down S2, you should find that the test voltage setting displayed on the top line of the LCD screen changes to match.

If this occurs, it shows your *Digital Insulation Meter* is working correctly.

Setting the test voltage

If everything seems OK at this stage, it's time to do the final adjustment: setting the test voltage levels. This is easy enough to do because it simply involves monitoring the DC-to-DC converter's output voltage on a single range with your DMM, while carefully adjusting trimpot VR1 using a long and narrow insulated screwdriver.

Here's the procedure: first turn off the power to the *Digital Insulation Meter* using S3. Then swing up the lid and main board assembly to allow you to access the DC-to-DC converter board.

Next connect the DMM's positive lead to the '+HV out' terminal pin at the rear of the converter board just above D3, and connect the DMM's negative lead to one of the two 'earth' terminal pins of the same board. The TPG pin just above TP3 may be easier to access, but you can use the centre (GND) pin on the right-hand end of the board if you prefer.

Now turn the DMM on, and select the 500V DC range (or higher). Then turn on the meter using S3, switch S1 to its '250V' position and then carefully press and hold down S2 and the DMM reading should be around 250V. Then adjust trimpot VR1 to give a reading of 225V.

By doing this, the resultant test voltage across a 1MΩ load should be very close to the setting.

Alternatively, if you envisage testing equipment with internal MOVs, or possibly portable RCDs, do the voltage adjustment on the 250V range. In this case, adjust trimpot VR1 to give a reading of 265V. This will result in a test voltage across a 100kΩ load of close to 250V.

(Pedantic readers who have very accurate DMMs may prefer to make the adjustment to 262V, but the resulting test voltage will still depend on the overall resistor tolerances.)

Either way, you only have to adjust VR1 on one range as the other ranges will be pretty close to their nominal values.

Once you are satisfied with the voltage adjustment, you can turn off the power via S3, remove your DMM measuring leads and refit the lid assembly into the box.

Now fit the screws which hold the lid and box together and your *Digital Insulation Meter* is now ready for use. ***EPE***

TechnoTalk

Blooming marvellous

Mark Nelson

Did you know that you can stimulate plant growth by colour-filtered artificial light? Or that LEDs could reduce the number of flowers imported from overseas? Nor did Mark until he listened to *Farming Today* early one morning...

HORTICULTURE, you might feel, has little to do with this magazine's theme, but after you have read this month's column you won't be able to deny this is 'practical electronics', in a totally everyday application! And if you have a greenhouse, you might even try experimenting along these lines to boost your tomato crop.

Even so, listening to the farming programme on *BBC Radio 4* at 5.45am was not the time when I expected to hear something of interest to an electronicist. But fact can turn out stranger than fiction, and that was certainly the case on 13 March, when presenter Anna Hill reported that high-tech horticulture powered by LEDs could bring profitable rose growing back to Britain, and Chris Plackett explained how this could help reduce the volume of flowers we currently import by 75%.

In case you are wondering who Chris Plackett is, he's the commercial director of the Warwickshire-based Farm Energy Centre, which describes itself as the UK's leading energy consultancy with specialist expertise in the farming and horticulture sectors.

Not like us

You hardly need telling that LEDs deliver long life and greater energy efficiency than other kinds of lighting, but you probably didn't know that their spectral output (light colour or wavelength) can be matched to the varying needs of growing crops. Plants are not like us; they have very different needs from humans where light is concerned. 'Cool' or blue sources provide the light needed for lush green foliage plants, while 'warm' red ones provide the light needed for blooming flowers and fruit production.

Horticulturalists can 'fine tune' the light wavelength used on their crops for the particular results they require; for example, to maximise photosynthesis. But because off-the-shelf lighting equipment is optimised to assist human vision, much of the lighting provided in horticulture is not absorbed by plants and is thus wasted.

But why spend money providing artificial light for plants? In a nutshell, to compensate for gloomy light quality and the shorter daylight periods in winter, enabling our growers to compete with their competitors in sunnier climes. This means more profits for our own flower and fruit growers, reducing the outflow of currency and avoiding the financial and carbon cost of importing produce from overseas.

Growsave

The Growsave project (a Farm Energy Centre initiative) clarifies the problem facing growers, who require high intensity light to 'make good' the lack of sunlight that we suffer from in the UK during the late autumn, winter and early spring months. The current light source of choice is high pressure sodium (HPS), but this is only a compromise solution. The light quality of sodium is fixed and is by no means ideal for some plants.

Particular problems with sodium are a shortage of output in the blue and red parts of the spectrum, together with a significant radiant heat output that is difficult to put to good use. Problems occur also with tall 'vine crops' such as tomatoes, because it is difficult to get the light from HPS lamps mounted above the crop to penetrate into the leaf canopy.

Replacing sodium lighting with compact (and cool) LED clusters offers significant advantages. Overheating of the parts of the plant that are closest to the lamp is less likely to be a problem, while moving some of the light down into the leaf canopy reduces the heat 'waste' from sodium lamps positioned in the greenhouse roof-space and reduces the need for ventilation and leaving gaps.

What's more, getting light to where it is really needed (inserted low in the canopy) provides the greatest biological efficiency. So-called interlighting modules are used for this, with a mixture of LED colours to optimise photosynthesis in the lower leaves.

Pie in the sky?

According to Chris Plackett, this is not pie in the sky thinking. 'LEDs are already being used by growers and are delivering true benefits. The Dutch are utilising this technology', he asserts.

In the Netherlands, LEDs are being used on a wide range of crops, including flowers, salad vegetables and herbs. One of these users is cut-flower grower Niels Kreuk in Andijk, a small lakeside village an hour's journey north of Amsterdam. In his three-level glasshouse, strips of Philips LED lights illuminate the lilies in the lower two layers; natural sun takes care of the top layer of plants. An interesting aspect of this particular LED installation is that the blue LEDs in the red/blue recipe have been coated to make them provide white light, for staff visibility and comfort. However, the plants still see the light as blue.

In the same village, an orchid breeder, Arjen Peerdeman, is also using LEDs to improve production efficiency. With help from Philips, the business developed the correct recipe of red and blue LEDs to optimise plant growth, again in a stacked system. Now, they can produce 425,000 plants on a footprint of 54 square metres, a major gain in space efficiency. Energy usage has been cut in half, and there may be other benefits as well. Arjen says his orchids show some signs of more active root tips, although he admits the evidence is not yet proven.

The Heineken effect

Rose grower Marjoland in Waddinxveen, which produces 60 million stems per year, is testing LED interlighting in an attempt to save energy at the same time as improving crop output and quality. A 12-month trial indicates a 10% increase in flower production resulting from having more light on the new branches as they form. Rather like Heineken beer, the interlighting modules deliver light to the places that the previous sodium lamps could not reach.

There may be other benefits too, as Nigel Paul, professor of plant science at Lancaster University explains. 'LEDs go beyond energy efficiency', he says. 'You can tune them to deliver quality or pest and disease control, or pigmentation, or habit. The biggest benefits may be in exploiting properties of LEDs – intelligent lighting – that conventional lighting doesn't have. It's really promising, but not proven.'

Currently, the big issue is achieving the right spectral balance for growers – and the cost. 'There is no problem developing energy-efficient LEDs for this – the technology is pretty mature, but the unit price is still too high,' he states.

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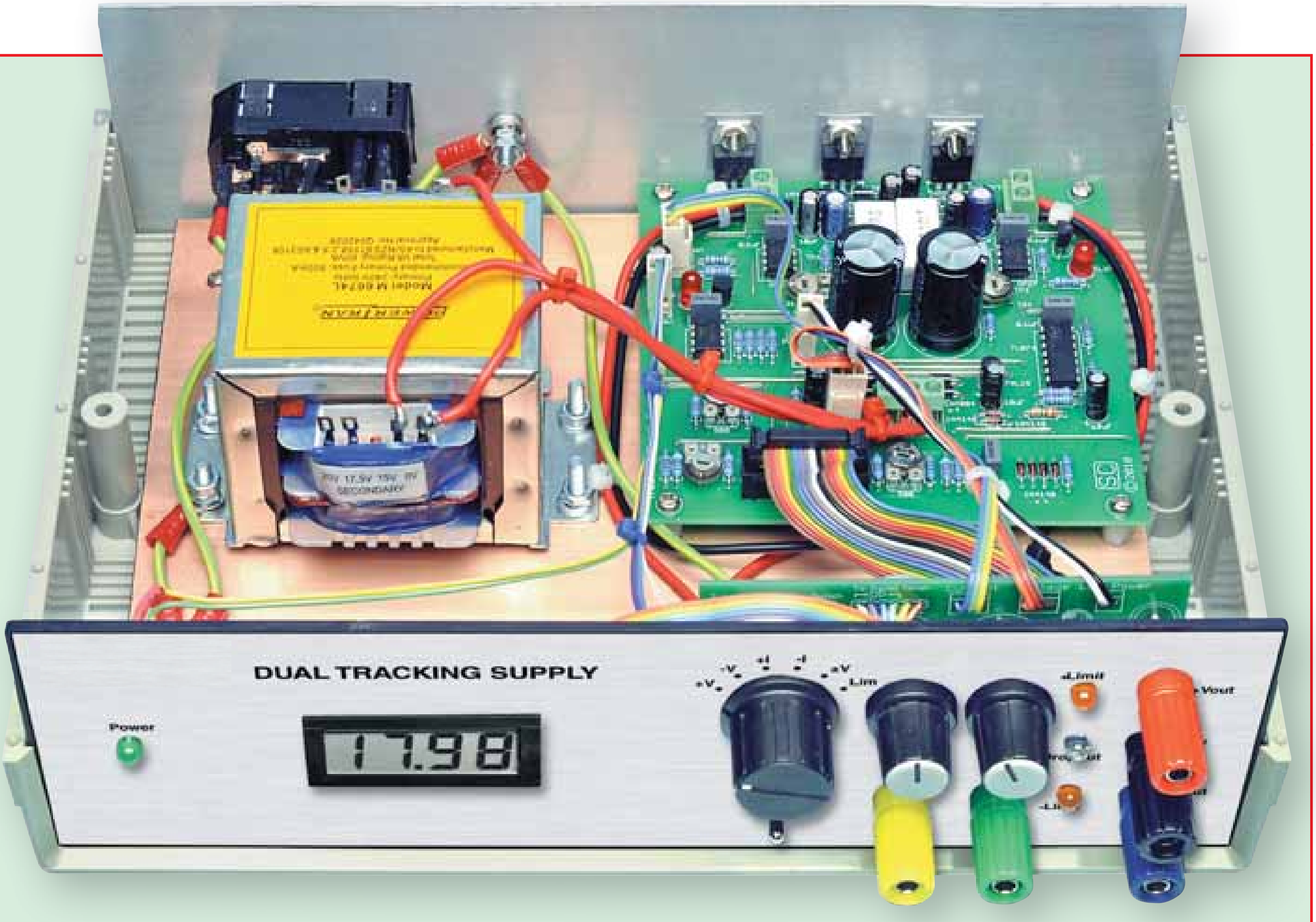


Dual Tracking ±0V to 19V Power Supply

Part 1 by NICHOLAS VINEN

This linear bench supply can deliver up to 1.6A from positive and negative outputs with a range of ±0V to 19V. It has adjustable current limiting for both outputs and can display the voltage or current reading for either rail. If powered from an AC plugpack, no mains wiring is required, although less current is available. It also has a 5V 750mA output for powering digital logic ICs and microcontrollers.

THIS tracking bench power supply is built almost entirely from standard components, but provides high performance. It is a linear supply that offers very good regulation and very low ripple and noise (see specifications table). It also boasts a digital display for voltage and current readouts, and this can also show the voltage across both rails or the present current-limit setting.

The primary outputs track each other, providing balanced rails, or a load can be connected across both to double the voltage. Either way, the current limit can be adjusted from 0-1.6A (0-1.0A for the plugpack version). The internal regulators are protected against excessive temperature or current.

A third output supplies a fixed 5.0V at up to 750mA. The supply also incorporates an earth terminal, a load switch (which controls all three outputs) and a power switch.

This supply is particularly well suited for breadboarding, especially for circuits which mix digital logic and analogue signal processing. If you prototype this type of circuit often, you will be familiar with the hassles involved with building a power supply each time, which is able to deliver 5V and/or 3.3V, along with balanced rails (eg, ±15V) for the op amps.

With a tracking supply such as this one, not only is most of that effort spared, but also you can easily observe the current consumed by the op amps and set the current limit to a suitable level, so that a wiring mistake in the prototype will not cause any damage.

We have tried to keep the cost and complexity down as much as possible, while also providing several improvements, over other designs. For example, we include current readout, adjustable current limit, fixed 5V output, digital display, a voltage measurement across both outputs and the plugpack supply option.

Construction is simplified by mounting most of the front panel components on a second PC board. This is connected to the main PC board via several ribbon cables and a few heavy duty wires.

While all of the parts can be obtained from virtually any large electronics retailer, the 0.1Ω 5W shunt resistors can be replaced with less common 1% types (or better) for improved current measurement accuracy. Alternatively, use a millivoltmeter to test a number of 5% resistors for accuracy. We chose two at random for our first prototype, and as luck would have it, they were within 1%.

Features

Because this is a tracking supply, under normal conditions, the absolute voltage at the negative output matches that of the positive output. In other words, if the positive output is adjusted to +9.3V, the negative output will be –9.3V. As a result, only one voltage adjustment knob is required. Many circuits, especially those with op amps, work best with balanced rails.

The 5.0V output is supplied by a 7805T regulator, which has its own current and thermal limiting. This rail also powers the panel meter and power LED, so if you manage to short the output, it will be obvious! It's best to avoid shorting it if possible, but if the display goes blank, disconnect the 5.0V output (or clear the short) to restore it.

Table 1: Specifications

	Internal mains transformer	External AC plugpack
Output voltage	±0-19V or +0-38V	
Output current	Up to 1.6A (see Fig.5)	Up to 0.9A (see Fig.6)
Load regulation	0.1% (0-1A)	0.1% (0-500mA)
Line regulation (230V ±10%)	0.2%	0.2%
Noise (0-1A)	<525µV peak-to-peak (see Fig.7)	
Ripple (0-1A)	<1mV RMS, <1.7mV peak-to-peak (see Fig.7)	
Display	+ Voltage, – Voltage, + Current, – Current, Total Voltage, Current Limit	
Voltage reading accuracy	Typically <1%	Typically <1%
Current reading accuracy	Typically <2.5% ±10mA	Typically <2.5% ±10mA

The main current limit is controlled via a second knob on the front panel. You can view the current limit setting on the display while setting it accurately – there is no need to connect a load to make the adjustment.

The current limit is applied for both primary outputs with a typical accuracy of ±3mA, plus the measurement error. If the current from either primary output reaches the limit setting, that output voltage will drop as far as necessary to avoid exceeding the limit. This means you can also use the supply as a current source (from the positive rail) or sink (from the negative rail) by setting the voltage at maximum and the current limit as appropriate.

Our current limiting scheme is not a 'foldback' design. With a foldback scheme, once the current limit is exceeded, the output voltage drops virtually to zero until the overload is cleared. This provides better protection in the case of a dead short and limits power dissipation within the supply, but foldback designs cannot be used as a current source or sink, and they can be unstable with reactive loads.

Because the two rails track, if the positive output is being current limited then the negative output voltage will also drop. However, the reverse is not true. If the negative output current limit is exceeded, the positive output voltage will not necessarily change. It has been designed this way to keep cost and complexity low.

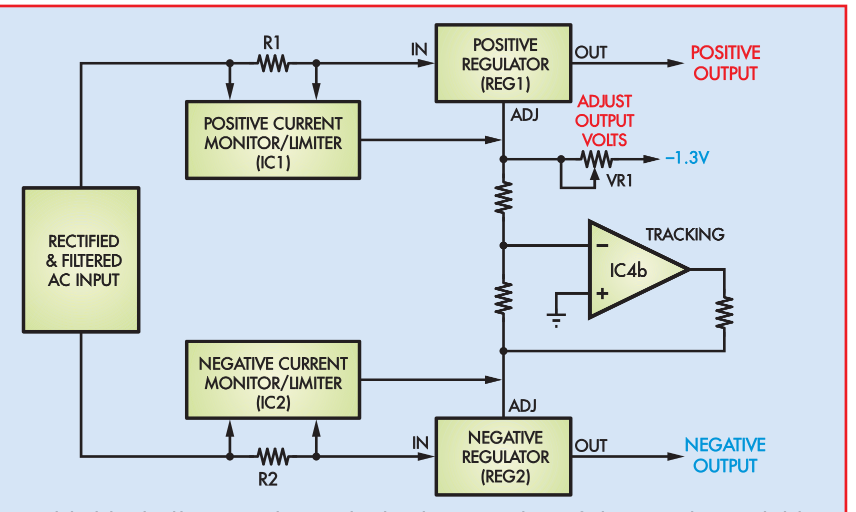
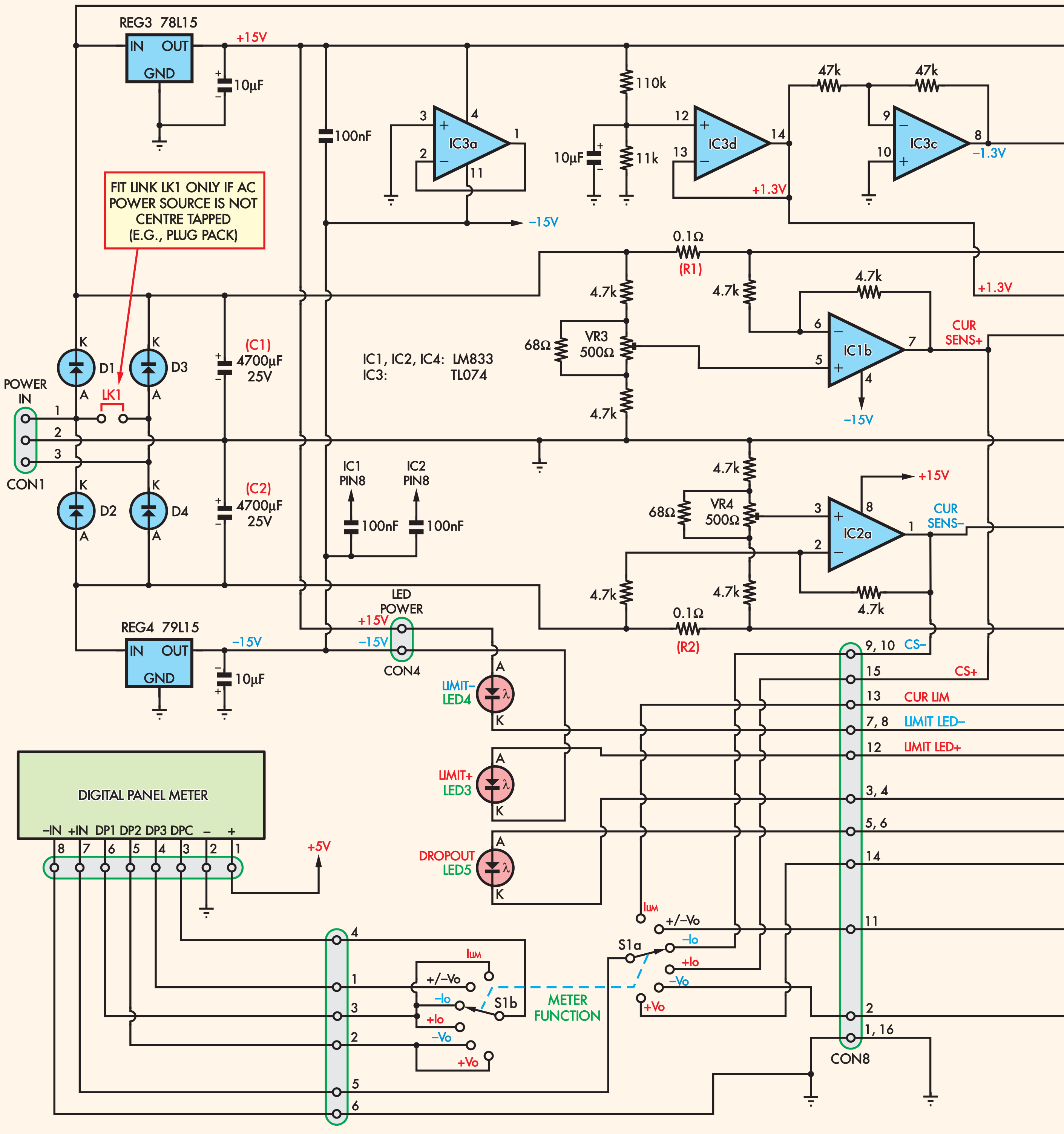


Fig.1: this block diagram shows the basic operation of the supply. Variable regulators REG1 and REG2 provide the positive and negative output rails, while IC4b ensures that REG2 tracks REG1. Resistors R1, R2, and IC1 and IC2 monitor the rail currents and provide limiting as necessary.



DUAL TRACKING ±19V POWER SUPPLY

D1-D10 (1N4004), TVS1

D11–D16: 1N4148

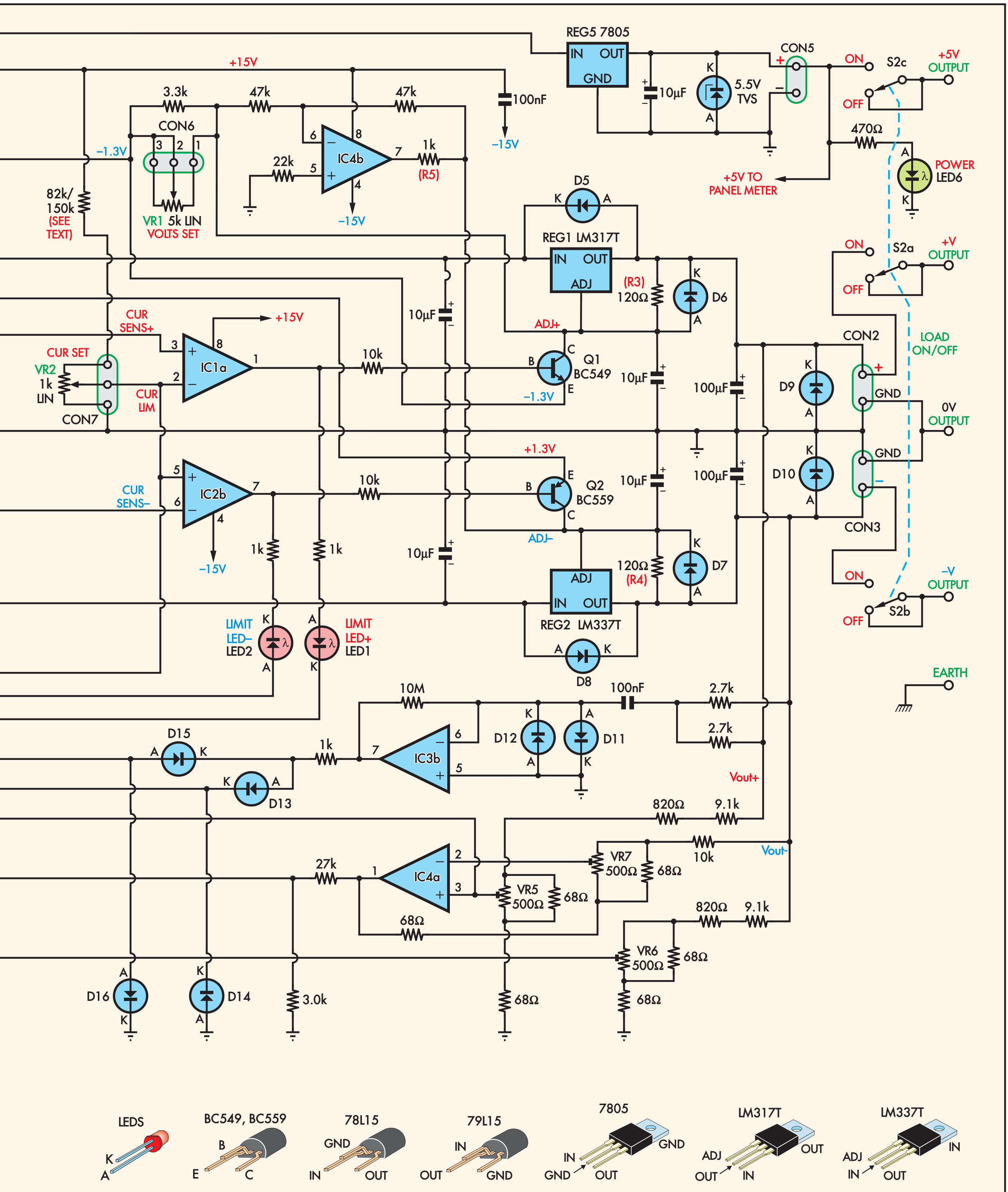
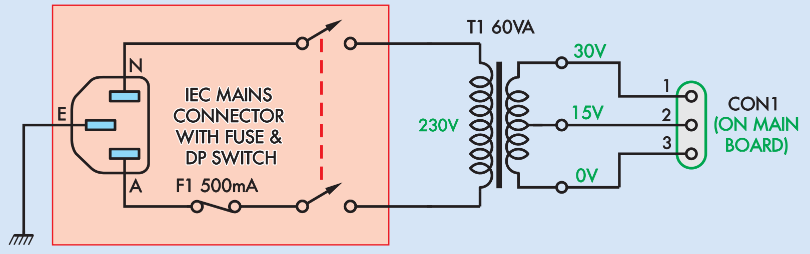
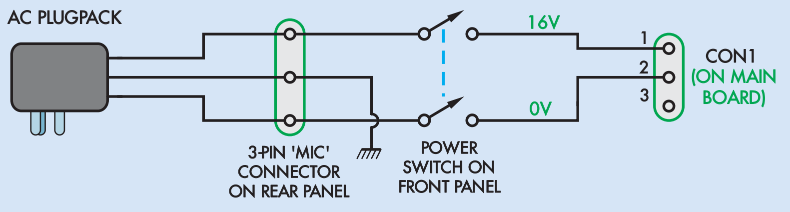


Fig.2: this diagram shows the complete circuit minus the mains transformer and the alternative plugpack supply. The parts shown with green labels mount on the front-panel PC board, while the remaining parts (except for the panel meter and power LED) are all mounted on the main board.



DUAL TRACKING SUPPLY MAINS SUPPLY OPTION

Fig.3: the mains-powered version uses an IEC connector with an integrated switch and fuse, plus a 60VA 30V centre-tapped mains transformer.



DUAL TRACKING SUPPLY PLUGPACK SUPPLY OPTION

Fig.4: this supply option uses a 16V 1.38A AC plugpack, which connects via a 3-pin microphone connector on the rear panel of the unit.

You can also use the current-limiting feature when 'bridging' the outputs to get the higher voltage range.

Note that if you are close to drawing the maximum current available at a given voltage setting, the current limit may kick in early. This is indicated by the current limit and dropout LEDs lighting simultaneously, and will be due to the large 100Hz ripple voltage on the filter capacitors in this condition. Generally, it's best to avoid using the supply right at its limit, in which case this condition is avoided.

Supply options

A mains transformer or AC plugpack can be used to run the supply. The only difference is the amount of current that can be drawn from the outputs at a given voltage setting. Note that slightly less current is available if you use the LED display instead of the LCD option, due to its own current consumption. This will be more noticeable with the plugpack version.

The specified mains transformer is a 30V 60VA type with a centre tap. The transformer is connected via an IEC socket with integrated switch and fuse, to keep the wiring as simple as possible.

If you prefer to avoid mains wiring, you can use a 16V AC 22VA plugpack instead. Virtually all plugpacks have a single secondary winding, so we can't use full-wave rectification. This means that the filter capacitors are charged at 50Hz instead of 100Hz, reducing the output current further.

The specified plugpack has an earth wire, so the front earth terminal works with either supply option. Do not use a plugpack with a higher voltage rating, as it could overload the current sense amplifier inputs.

We assume that most constructors will opt for the 60VA power transformer. However, we are also presenting the AC plugpack version so that the project can easily be built by school students as part of the electronics syllabus.

LED or LCD panel

We have chosen a digital display (LED or LCD) because such displays are more precise and are cheaper than analogue meters.

The display options are the Jaycar QP-5580 3.5-digit high-brightness LED panel meter and the Altronics Q0571 3.5-digit LCD panel meter. Both are 'common ground' types; ie, their power supply does not have to float relative to the voltage being sensed.

The LED meter is larger and slightly more expensive than the LCD meter; the LED meter is also very bright and easier to wire up. Ultimately, both work well, so the choice is yours to make.

There are six readings we want to show (see Table 1) so there is a 6-way rotary switch that selects the desired mode. One switch pole connects the selected voltage to the display's input and the other selects the appropriate decimal place location.

Heatsink

The aluminium rear panel of the case is used as a heatsink for the three main regulators. They must be electrically insulated from it, but because they can dissipate up to 30W each, the insulation must have a low thermal resistance and therefore mica washers are specified, *not* silicone types.

If you want to make the supply run cooler, or deliver more current at low voltages, a finned heatsink can be drilled and attached to the rear panel using the regulator mounting bolts. Either the Jaycar HH-8555 or Altronics H0550 is suitable, since they have 10mm fin spacing and the regulator tabs are spaced just under 30mm apart – but note that you will need M3 × 20mm mounting screws.

Circuit description

While the above account of the new power supply's features may imply a very complex circuit, the basic circuit is not hard to follow. This is depicted in the block diagram of Fig.1. It essentially consists of positive and negative regulators which are forced to track together by op amp IC4b.

IC4b is effectively a negative voltage follower. It works so that the voltage setting called for from the positive regulator REG1, by potentiometer VR1, is fed to its inverting input. IC4b then inverts the signal and feeds it to the ADJ terminal of the negative regulator, REG2.

There is a lot of ancillary circuitry, which provides all the current limit and metering options, but IC4b and the two adjustable 3-terminal regulators are the heart of the circuit.

Turning now to the main circuit diagram, Fig.2, it is rather large, but each section is quite simple in its operation. Despite the large number of op amps, there are in fact only four DIP IC packages on the board, plus five 3-terminal regulators (two in TO-92 packages) and two transistors. The remaining components are resistors, capacitors, diodes, LEDs and connectors.

Note that some of the components shown in Fig.2 are mounted on the front-panel PC board. These are the components labelled with green text. The others are mounted on the main PC board. Several ribbon cables and heavy duty wires connect the two together, via connectors CON2 to CON8.

The AC supply is shown separately in Fig.3 and Fig.4 (depending on which version is being built). In either case, power from the mains transformer, or AC plugpack, is delivered to CON1, on the left-hand side of the circuit.

If a mains transformer is used, the AC waveform is full-wave rectified by diodes D1 to D4. By contrast, for a plugpack, the secondary is connected between pin 1 and pin 2, and link LK1 (on the main board) is installed. This connects the bridge diodes in parallel for half-wave rectification to give lower voltage losses.

The rectified voltage is filtered by capacitors C1 and C2, both 4700µF 25V (or higher), and the resulting DC rails are fed through shunt resistors R1 and R2 to the main regulators REG1 and REG2 (over on the right-hand side of the circuit). In addition, the 78L15/79L15 linear regulators REG3 and REG4 (left-top and middle of the circuit) produce ±15V for the op amps.

The +15V rail is also used as a voltage reference for potentiometer VR2 and to generate the ±1.3V bias rails (more on these later).

Regulation

REG1 and REG2 are LM317T and LM337T adjustable regulators. They are responsible for maintaining the correct output voltage and rejecting ripple from the AC supply. The 10µF capacitors across their inputs reduce the effect of the shunt resistance on the output voltage regulation.

The 10µF capacitors on the ADJ pins, in combination with the 100µF capacitors across the outputs, improve ripple rejection and reduce noise. Diodes D9 and D10 prevent voltages applied to the supply's outputs (eg, by an inductive load being switched off) from damaging any internal components.

REG1 and REG2 develop a nominal 1.25V between their OUT and ADJ terminals. With a 120Ω resistor (R3 and R4) connected between them, this means the quiescent current will be just over 10mA, which satisfies the minimum load requirement of the regulators.

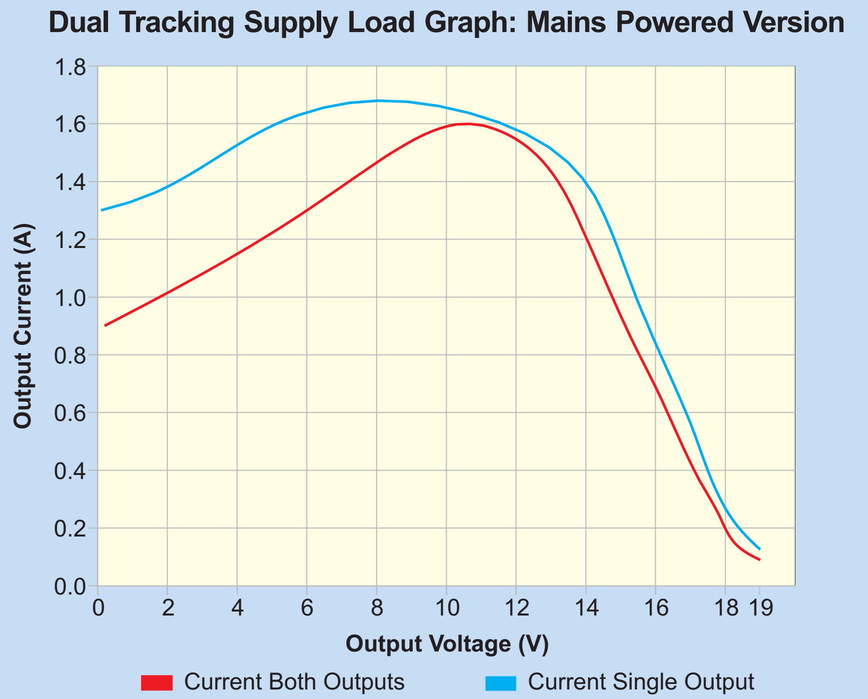


Fig.5: the load graph for the mains-powered version. It shows the maximum current available at any voltage setting before dropout for both dual outputs and a single output.

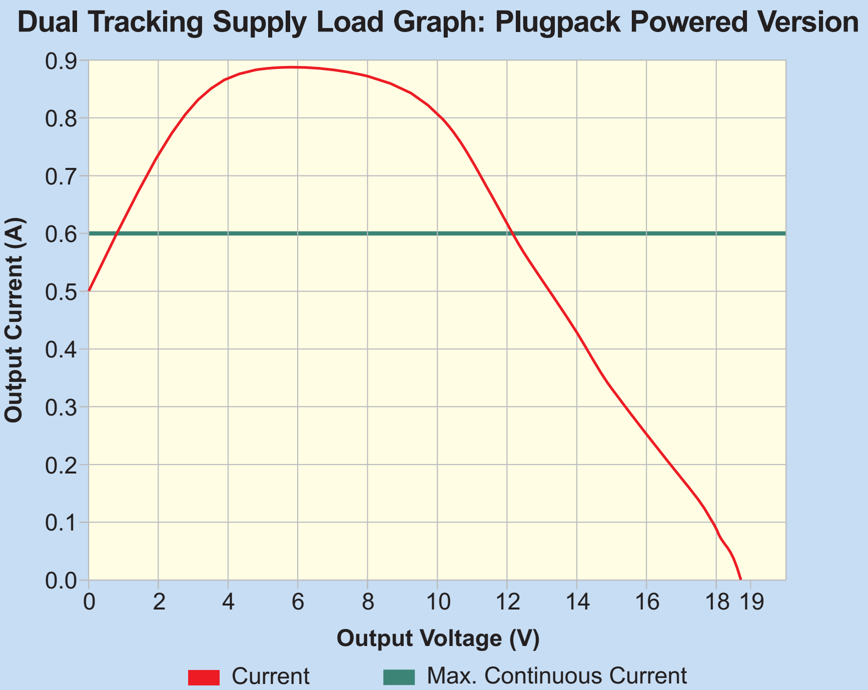


Fig.6: the load graph for the plugpack version. The curves are the same for both dual outputs and for a single output. Note that the total continuous current drawn from all outputs should not exceed 600mA.

REG1's output voltage is controlled by a potentiometer (VR1) connected between ADJ and –1.3V. This acts as a voltage divider in combination with resistor R3.

If VR1 is set to, say, 1kΩ and the voltage across R3 is 1.25V, then the voltage across VR1 will be 10.42V. In this case, the output voltage is 10.42V – 1.3V + 1.25V = 10.37V.

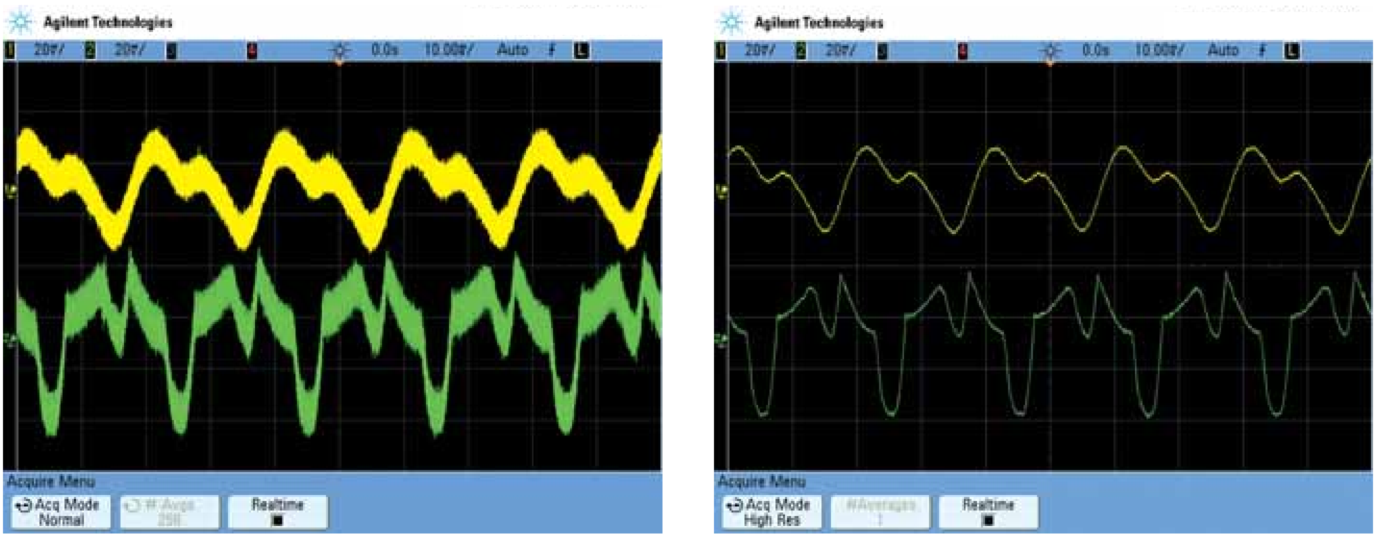


Fig.7: these scope grabs show the amplified noise and ripple at the outputs (yellow positive, green negative). The maximum ripple is 600μV RMS (1200μV p-p) at 1A for the positive rail, and 940μV RMS (2200μV p-p) for the negative rail. The right-hand scope grab shows the waveforms after averaging, which removes the noise component.

Volts set VR1 is mounted on the front-panel board, and is connected to the main board via CON6. It has a 3.3kΩ resistor in parallel, which sets the maximum output to 19.5V.

The –1.3V bias is important because it allows the output to be adjusted down to 0V. Without this, the ADJ pin could only go to 0V and so the output would not go below 1.25V. The –1.3V bias is slightly more than is necessary to account for regulator and resistor variations.

This –1.3V rail is generated by op amp IC3c, connected as an inverting amplifier. Its input is +1.3V, which is generated by IC3d. IC3d is a voltage follower with its input tied to a voltage divider (110kΩ/11kΩ) between +15V and 0V.

Tracking

As noted earlier, op amp IC4b is responsible for the negative output voltage tracking the positive output (see the block diagram of Fig.1). Because we know the voltage across resistors R3 and R4 is maintained at 1.25V, if the ADJ terminal voltages track, then so will the output voltages.

IC4b's output supplies current to REG2's ADJ terminal via 1kΩ resistor R5. Since there is 1.25V across R4, the current through R5 must be about 10mA. This means there is always 10V across R5.

Because IC4b's output can swing over a range of at least ±12V, REG2's ADJ pin can be controlled over a range of +2V to –22V, allowing tracking across the full range of output voltages.

Current sensing

The current flowing to the positive and negative outputs passes through resistors R1 and R2 (0.1Ω). The voltage drop across them is sensed by op amps IC1b and IC2a (each half an LM833).

IC1b and IC2a are configured as differential amplifiers with a gain of one. The output is ground-referenced and directly proportional to the drop across the sense resistor. For example, if there is a 50mV drop across R1, the output of IC1b will be close to 50mV, and similarly for R2 and IC2a. IC2a's inputs are swapped relative to IC1b because current through R2 goes in the opposite direction.

Consider the voltage at pin 5 of op amp IC1b, the non-inverting input. Assuming precisely equal resistors and that trimpot VR3 is centred, it is exactly half the voltage across C1. If no current flows through R1, then pin 6 of IC1b, the inverting input, is at the same potential. Since the difference between the inputs of IC1b is 0V, its output should be at 0V.

As current begins to flow through R1, the voltage at pin 6 of IC1b decreases due to the voltage drop across R1. However, the voltage at pin 5 remains the same, so the output of IC1b must rise to bring pin 6 up to the same voltage as pin 5. If the drop across R1 is 0.1V then IC1b's output must rise by 0.1V for the two inputs to remain at the same voltage.

Because a differential amplifier requires very accurately matched voltage dividers to operate correctly, we can't rely on the 1% tolerance resistors; they're not good enough. Trimpot VR3 allows the dividers at the inputs of IC1b to be adjusted so that their ratios match. VR4 does the same job for IC2a.

Ideally, we would use 50Ω or 100Ω trimpots (1% to 2% of 4.7kΩ). A higher value makes accurate adjustment too tricky. Since trimpots below 500Ω are hard to get, we have shunted 500Ω trimpots with 68Ω resistors. The resulting adjustment range is similar.

Because the inputs of the LM833s sit at half of the pre-regulated supply voltage, and their guaranteed input voltage range is ±12V (typically ±14V), the maximum voltage across C1 and C2 should not exceed 24V. (We have tested the mains-powered version and ensured that it does not exceed 24V with the maximum permissible supply voltage in the UK).

For the plugpack version, if the mains voltage is well above 230V, the filtered voltage can be as high as 25.5V. In this case, the LM833's input voltage is still within typical specification. In the highly unlikely event that this affects the current limiting, that IC will need to be replaced with another sample.

Current sense errors

The combination of 0.1Ω shunt resistors and a differential gain of one means that the current sense outputs have a scale of 100mV/A. This is handy, since the panel meters we are using have a 200mV full scale. We can display currents up to 1.999A with 1mA resolution by enabling the decimal place after the first digit.

However, the reading precision is not as good as this resolution. While we have found that it is possible to trim the output to within 1mA of the correct value, there are four sources of error:

1) The tolerance of R1 and R2. Common 0.1Ω resistors are only guaranteed to be within 5%. In practice, they are generally much closer than that, but better results can be obtained with 1% resistors rated at 0.5W and above (eg, Farnell 1653230).
2) The measurement includes about 10mA that is consumed by the regulator circuits. This is unavoidable, since if we place the shunts after the regulators, we will seriously prejudice the load regulation of the supply. This error can be trimmed out with presets VR3 and VR4, but doing so inevitably degrades common-mode rejection and possibly increases the scale error.
3) IC1 and IC2 have an input offset voltage error, which results in a similar error at the output. We have chosen the LM833 for IC1, IC2 and IC4 because it is a common chip with a low input offset voltage, typically below 0.3mV. This represents an error of up to 3mA, which can be trimmed out at the same time as the regulator current error.
4) Due to the extreme resistor matching requirements, temperature drift is an issue. Since the divider resistors do not heat up and cool down at exactly the same rate, the divider ratio drifts. We have found that reducing the divider resistor values reduces temperature drift, so we settled on 4.7kΩ.

Once the supply is trimmed and after it has warmed up, the error is typically no more than ±3mA plus 1% of the reading. The error when cold is more like 15mA, so for accurate readings, let the supply warm up first.

This internal view shows the completed plugpack-powered version of the supply. It can be built into a smaller case than the mains-powered version.

Current limiting

The 1kΩ current-limit adjustment potentiometer, VR2, connects to the main board via CON7. It acts as a voltage divider with either an 82kΩ resistor (mains version) or 150kΩ resistor (plugpack version) to generate a voltage in the range of 0 to 170mV (or 0 to 100mV). This represents a current limit of 0 to 1.7A (or 0 to 900mA for the plugpack powered version).

This voltage, along with the current sense voltages, is fed to op amps IC1a and IC2b. Let us consider IC1a when the current sense voltage is below the preset limit. In this case, IC1a's pin 1 output will be low (about –13V), keeping *NPN* transistor Q1 and LED1 turned off.

If the current sense voltage exceeds the preset limit, IC1a's output swings positive, turning on Q1 and LED1 (along with the corresponding front-panel LED, LED3). Hence, Q1 pulls REG1's ADJ pin low, reducing REG1's output voltage. A steady state is reached in which the output current flow is just below the current limit and Q1 is held partially on.

Because the LED current partly depends on how much current is being sunk from the ADJ pin, the degree of overload is indicated by the brightness of the limit LEDs (LED3 and LED4).

If the load current is reduced, Q1 turns off and REG1's output voltage returns to normal. Q1's emitter is connected to –1.3V, for the same reasons as previously mentioned with respect to VR1. The output voltage needs to be brought down nearly to 0V in cases of severe overload (eg, short circuits).

While LED1 may be helpful during testing, its real purpose is to add an approximate 2V drop between the output of IC1a and LED3. This is necessary because LED3's cathode (K) is connected to –15V, but IC1a's output can only swing to –13V. Without this additional drop, LED3 would not turn off properly. A 1kΩ resistor provides current limiting for both.

Current limiting for the negative output operates identically, but is controlled by IC2b, which drives Q2. When Q2 is turned on, so are LED2 and LED4. Q2's polarity and voltages are reversed compared to Q1, and the LEDs are connected in the opposite manner.

With the plugpack-powered version, it is a good idea to keep the current limit setting below 500mA. Otherwise, if a dead short is placed across the outputs, the ±15V rails can drop and the output current will only be limited by REG1 and REG2's internal circuitry.

LED dropout indicator

If high currents are drawn from the regulated outputs, the ripple voltage across the main filter capacitors, C1 and C2, will increase to a high level, and as result, the outputs may no longer be properly regulated, and there will be hum superimposed on the DC voltage.

This is the completed mains-powered version with the Altronics 3.5-digit LCD readout. The Jaycar LED readout can also be used – details next month.

This is clearly undesirable, so a dropout LED is mounted on the front panel. It lights if there is any significant AC component on either output. Two 2.7kΩ resistors mix the output voltages and the DC component is removed by a series 100nF capacitor. This signal is clipped to a maximum of 0.7V peak-to-peak by diodes D11 and D12, and is then amplified by IC3b.

The gain is around 575 (taking into account the impedance of the 100nF capacitor) and the resulting signal is then rectified by diodes D13 to D16 and applied to the dropout LED (LED5) on the front panel. This LED is a red, high-brightness type and lights dimly with just a few millivolts of ripple on either output, growing progressively brighter with increasing ripple. It is quite bright by the time the ripple waveform reaches 100mV peak-to-peak.

Fixed output

Regulator REG5 provides a fixed 5V output at up to 1A to power the 3.5-digit LED or LCD panel meter. Since the panel meter doesn't need anywhere near 1A, it is also fed to a binding post on the front panel, so it can be used as a low-current auxiliary output.

Transient voltage suppressor TVS1 protects the circuit in case the 5V output is shorted to either the main positive or negative outputs. If it is shorted to a positive voltage in excess of 5V, the 5V rail voltage will rise and TVS1 clamps the 5V rail to around 7V to 8V to protect the panel meter (Note: a 6.8V 5W Zener diode can be used instead of TVS1 – see next month).

If the positive rail current limit is set at its maximum, TVS1 could be conducting around 1.5A and dissipating 10W or more. TVS1 is only rated to dissipate that much power for about two seconds and if the short is maintained, TVS1 will ultimately fail.

This means that if such a short occurs, then the load or power must be switched off immediately.

By contrast, if the 5V output is shorted to the negative output, TVS1 is forward-biased and prevents the 5V rail from dropping below about –1V. Dissipation in this case is far less, but it's still a good idea to disconnect the outputs as soon as possible.

The only remaining circuitry on the main board consists of the three voltage divider networks for driving the display. Since the panel meter is 200mV full-scale (ie, 199.9mV is displayed as 1999), we must divide the output voltages down by a factor of 100. A voltage of, say, 10V becomes 100mV, which is displayed as '10.00'.

The upper portion of these voltage dividers consists of 9.1kΩ and 820Ω resistors in series, for a total resistance of 9920Ω. The lower portion consists of two 68Ω resistors, one of which is in parallel with a 500Ω trimpot (VR5). By adjusting the trimpot, we can get very close to having an exact 100:1 ratio.

Resistor temperature drift is the most significant issue for making accurate readings, and keeping the total resistance to 10kΩ or below helps significantly.

The third reading to be generated is the voltage across both rails, which is monitored by IC4a, another differential amplifier. The positive rail 100:1 divider for the panel meter is re-used, but the negative divider is not since it needs separate trimming. Once again, we are using a 500Ω trimpot (VR7) in parallel with a 68Ω resistor to compensate for any errors.

Because this reading can go above 20V, it must be further divided by 10 to stay within the 200mV range of the panel meter. A 10:1 divider on the output of IC4a (27kΩ and 3kΩ) gives the correct voltage level.

Front panel board

To simplify construction, the following components are mounted on the secondary PC board: the 6-way meter function switch S1, voltage and current adjustment potentiometers VR1 and VR2, LEDs 3, 4 and 5, load switch S2 and the five binding posts – positive output, 0V, negative output, 5V output and earth.

As can be seen from the circuit of Fig.2, the load switch can disconnect all three outputs from the regulators.

The six readout signals are delivered to the front panel from the main PC board via a 16-way ribbon cable. Switch S1a connects the selected signal to the panel meter. At the same time, the other half of switch S1 (S1b) selects the appropriate decimal place for that reading.

A 6-pin connector joins the front panel to the panel meter. It carries the voltage reading to be displayed and its ground reference, plus the wires to select each decimal place. At any one time, one of the three decimal place

Parts List – Dual Tracking ±0V to 19V Power Supply

1 PC board, code 851, 113mm × 105mm (main board)
1 PC board, code 852, 98mm × 58mm (front panel board)
1 PC board, code 853, 63mm × 28mm – required only if LCD panel meter used
2 2-way small screw terminal blocks (5.08mm pitch)
1 3-way small screw terminal block (5.08mm pitch)
1 8-way polarised header connector (2.54mm pitch)
2 3-way polarised headers (2.54mm pitch)
2 3-way polarised header connectors (2.54mm pitch)
2 2-way polarised headers (2.54mm pitch)
2 2-way polarised header connectors (2.54mm pitch)
1 16-way IDC vertical connector (2.54mm pitch)
1 16-way IDC line socket
3 TO-220 mica insulating pads, with bushes
4 9mm tapped nylon spacers
3 M3 × 10mm pan-head screws
8 M3 × 6mm pan-head screws
3 M3 nuts
1 3PDT miniature toggle switch
1 6-way 2-pole rotary switch
2 black push-on knobs
1 black 24mm knob
5 binding posts (red, black, white, green, yellow)
1 1m-length 0.71mm tinned copper wire
1 500mm length 16-wire rainbow ribbon cable
Heavy duty hookup wire (1m red, 500mm green/yellow, 500mm black)
1 50mm length heatshrink tubing (3mm diameter)
1 3.5-digit LED panel meter (common ground) (Jaycar QP-5580), or 3.5-digit LCD panel meter (common ground) (Altronics Q0571)
15 small cable ties
1 small quantity of thermal grease
1 8-way 90° polarised header (2.54mm pitch) – required only if LCD panel meter used
1 5kΩ 16mm linear potentiometer (VR1)
1 1kΩ 16mm linear potentiometer (VR2)
5 500Ω horizontal trimpots (VR3 to VR7)

Plugpack-powered version only
1 plastic instrument case, 200mm × 158mm × 64mm (Jaycar HB-5912)
1 16V AC 1.38A AC plugpack with earth lead (Altronics M9332A)
1 DPDT miniature toggle switch
1 3-pin male chassis mount microphone socket
1 3-pin female line microphone connector
1 aluminium sheet, 190mm × 60mm for rear panel
1 aluminium sheet, 170mm × 127mm
1 5.3mm eyelet crimp lug
1 M4 × 15mm pan-head screw
1 M4 star washer
1 M4 nut
4 No.4 × 6mm self-tapping screws

Mains-powered version only
1 plastic instrument case, 260mm × 190mm × 80mm (Jaycar HB-5910)
1 60VA 30V centre-tapped mains transformer (Jaycar MM2005)
1 chassis-mount IEC socket with fuse and power switch (Jaycar PP4003)
2 500mA M205 fast-blow fuses (1 spare)
1 aluminium sheet, 248mm × 76mm for rear panel
1 aluminium sheet, 224mm × 155mm
7 4.8mm insulated spade crimp lugs
7 5.3mm eyelet crimp lugs
7 M4 × 15mm pan-head screws
4 M4 spring washers
6 M4 star washers
10 M4 nuts
6 No.4 × 6mm self-tapping screws
1 200m length 5mm diameter heatshrink tubing

Semiconductors
3 LM833 dual op amps (IC1, IC2, IC4)
1 TL074 quad op amp (IC3)
1 LM317T adj. regulator (REG1)
1 LM337T adj. regulator (REG2)
1 78L15 linear regulator (REG3)
1 79L15 linear regulator (REG4)
1 7805 linear regulator (REG5)
1 BC549 *NPN* transistor (Q1)
1 BC559 *PNP* transistor (Q2)
10 1N4004 diodes (D1-D10)
6 1N4148 diodes (D11-D16)
1 P4KE6.8 5.5V transient voltage suppressor (TVS1) or 6.8V 5W Zener diode
2 5mm red LEDs (LED1, LED2)
2 5mm amber or orange LEDs (LED3, LED5)
1 5mm high-brightness red LED (LED4)
1 5mm green LED (LED6)

Capacitors
2 4700µF 25V or 35V electrolytic
2 100µF 25V electrolytic
8 10µF 25V electrolytic
5 100nF MKT polyester

Resistors

1 10MΩ	8 4.7kΩ
1 110kΩ	1 3.3kΩ
1 100kΩ	1 3kΩ
4 47kΩ	2 2.7kΩ
1 27kΩ	4 1kΩ
1 22kΩ	3 820Ω
1 11kΩ	1 470Ω
2 10kΩ	2 120Ω
2 9.1kΩ	7 68Ω

2 0.1Ω 5W 5% or 0.1Ω 1W 1% (Farnell 1653230)
1 150kΩ (mains version) or 82kΩ (plugpack version)

wires is connected to the common wire and the other two are disconnected. The 5V power for the panel meter comes directly from the main board.

The two primary regulated outputs and their ground returns, as well as earth, are connected to the front panel via heavy duty wire. Because the front panel carries the load switch and output terminals, no extra wiring is necessary. However, the main power switch, power LED and panel meter are mounted separately.

That's it for this month. Next month, we will describe how to build the PC boards, install them in the case and wire it all up.

Solar-Powered Lighting System

Part 2 – By JOHN CLARKE

Last month, we described the operation of our new off-grid lighting system, featuring free power courtesy of the sun! Now we move on to the fun part: building it!

WE'RE confident that this will be a *very* popular project, offering far more features than typical 'solar chargers'.

One thing we didn't mention last month is that being all low-voltage, it would make a perfect school electronics project. And the fact that it is decidedly 'green' will bring a warm glow to any environmentalist teacher's heart!

To fully understand the project, you will need to refer to the detailed explanation given in Part 1 last month. It also contains the circuit diagram, which you might need to refer to during construction.

Construction

The controller is built on a PC board coded 845, measuring 133mm × 86mm, and is available from the *EPE PCB Service*. The PC board is designed to be housed in a 157mm × 95mm × 53mm utility box (size UB1), clipping into the integral mounting slots moulded in the side of the case.

Begin construction by checking the PC board for breaks in copper tracks or shorts between tracks and pads; repair if necessary. Next, check the hole sizes are correct for each component. The screw terminal holes are 1.25mm in diameter (compared to the 0.9mm holes for the ICs, resistors and diodes).

Board assembly can begin by inserting the links and the smaller resistors. When inserting the resistors, use a digital multimeter (DMM) to help in reading/confirming their resistance values, especially where close colours might be misleading.

We used tinned copper wire for the links, although 0Ω resistors may be supplied in kits. These look like small resistors, but have just one black stripe around their body.

As mentioned last month, resistor R2 (100kΩ) is only installed if a standard PIR detector is to be used. It is left out if the recommended (Altronics) PIR is used.

Next are the diodes, mounted with the orientation as shown on the overlay diagram, Fig.6. Don't mix up the Zener diodes and ordinary diodes. Now is a logical time to solder in the PC stakes and the 3-way headers for LK1 and LK2, plus a 2-way pin header for TP3 and TP4.

Provided you follow the printed circuit board layout (Fig.6) carefully, you should have no problems mounting the capacitors. Note that the four electrolytics are polarity 'conscious' and must be inserted the correct way around, as indicated in Fig.6.

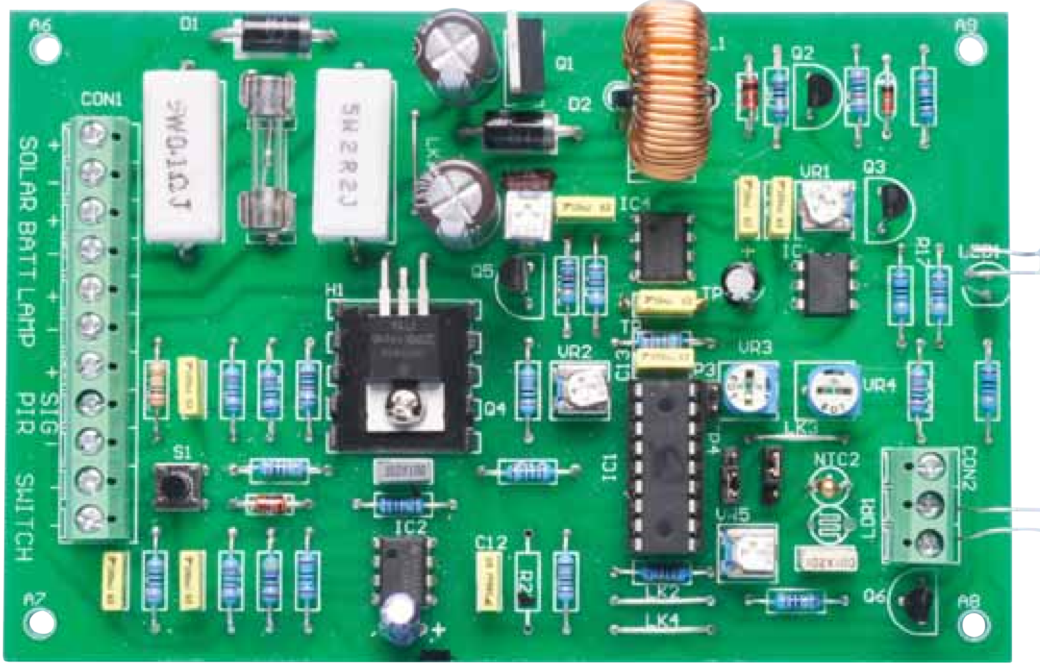
The PIC micro, IC1, is mounted on an 18-pin IC socket. Solder in the socket (with the notch in the direction shown), but at this stage, don't plug in the IC. It's left out until the 5V supply is adjusted. The remaining ICs can either be mounted using sockets or mounted directly on the PC board. Ensure each IC is placed in its correct position and is oriented correctly, with the notch (or pin 1 indicating dot oriented) as shown.

When you solder the fuse clips in, you'll see they have an end stop or small lugs to prevent the fuse sliding out. The lugs need to be at the outer ends of the fuse – if soldered in back to front the fuse won't go in.

The 0.1Ω 5W resistor can be mounted now. The value of resistor R1 needs to be chosen according to the lamp or lamps used. For more details, see Table 2.

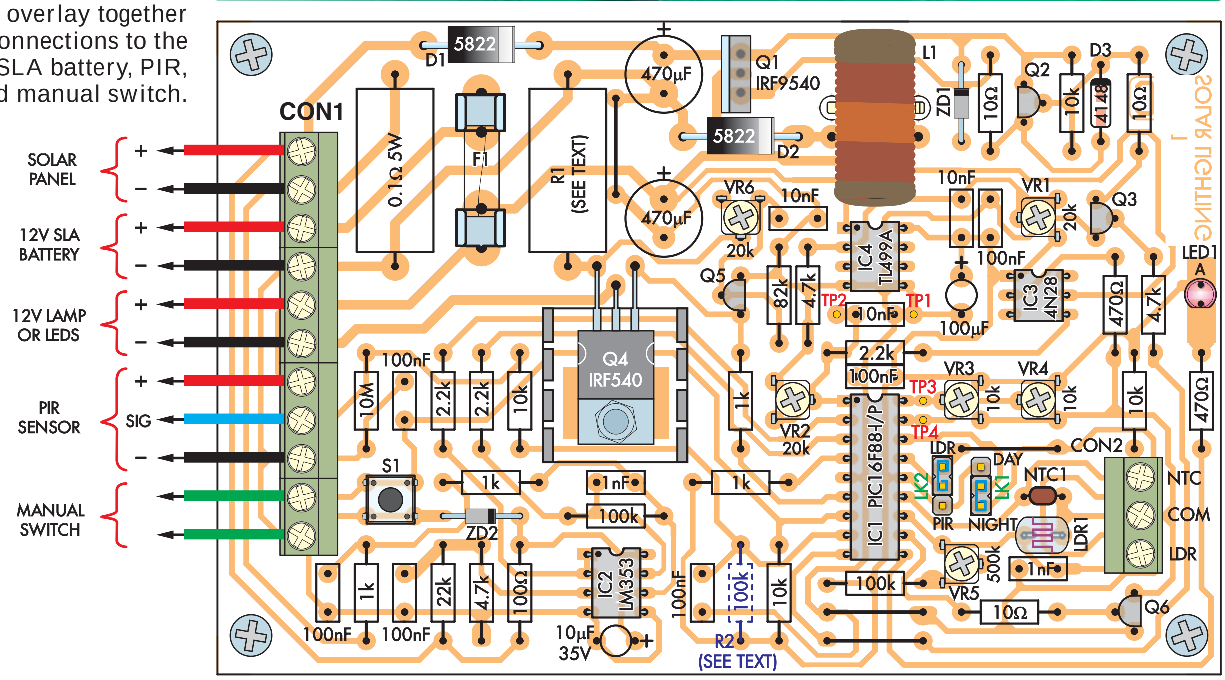
Next are the trimpots – again, take care to place the correct value in each position. Note that most trimpots are marked with a code rather than the actual ohm value. For the 10kΩ trimpots, the marking may be 103, the 20kΩ trimpots 203 and the 500kΩ trimpot 504.

Install the transistors and MOSFETs, taking care not to confuse Q2, Q3 and Q5 (all BC337 types) with Q6 (a 2N7000). Also, ensure that Q1 is the IRF9540.



Same-size photo of the completed PC board. As you can see here, both the LDR and LED can be mounted on the board (the LDR via CON2) and bent over 90° to line up with holes in the case.

Fig.6 (below) matches this photo and shows the component overlay together with the connections to the solar panel, SLA battery, PIR, LEDs and manual switch.



MOSFET Q4 is the IRF540 and is mounted horizontally on the PC board using a small finned heatsink. The leads are bent at 90° before being inserted into the PC board. It's easiest to fasten Q4 to its heatsink and the PC board with its screw; ie, *before* soldering it in place, to ensure that it lines up with the screw hole in the PC board.

The 11-way terminals are made using three 3-way and one 2-way section, which dovetail together before installing onto the PC board. The wire (entry) side should face the outside of the PC board.

Switch S1 can be installed now, followed by LED1, which is mounted so the top is about 25mm above the PC board. Ensure the anode (the longer lead) goes into the hole marked 'A'. The coil, L1, is mounted upright and secured to the PC board with a cable tie as well as being soldered (see the photo and layout diagram above).

Finally, the LDR (light-dependant resistor) can be installed. If you use a clear-lid UB1 box to house the *Solar-Powered Lighting Controller* you may be able to install LDR1 directly onto the PC board. Where the lid is not clear, or if the box will not be exposed to ambient light, the LDR can be fastened to the CON2 connector terminals so that it 'sees' through a hole in the side of the box. As we mentioned last month, it can be remotely located using figure-8 wire. Note that it is either on the PC board or remote, not both! LDRs are not polarised.

Similarly, the NTC thermistor can be installed on the PC board *or* remotely, using a figure-8 cable connection for external temperature sensing of the battery.

Setting Up

Before we tackle the setting up procedure, links LK1 and LK2 need a jumper shunt, with the various options shown

Table 1: Lamp operation

PIR (LK1)	LDR (LK2)	Lamp ON	Lamp OFF
In	Night	PIR movement detection or with S1 during night time only	Timer timeout, S1 or at dawn
In	Day	PIR movement detection or with S1 during day time only	Timer timeout, S1 or at dusk
In	Night (LDR1 disconnected)	PIR movement detection or with S1 during day and night	Timer timeout or S1
Out	Night	Day-to-night transition or with S1, night only	Timer timeout, S1 or automatically at dawn
Out	Day	Night-to-day transition or with S1, day only	Timer timeout, S1 or automatically at dusk
Out	Night (LDR1 disconnected)	S1 during day or night	Timer timeout or S1

Table 1: reproduced from last month, this shows the various options available with the PIR link in and out and the LDR link (LK2) dark, light or disconnected.

Output current	200mA	350mA	500mA	700mA	1A	2A
R1 (all 5W)	3.3Ω	2.2Ω	1.5Ω	1Ω	0.68Ω	0.33Ω

Table 2: resistor (R1) value for constant current LED drive or for over-current limiting.

TP4 Voltage	Timeout period	Timeout steps	Timeout calculation (approximately)
0V-2.5V	2s-250s (4m)	2 seconds	TP4 voltage x 100s
2.5V-4.9V	4m-480m (8h)	4 minutes	(TP4 Voltage–2.5V) x 200m
5V	No timeout		

Table 3: timeout adjustment using VR4. This is measured between TP4 and TP1 (ground) while S1 is pressed.

in Table 1. If you are not sure at the moment, take a guess: they can be readily altered later on.

With IC1 still out of circuit, but the fuse in place, apply power to the '12V SLA Battery' + and – inputs on connector CON1. With a DMM, measure the voltage between pins 5 and 14 of IC1, then adjust VR1 for a reading of 5.0V.

Now switch off power and plug IC1 into its socket, taking care to insert it correctly: the right way around and no pins bent out of position. Apply power again and measure the voltage across the same (12V SLA battery) inputs. Multiply the measured voltage by 0.3125. For example, if the voltage is 12V, 0.3125 x 12V = 3.75V. Make a note of this figure.

Now you need to calibrate the battery voltage so that the 20°C cut-off voltage for the battery is 14.4V, and the float voltage is 13.5V.

This is really easy: press and hold down switch S1 (otherwise the reading will be false) and connect your multimeter between TP1 and TP2 (with it set to read up to 20V). Adjust trimpot VR2 so that the reading equals the calculated voltage you wrote down (ie, xV x 0.3125).

Setting the lamp current

The *Solar-Powered Lighting Controller* lamp driver can be set up to drive LEDs directly, or alternatively low-power 12V lamps. Fig.7 shows some of the types of lighting that can connect to the Controller.

The 12V lamp varieties could be compact fluorescent lamps (CFLs), halogen filament globes or LED globes. The distinction we are making between LEDs and 12V LED globes is that while 12V lamps can be directly driven from a 12V supply, standard LEDs cannot. This is because LEDs must have a current-limited supply to prevent damage.

Some 12V LED globes use single or multiple LEDs in the one housing, which include some form of current limiting. 12V LED lighting may be not very efficient because of losses, especially if they use simple-current limiting resistors.

For example, a typical 5W LED MR-16 halogen light replacement may well drive the LED at 5W, but the overall power used by the lamp is 7.2W. This represents a 2.2W or 31% loss (69% efficiency) in delivering power to the LED or LEDs. Note that this efficiency is not the amount of light output for a given power input, it is simply the power lost.

So, while white LEDs are more efficient at producing more light for a given power than halogen lamps, the loss in the current-limiting resistor for the LED may change this.

When using individual white LEDs directly, the Controller is set to drive them at the required current. As an example, three star 1W LEDs would be driven at around 300mA to 340mA and use a 2.2Ω resistor for R1. For three 3W LEDs, the current is around 700mA and R1 is 1Ω instead.

For 12V lighting, it may be more efficient to use a halogen 12V lamp, such as the Altronics 12V bulkhead light (cat no X2400) instead.

Current adjustment over a small range is available using trimpot VR6. The easiest way to measure LED current is to connect a multimeter (on a DC current range) across the fuse clips with the fuse removed. The quiescent current drawn while the lamp is off can be subtracted from the total LED drive current for more accuracy.

If you require more than three LEDs, then a separate LED driver can be used that is designed to drive several LEDs in series from a 12V supply.

An example of a driver that can power up to six 1W-LEDs in series is the Altronics M3310. The setting up for the Controller lamp driver for use with a separate LED driver is the same as for standard 12V lighting where R1 is 0.33Ω.

Timeout

Depending on your application, the timer will need to be set to an appropriate period. Timeout periods can be adjusted from as low as two seconds up to about 8 hours using trimpot VR4.

Table 3 shows the timeout with respect to voltage, set by VR4. To measure this voltage, a multimeter is connected between TP1 and TP4 and the S1 switch is pressed. The measured voltage provides a means to calculate the expected timeout. For voltages up to 2.5V, the timeout period in ***seconds*** is calculated as the voltage measured (in volts) multiplied by 100. By way of example, a 1V setting will provide 100 seconds.

Above 2.5V, the voltage is multiplied by 200 ***minutes*** after first subtracting 2.5V from the voltage measurement. So a 3V reading will provide a timeout of (3V-2.5V) x 200min, or 100 minutes.

Temperature compensation for the cut-off and float voltage is set using VR3. The voltage can be measured between TP1 and TP3, while S1 is pressed. Compensation is adjustable from 0mV/°C to –50mV/°C. The actual compensation is directly related to the measured voltage. Just divide the voltage by 100 to get the mV/°C value. The actual compensation value required depends on the battery, with manufacturers specifying this mV/°C value. Typically, the value for a 12V battery is –19mV/°C. So VR3 would be set to 1.9V as measured at TP3.

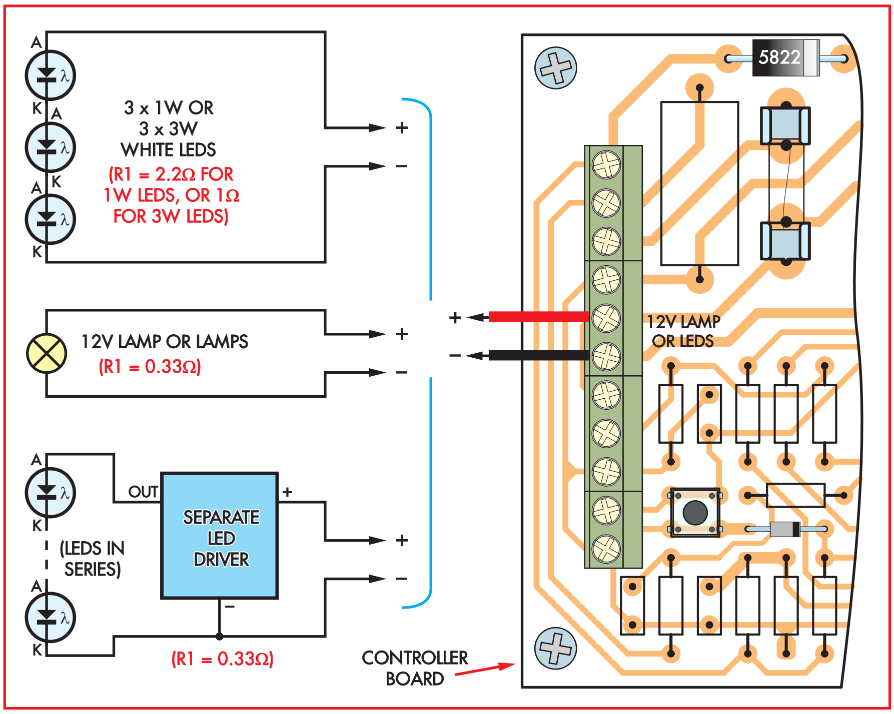


Fig.7: the Solar Lighting is designed to drive three 1W or three 3W LEDs in series or 12V lamps. Note the value for R1 is different for each lighting circuit. For more than three LEDs in series, a separate driver is required.

Installation

The *Solar-Powered Lighting Controller* is designed to mount in a UB1 box with wires for the external connections passing through cable glands. The charge LED (LED1) is bent over and protrudes through a hole in the side of the box.

Fig.6 shows the wiring connections for the solar panel, the battery and the lamp plus the PIR and manual switch terminals at CON1, and the external NTC thermistor and external LDR at CON2. As noted the NTC and LDR can be mounted on the PC board ***or*** mounted remotely (ie, only one LDR and one NTC should be connected).

In most installations, the NTC thermistor can be mounted on the PC board because the Controller and battery would be housed close to each other and their temperatures would, therefore, be similar.

However, an external NTC thermistor, attached via a length of figure-8 wire and mounted against (glued or taped) the side of the battery, would be necessary if the battery is installed any distance from the Controller.

Mounting the LDR

The LDR needs to be mounted so it receives ambient light, but so that it does not receive light from the lamp(s) controlled by the Solar-Powered Lighting Controller. For some installations, the LDR can be mounted inside on the PC board if you use a transparent box and if the Controller is exposed to the ambient light.

Alternatively, the LDR can be wired into CON1 and exposed to ambient light by having the LDR mounted into a hole in the side of the case.

Where the Controller is mounted inside a cabinet or other dark place, the LDR can be mounted using a length of figure-8 wire in a position where it will be exposed to ambient light.

Solar panel position

The solar panel should be mounted on a roof or similar position, and in the UK should be set facing south.

Inclination should be roughly 53° up from horizontal for the UK. If in doubt, several Internet sites will help you, and also suggest better angles for mid-winter or high summer.

Incidentally, many solar panels do not like to be partially shaded – we've seen reports that even a small percentage of shading reduces the output to near zero – so care should be taken to avoid any possibility of shadowing (eg, from a pole or tree) as the sun traverses the sky.

Mounting the PIR

When mounting the PIR sensor, its position should be placed to provide coverage of the desired detection area. You can test coverage by temporarily mounting the PIR detector, connecting a 12V supply and watch the detect LED light as you move around the detection area.

PIR wiring varies depending on whether you are using the (recommended) special low-current Altronics PIR sensor or a standard PIR detector.

Fig.8 shows typical wiring for both of these types of PIRs. Note that R2 is NOT used for the Altronics PIR, but it MUST be installed when a standard PIR detector is used. Four-way alarm cable is normally used for this wiring, with only three of the wires used.

Most PIR units have a 'tamper' detector of some sort, which normally uses the fourth wire, but in this case, the tamper detector can be ignored.

The lamp

We made up an LED lamp using three white LEDs, and this was shown in the photographs last month. The lamp is wired into the Controller using figure-8 wire.

An LED light can be made using a clear plastic utility box or an IP65-rated box with a clear lid. This latter style of box

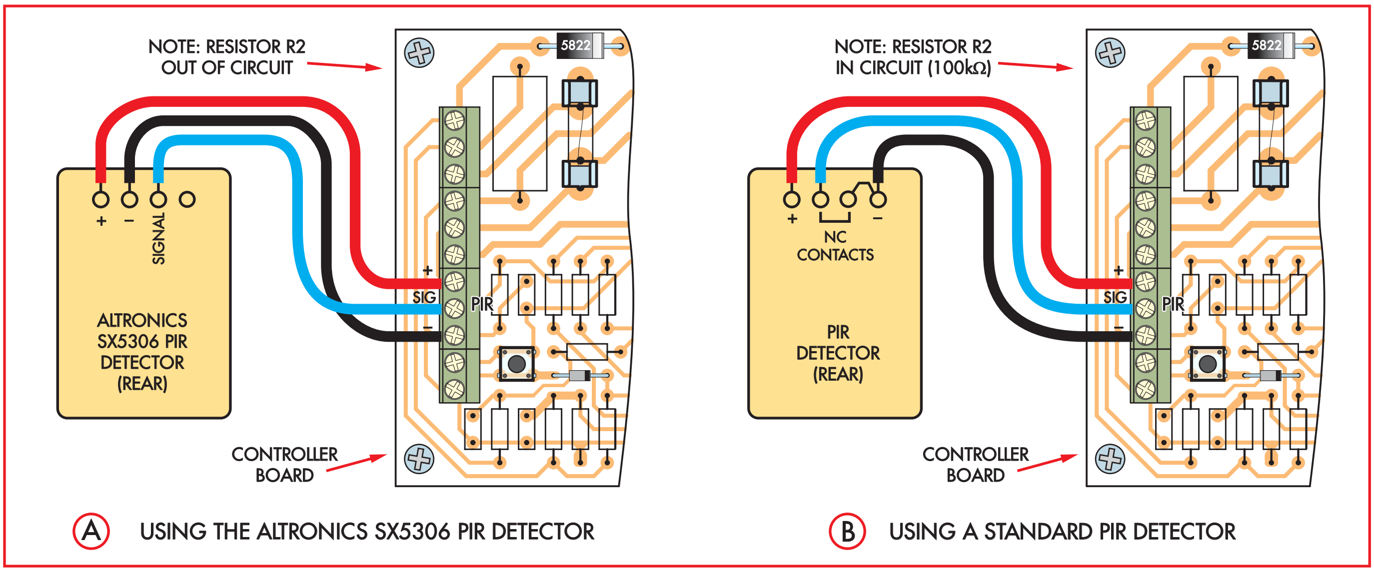


Fig.8: this shows how to wire up a PIR detector to the Solar-Powered Lighting Controller. When using the Altronics SX5306 PIR detector, the plus/minus power leads and the signal wire are connected to the controller as shown. Resistor R2 is not used on the controller PC board. For use with standard PIR Detectors, the minus supply is linked to one of the NC contacts on the PIR detector relay. The second contact of the NC contact becomes the trigger wire for the controller. Note that R2 needs to be soldered on to the controller PC board when using this standard type of PIR detector that uses a relay.

is more suited to outside use where it must be waterproof. The LEDs require heatsinking, so are mounted onto an aluminium plate that sits inside the box. The IP65 box has integral mounting bosses for attaching the plate. A plastic utility box (the type we used to house the Controller) has integral (moulded) side clips for mounting the aluminium plate horizontally.

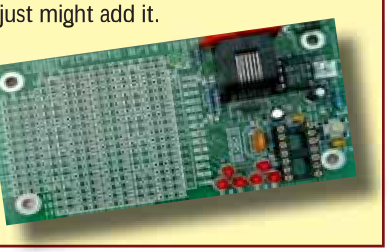
The LEDs are mounted on to the plate using nylon screws and nuts. We used three 1W LEDs arranged in a triangle pattern on to the plate, but as discussed earlier, 3W LEDs could be used instead.

The LEDs are wired in series and the wires taken out of the box via a cable gland (even though the gland is 'waterproof'; for outside use, the box should be mounted so the gland emerges from the underside).

To spread the light more evenly, we cut a 'diffuser' to fit inside the lid, made from a piece of translucent plastic – actually we used a kitchen cutting mat which was about 0.5mm thick and easily cut with scissors – but any suitable translucent plastic sheet could be used.

Looking end-on at the completed project showing both the LDR and LED inside the box, 'seeing' through appropriately placed holes. If better water resistance is required (though not waterproofing) some clear film or plastic could be glued over the holes on the inside.

Finally, use crimp connectors for the wires connecting to the battery terminals. Never attempt to solder wires direct to the battery, as this can cause irrepairable damage. ***EPE***



Jump Start

By Mike and Richard Tooley

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

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

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* page 75 in this issue).

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

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

Coming attractions

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

Quiz Machine

In this month's Jump Start *we'll design and build a simple* Quiz Machine *for use in school and college, as well as for family fun and entertainment.*

Under the hood

Our *Quiz Machine* will consist of a 'master unit' that can be used with any number of 'contestant units'.

Each contestant unit has an answer button and an LED indicator that remains illuminated on when the answer button has been pressed, even if only momentarily (so there is no need to hold the button down to signal that an answer is being offered). The master unit has a buzzer, LED and a reset switch, so that only the question master can over-ride the system in readiness for a new question.

The contestant units in our *Quiz Machine* use the silicon-controlled rectifier (SCR) technology that we introduced in May's *Jump Start*. These handy devices can be made to switch very rapidly from a non-conducting state to a conducting state by applying a trigger pulse to their input (gate) terminal. Once triggered into the conducting state, the SCR will remain conducting, 'latched' into the 'on' state until the forward current is removed from the device when the question master operates the reset switch.

An important feature of a *Quiz Machine* is the need to lock-out answers from other contestants once any of the answer buttons have been pressed. This can be achieved quite easily using a multiple wire connecting system with two or three wires connecting each of the contestant units to the master unit, as shown in Fig.1(a).

Since this is a little cumbersome, and involves a great deal of wiring, we decided to develop a system based on the use of only two wires in a 'daisy' chain arrangement, where each contestant unit is connected in turn to the next contestant unit in the chain, see Fig.1(b).

Design notes

The basic arrangement of our *Quiz Machine* is shown in Fig.2. This shows the master and contestant unit PCBs, and the components that are attached to them. In order to facilitate two-wire operation, it is necessary to have some means of maintaining the supply to the contestant units, so that the triggered SCR remains in a conducting state, while at the same time alerting the master unit to the fact that one of the contestant units has been activated. This is achieved by means of a voltage-sensing circuit that operates on the principle of the potential divider (see Fig.3).

In the basic potential divider shown in Fig.3(a), the output voltage, V_{OUT}, will be given by:

$$V_{OUT} = V_{IN} \times \frac{R2}{R1+R2}$$

In the *Quiz Machine*, R1 is simply a fixed resistor connected in the common positive supply to all of the contestant units, while R2 is the effective resistance of all of the contestant units when connected in parallel. With none of the contestant units activated, R2 will be very high, but when one of the units is in the triggered state the current demand will increase and the value of R2 will fall. This, in turn, will cause the output voltage to fall.

The voltage change produced by the potential divider needs to be sensed within the master unit. This can be achieved by means of the voltage-sensing circuit shown in Fig.3(b). The voltage-sensing arrangement produces an output that triggers an SCR in the master unit whenever any one of the contestant units has been activated.

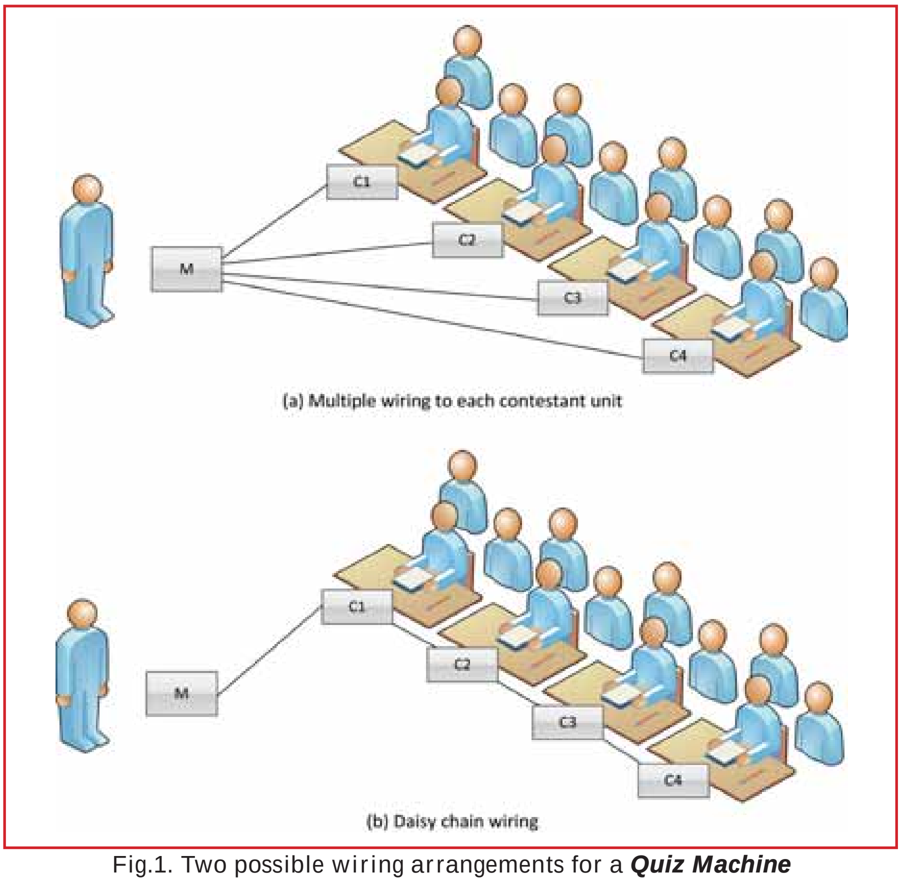


Fig.1. Two possible wiring arrangements for a ***Quiz Machine***

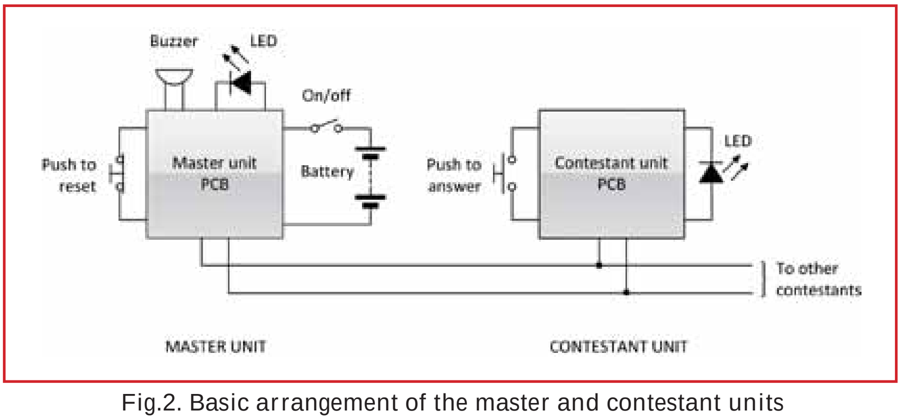


Fig.2. Basic arrangement of the master and contestant units

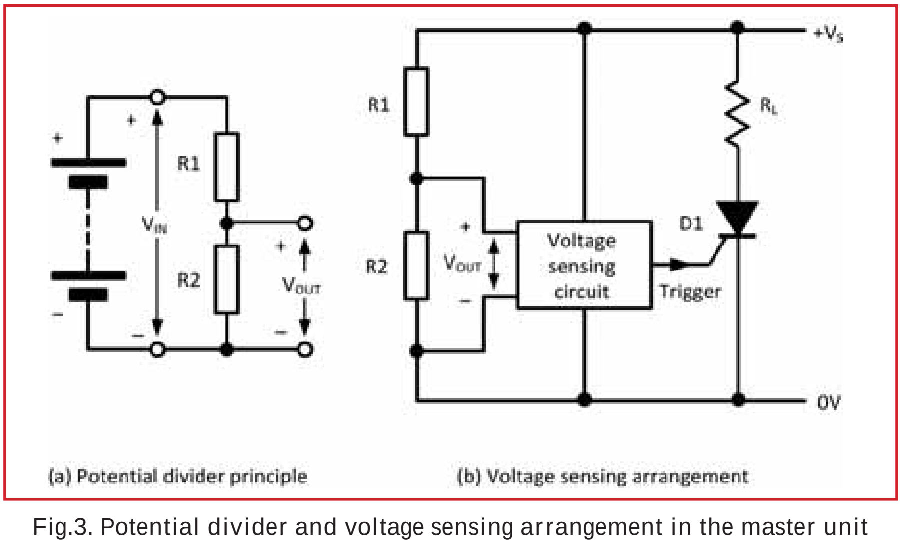


Fig.3. Potential divider and voltage sensing arrangement in the master unit

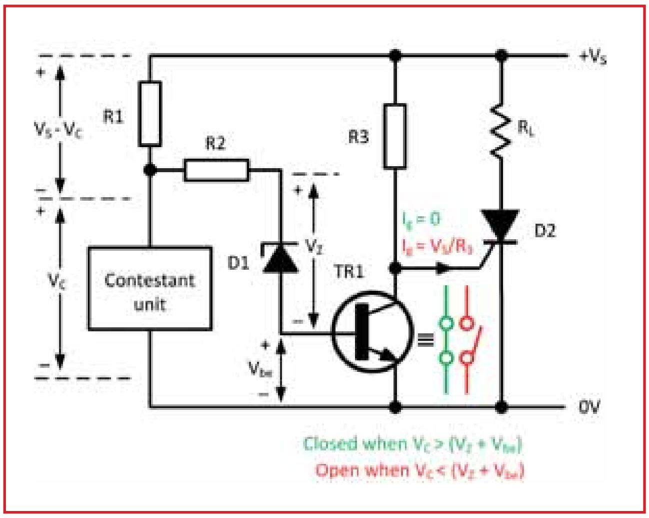


Fig.4. Voltage sensing arrangement used in the master unit

The voltage-sensing arrangement used in the master unit is shown in Fig.4. This uses a Zener diode (D1) which acts as a 'voltage reference'. Zener diodes are silicon diodes, but unlike normal diodes, they exhibit an abrupt reverse breakdown at relatively low voltages (for example, 5.6V, 6.8V or 7.5V). A typical V/I characteristic for a 7.5V Zener diode is shown in Fig.5.

Note how the reverse voltage remains constant for a wide range of reverse current. This property makes this type of diode ideal for providing us with a reference voltage against which another voltage can be compared.

The transistor shown in Fig.4 operates as a switch. When the input to the voltage-sensing arrangement exceeds the sum of the Zener voltage and base-emitter voltage for TR1, current will flow into the base of TR1, causing it to turn on and conduct heavily. The rapid increase in base current will result in a corresponding increase in collector current (see May *EPE*), and this will cause the collector voltage to fall to a very low value. In this state, there will be insufficient voltage present at the gate of SCR D2 to cause it to be triggered. D2 is thus placed in the off state, waiting for a response from one of the contestant units.

When any one of the contestant units is activated, the supply current will increase and the input to the voltage-sensing arrangement will fall below the threshold required for the Zener (D1), to conduct. In this condition, TR1 will rapidly switch off and enter a non-conducting state.

As a result. the collector current of TR1 will rise to a value which will be sufficient to trigger D1. Once triggered, D1 will remain in the conducting state (along with the SCR in the activated contestant unit) until the circuit is reset by momentarily interrupting the supply.

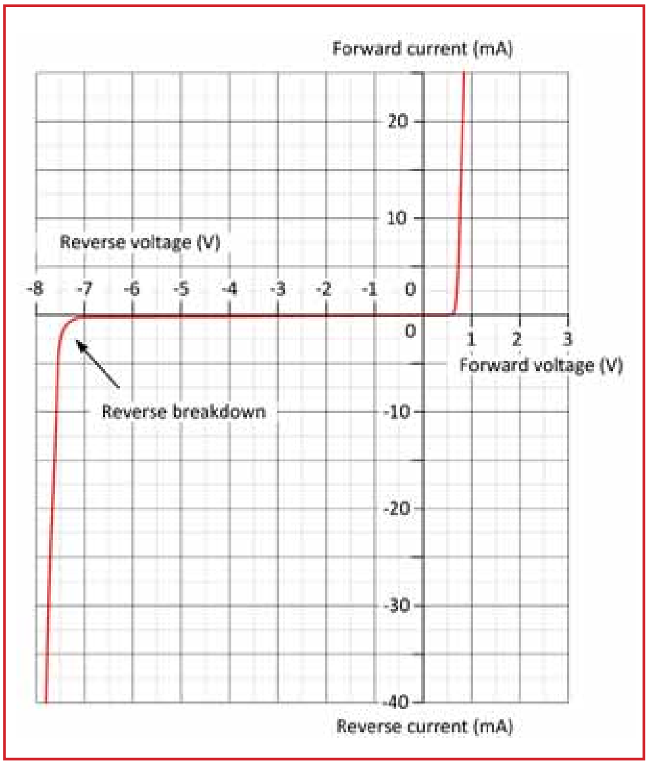


Fig.5. The V/I characteristic for a 7.5V Zener diode

Get real!

Besides being a useful tool for designing and simulating electronic circuits, Circuit Wizard can also provide you with insight to how individual components work. For example, the voltage characteristic of a Zener diode can be quickly and easily obtained by constructing a simple 'test circuit', like the one shown in Fig.6. This circuit uses a power supply that feeds current to a nominal 7.5V Zener diode via a series current-limiting resistor, R1.

The circuit shown in Fig.6 uses a 'virtual instrument' to measure the Zener voltage when current is applied to it. The voltmeter is obtained by selecting 'Gallery' then 'Virtual Instruments' followed by 'Digital Multimeter'. The DMM virtual instrument can then be dragged into the circuit.

The power supply is obtained by a similar process, but this time you need to select 'Gallery' then 'Power Supplies' followed by 'Input Voltage'. The voltage source can then be dragged to the open circuit window.

When you have placed the voltage source in your circuit, you can right-click the mouse on the input terminal and select 'Properties'. This will produce a dialog box in which you can set the required voltage in the 'Value' field, and also designate a key that will allow you to adjust the

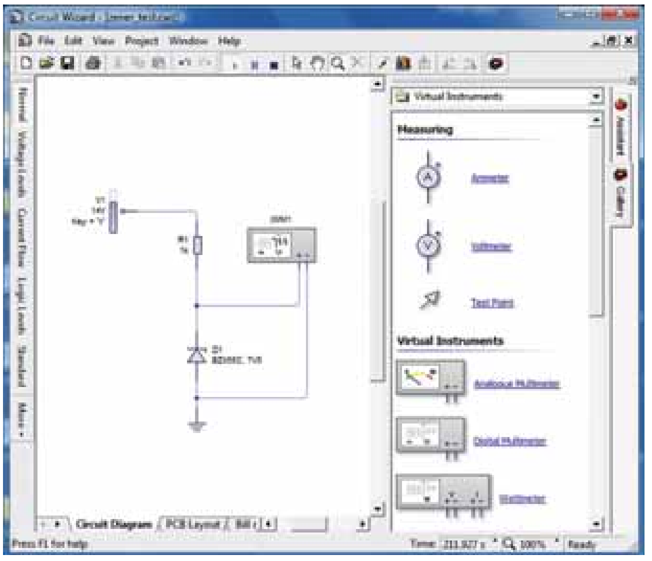


Fig.6. Using Circuit Wizard to measure the voltage of a Zener diode

voltage from the keyboard. In our case, we used the 'V' key, which will raise the voltage in 1V steps each time the key is pressed unshifted, and reduce the voltage in 1V steps each time the key is pressed with the shift key.

When the circuit is complete, you can use the 'Run' (right arrow) key to obtain a set of readings like those shown in Table 1. Note that we've included a column of 'real' results in order to show how the voltage obtained from Circuit Wizard compares with those obtained from a real circuit. Notice both sets of results show clearly how the Zener diode effectively 'clamps' the voltage once it exceeds 7.5V!

Table1: Comparison of values obtained from Circuit Wizard with a real circuit

Input voltage (V)	Zener voltage		Input voltage (V)	Zener voltage	
	Virtual circuit (Circuit Wizard)	Real circuit		Virtual circuit (Circuit Wizard)	Real circuit
4	4	4	10	7.52	7.62
5	5	5	11	7.53	7.64
6	6	6	12	7.54	7.65
7	7	7	13	7.55	7.66
8	7.48	7.58	14	7.55	7.67
9	7.51	7.60	15	7.56	7.68

Circuit Wizard

AS WITH all of our *Jump Start* circuits, we've given you the underpinning theory, putting it into practice using circuit simulation and converting it to a PCB design. The Circuit Wizard software that we've used throughout the series makes this process really simple and great fun, and we always recommend following the tutorials to enter the circuits and converting them to your very own PCB designs.

However, if this isn't your bag, you can simply use our artwork to prepare your boards or download our own Circuit Wizard files from the *Jump Start* website at: **www.tooley.co.uk/epe**. – Don't forget, if you'd just prefer a pre-made PCB, you can purchase these from the *EPE* Magazine PCB service (see page 78).

To start, let's enter the full *Quiz Machine* circuit into Circuit Wizard. Fig.7 shows our *Quiz Machine* circuit for two contestants. Ensure that you enter the circuit accurately and change each component to the appropriate model and/or value.

A neat feature of Circuit Wizard is the ability to assign a key to a switch, so that you can simply hit the corresponding key on your keyboard to simulate a button press (Fig.8). This is particularly useful when you want to see how a circuit responds to rapid or simultaneous button presses.

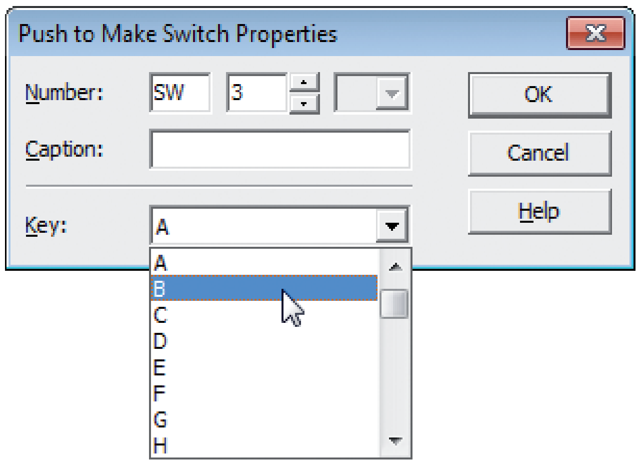


Fig.8. Setting a switch key in Circuit Wizard

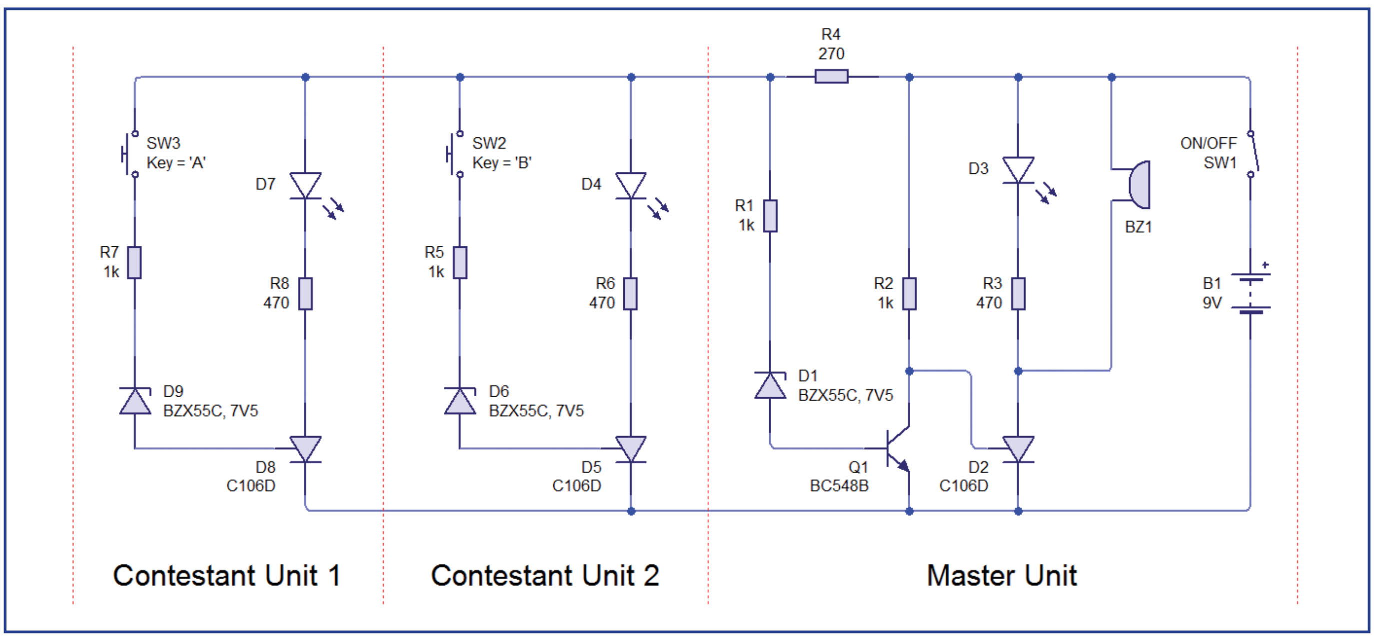
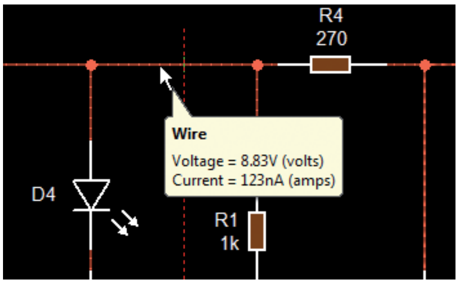


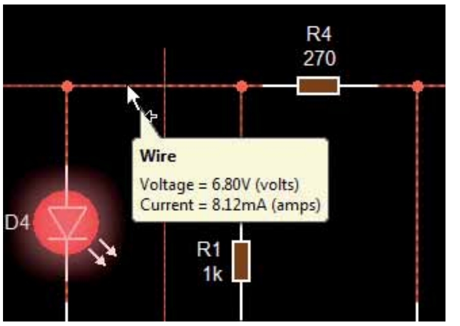
Fig.7. Simulating our *Quiz Machine* with two contestants

Run the circuit and test its operation. The 'Current Flow' view is really useful to see how the circuit functions in operation. By hovering the mouse over any point you can get a tooltip showing the voltage and current at that node. Try monitoring the voltage just to the left of R4.

Notice that when the buzzer is off, the voltage is around 8.8V – enough to trigger the SCR on one of the contestant units (Fig.9a). However, when either unit has been activated the voltage drops to 6.8V, no longer enough to trigger the remaining contestant SCRs and therefore 'locking them out' (Fig.9b).

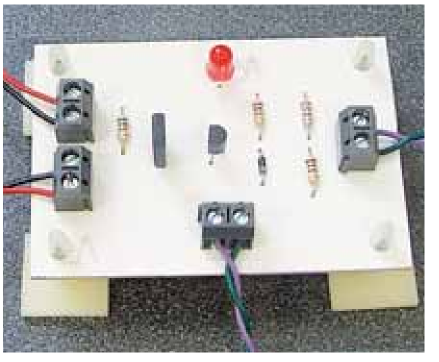


(a)



(b)

Fig.9. (a) Supply voltage with both units inactive (b) Supply voltage when one contestant unit has been triggered



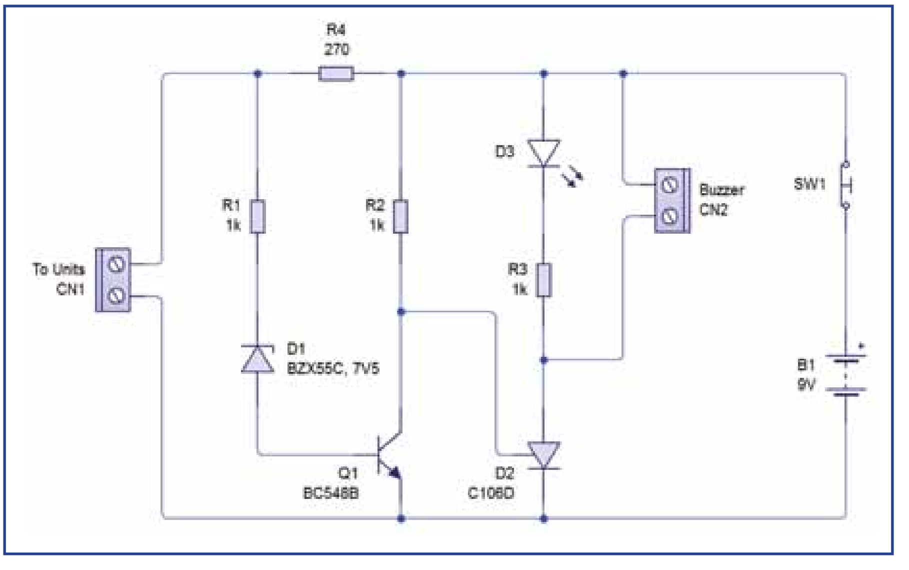
Quiz Master controller

SO, WE'RE satisfied that the circuit operates as we'd want – now it's time to look at converting it to a practical PCB that we can build for real. In our example PCB, we've decided to separate the circuit into a master unit and two or more contestant units that can be 'daisy chained' together.

However, you may prefer to design the project as a single PCB. Our *Quiz Machine* master unit and contestant unit circuits are shown in Fig.10 and Fig.11. Note that we've added two-pin terminal connectors where the units will connect to each other, and for an off-board buzzer.

As you can see, the two individual circuits are very simple, with a low component count and you should find that Circuit Wizard will automatically route your circuit into a functional PCB. However, we would always recommend first setting out the components manually before auto-routing the tracks, or manually adding the tracks to get a

Fig.10. Quiz Master Controller circuit diagram produced by Circuit Wizard



Contestant Slave Unit

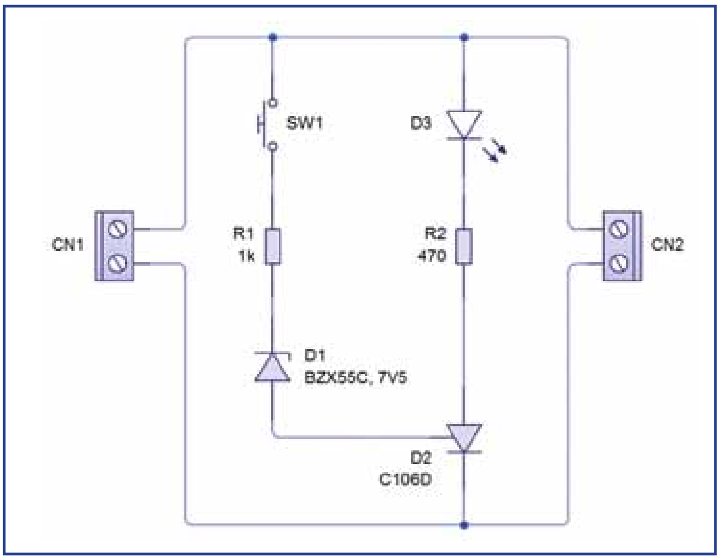
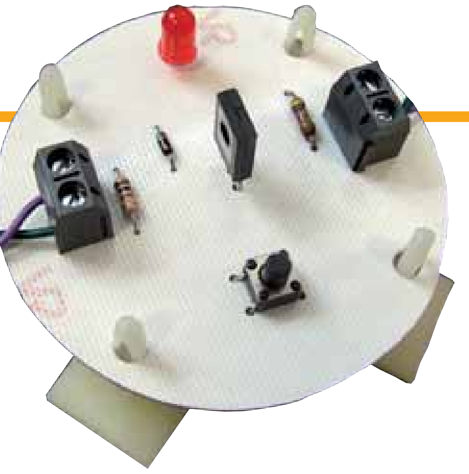


Fig.11. Circuit diagram for a single contestant unit, produced by Circuit Wizard



You will need...

Contestant unit

1 PC board, code 855 (Cont), available from the *EPE PCB Service,* size 64mm diameter
1 mini 'tactile' pushbutton switch, PC mounting, size 6mm × 6mm (SW1)
2 2-way PC-mounting screw terminal block (CN1 and CN2)

Semiconductors
1 BZX55C 7.5V Zener diode (D1)
1 C106D thyristor (SCR) (D2)
1 5mm red LED (D3)

Resistors
1 1k (R1)
1 470 (R2)

You will need...

Master unit

1 PCB, code 854 (Master), available from the *EPE PCB Service,* size 76mm × 51mm
1 miniature push-to-break switch
1 9V battery, with clip and leads (B1)
3 2-way PC-mounting screw terminal blocks (B1, CN1, CN2)
1 miniature 6V to 9V buzzer

Semiconductors
1 BC548B *NPN* transistor (Q1)
1 BZX55C 7.5V Zener diode (D1)
1 C106D thyristor (SCR) (D2)
1 5mm red LED (D3)

Resistors
3 1kΩ (R1, R2, R3),
1 270Ω (R4)

really smart layout. However, this is entirely up to you.

When converting the contestant units to PCB, we chose to customise the PCB layout conversion so that we could set the switch as a 6mm tactile button and change the PCB shape to a circle (Fig.12). We also unchecked automatic component placement, then having arranged the components so as to minimise cross-overs of the unrouted nets, we drew standard width tracks manually.

Once you've designed your PCB, it's always worth running a 'Quality Report' (Fig.13a). This really useful Circuit Wizard feature will check your PCB design against your original circuit to make sure that it matches up properly, as well as carrying out a number of checks on your design (Fig.13b).

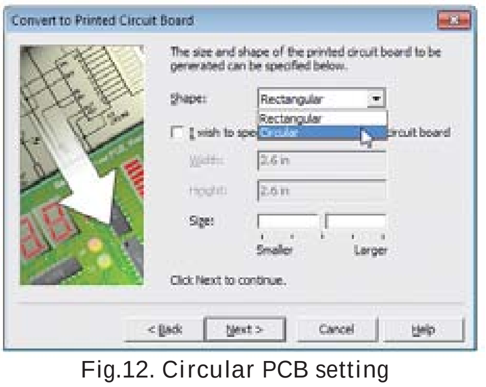
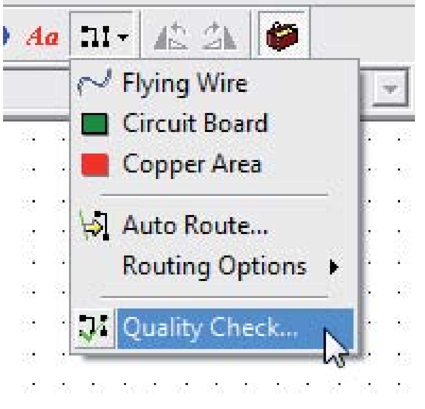


Fig.12. Circular PCB setting

A note regarding Circuit Wizard versions:

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start *series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.*



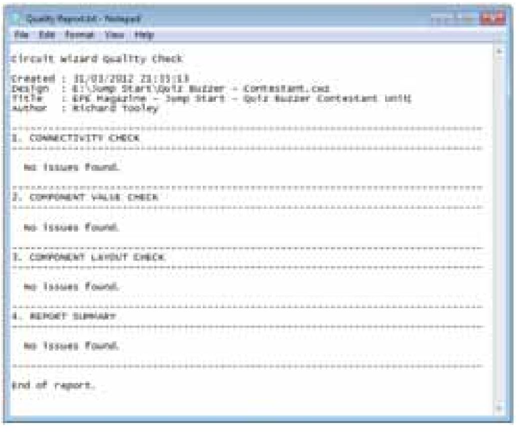


Fig.13. (a) Quality check toolbar (b) quality report

Our completed PCB designs are show in various views in Fig.14 and Fig.15.

As a final test before warming up the etch tank, we created a new Circuit Wizard file, then copied and pasted the master unit and two contestant unit PCBs on to the PCB layout sheet. After virtually wiring up and adding off-board components (battery, buzzer and push-to-break momentary switch), we could virtually test the whole system (Fig.16). Note that when the PCBs are pasted, Circuit Wizard automatically renumbers the components for each component; therefore, we would only recommend using the file for simulating the PCBs together, but actually producing the PCBs from the individual unit files. At the end of this instalment you will find our gallery showing some additional photographs taken throughout the production stages of our PCBs, as well as some shots of the finished article.

Teacher's Tip

If you're teaching electronics, it's a great idea to build one master unit and have all of the students design and build their own contestant units. You can then connect them all together and use them in class!

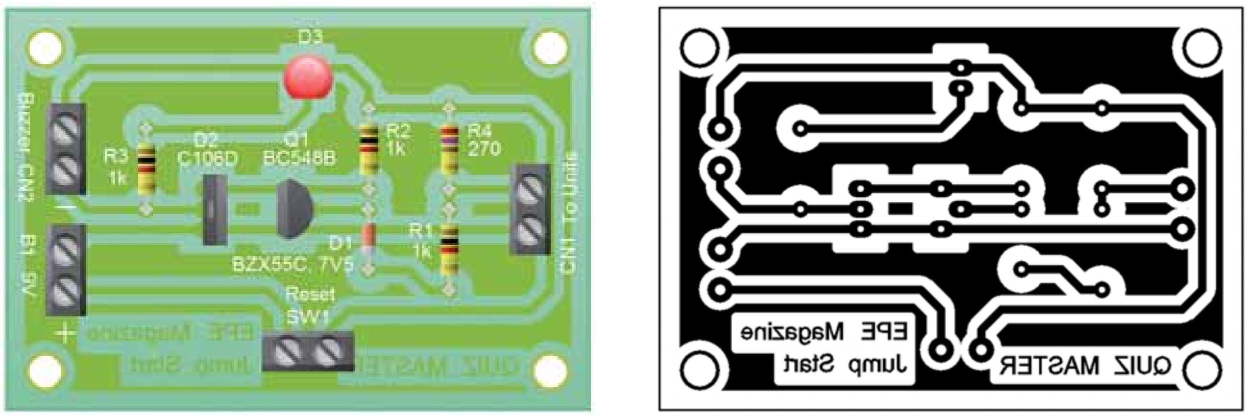


Fig.14. ***Quiz Machine*** master unit printed circuit board (PCB) component layout and copper track artwork

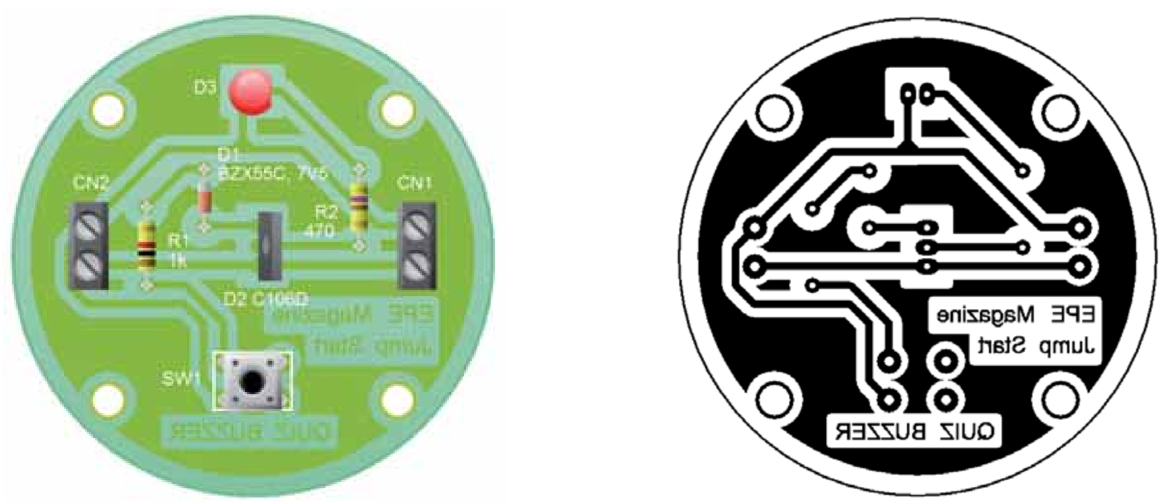


Fig.15. ***Quiz Machine*** contestant unit printed circuit board (PCB) component layout and copper track artwork

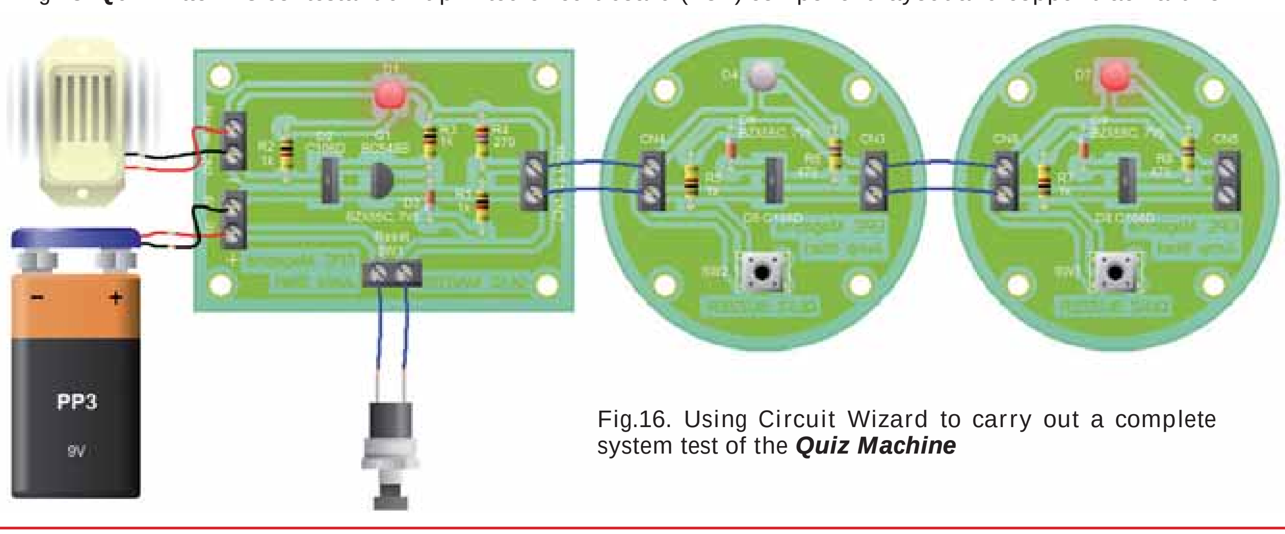
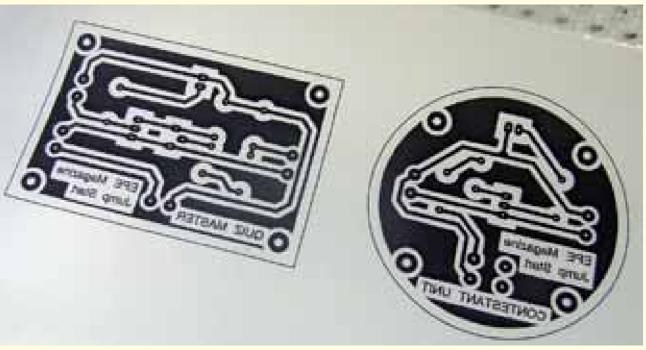


Fig.16. Using Circuit Wizard to carry out a complete system test of the ***Quiz Machine***

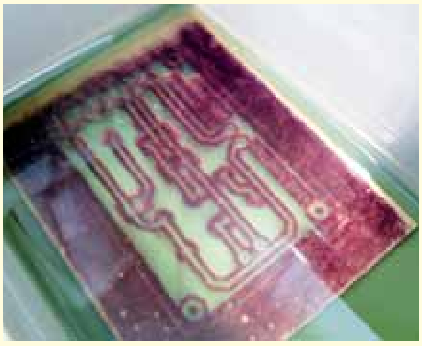
Photo gallery...



PCB artworks (printed on laser artwork film) for both units, ready on the UV exposure unit. Note that the film is print side up

Developed contestant unit entering etch bath

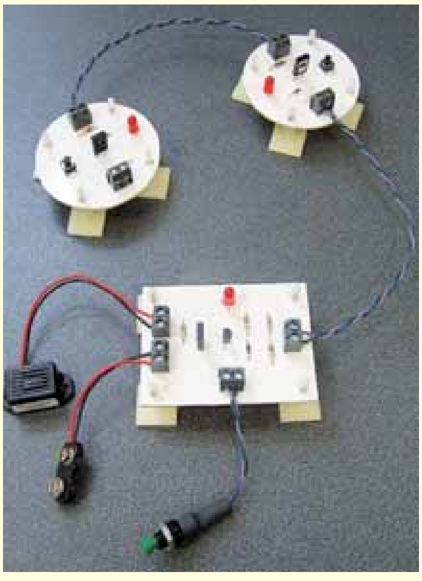
For more info:
www.tooley.co.uk/epe



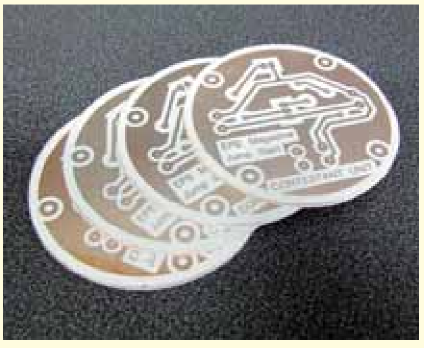
Master unit being developed prior to UV exposure

Contestant unit being 'rounded' using a bench disc sander

Drilling the contestant unit PCBs



Complete quiz buzzer system wired up ready for action!



Four contestant unit PCBs ready for drilling

Students from Chichester College trying out the prototype system

Next month

In preparation for the summer holidays, we will be developing and constructing a *Battery Tester* that will be ideal for checking the batteries that you'll need when away from home. See you next month!

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

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REVIEW . . .

PicoScope 2205 MSO

PC OSCILLOSCOPE

The 2205 MSO can certainly be recommended for anyone seeking a unit of this type, one that includes a signal generator and a basic logic analyser facility.

by Robert Penfold

IN THE world of electronics, Pico Technology is well known for its range of PC add-ons, which are basically fast analogue-to-digital converters that effectively turn the host computer into a storage oscilloscope. In fact, these units, with the aid of the accompanying Pico Technology software, generally go beyond the main task of providing a storage oscilloscope. Additional features such as waveform generation, data logging, and spectrum analysis are usually included as well.

Facts and figures

The PicoScope 2205 MSO reviewed here is one of the 2000 series entry-level units, but it is nevertheless a very capable unit. The MSO part of the name stands for 'mixed-signal oscilloscope', and refers to the fact that the unit can simultaneously display analogue and digital signals.

It is a standard dual-channel storage oscilloscope, but it also has a 16-channel digital input, and there is a waveform generator output. The bandwidth of the analogue channels is a respectable 25MHz, and the maximum sampling rate is quoted as 200 million per second for single channel operation (100 million per channel for dual channel operation).

There are a number of advantages when using a PC-based virtual oscilloscope, but there is a potential flaw with units of this type. The problem is that there can be a 'bottle-neck' in the link between the interface and the computer, especially when using a very fast converter that can produce many millions of samples per second.

The way around this is to have some memory in the interface unit to provide buffering, and in the case of the PS 2205 MSO there is a 48k buffer. The resolution of the unit is 8-bits, although 12-bit resolution is claimed when using a system of resolution enhancement.

The PicoScope unit is housed in a tough plastic case that measures about 180mm by 135mm by 30mm. Control knobs and switches are conspicuous by their absence. The unit is controlled entirely via the PicoScope 6 software running on the host PC.

There are two BNC sockets and an LED indicator light on the front panel. The two sockets are the main (channel A and channel B) analogue inputs, and there is no external trigger input. The indicator light switches on when the unit is connected to an active USB port, and it flashes when the unit is actually operating. There is a 20-way connector on the front panel that provides the 16-channel digital input. A third BNC connector on the rear panel is the output for the unit's built-in signal generator. Also on the rear panel there is a USB socket, and this is connected to a spare USB socket on the host computer using the supplied 2m cable.

The unit is powered from the host computer, which avoids the inconvenience of a mains adapter. However, the unit *must* be connected to a USB port that has a proper power output line. The unit will *not* work if it is connected to something like a passive USB hub, or a 'cut down' USB port on a portable PC of some kind.

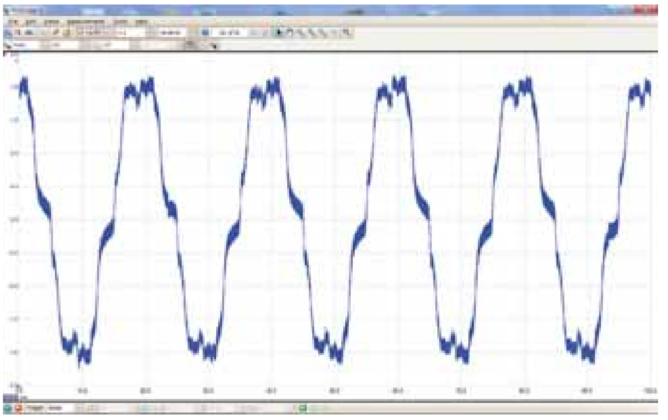

Fig.1. The PicoScope 6 software has a conventional Windows user interface. Here it is displaying electrical noise in the environment, which is predominantly 50Hz mains 'hum'

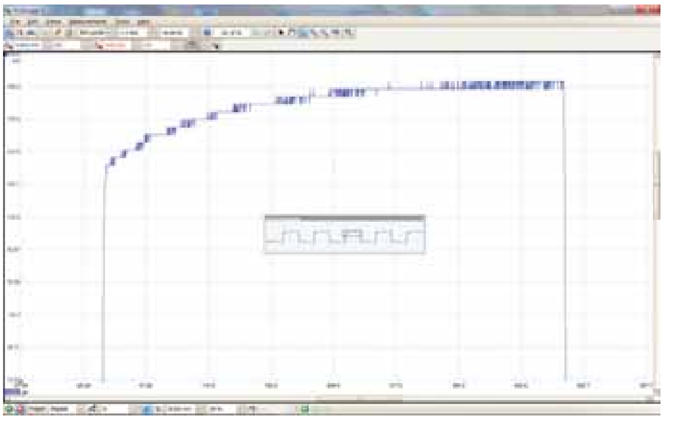

Fig.2. It is easy to zoom in on part of a waveform and then pan around it by dragging the rectangle in the thumbnail view

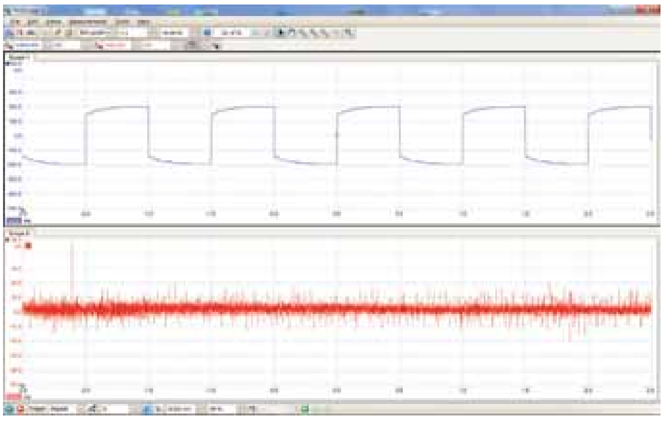

Fig.3. It is possible to have multiple windows. In this example the Channel A and Channel B traces are being displayed in separate windows

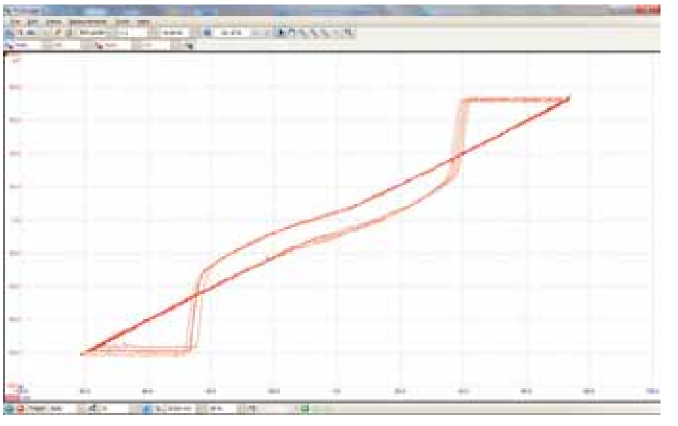

Fig.4. The time-base can be switched off so that the X axis can be controlled by an input signal. This enables lissajous **figures to be displayed**

The minimum specification required for the host PC is not very demanding. The processor must be a Pentium or equivalent type, and the minimum requirements for memory and free disk space is 50+ megabytes. The unit can be used with a USB 1.1 port, but a USB 2.0 type is recommended. The operating system can be Windows XP (SP2), Vista, or 7. I did not try it with an ageing PC, but it should work well with old PCs that have a very basic specification, provided one of the supported versions of Windows is installed.

Starting line

As tends to be the case these days, the only printed manual supplied with the unit is a multi-language Quick Start Guide that describes the installation process. Following its advice, I installed the software before connecting the PicoScope to the computer, and there were no problems in getting the system properly installed and working. The program has the usual built-in help system, and there is also some online help available.

The main piece of software provided with the interface is the PicoScope 6 program (Fig.1), which provides the virtual dual-trace oscilloscope function, together with a range of additional features. The user interface relies on conventional Windows-style menus and toolbars, and there are no virtual control knobs and switches.

The range of features offered by this program is enormous, but the conventional and well designed user interface makes it reasonably easy to use. The main functions are easily accessed via pushbuttons on the toolbars.

By default, the program runs in the single-trace oscilloscope mode. Buttons in the lower toolbar enable the two channels to be individually switched on and off, and with dual channel operation, the two traces are displayed in different colours (blue/red). Further buttons enable DC or AC coupling to be selected for each channel, and a range of full-scale sensitivities from ±50mV to +20V are available via drop-down menus. These have increments in the usual 1-2-5-10 sequence.

On all inputs, the maximum safe input potential is 20V. There is an Auto option for each channel, and this automatically selects the sensitivity that will display the waveforms most effectively.

The upper toolbar has a drop-down menu that enables the sweep rate to be set at preset steps from 50ns to 1000s, and this again increments in the usual 1-2-5-10 sequence. There is an Auto Setup button that makes it unnecessary to set the controls manually. Operating this button results in the input signal being analysed, and the program then provides the optimum settings, including the ones for sweep rate and sensitivity.

Zooming in

Several of the buttons on the upper toolbar enable changes to be made to the main display. One of these enables the view to be zoomed in the horizontal plane, and this is essentially the same as the X expansion control on a conventional oscilloscope.

There are normal Windows-style pan and zoom controls, including a type where you drag a rectangle around the part of a waveform that is of interest, and that area is the zoomed to fill the display area (Fig.2). A thumbnail view of the complete waveform is also displayed, and this shows a rectangle around the zoomed part of the waveform.

Panning around the zoomed view can be achieved by simply dragging this rectangle using the mouse. It is possible to have multiple windows, with each one displaying something different. At its most basic level, this simply entails having separate windows to display the waveforms for channels A and B (Fig.3).

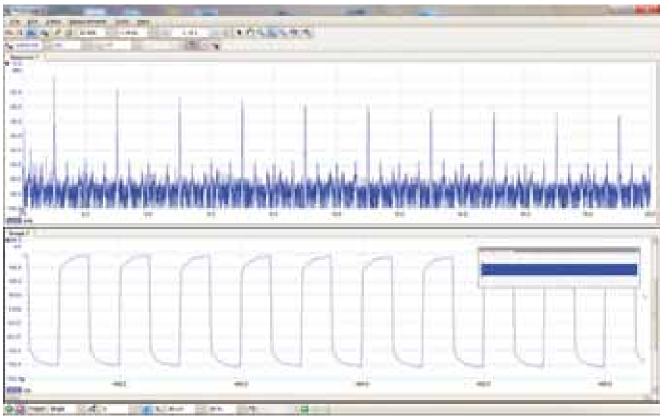

Fig.5. The PicoScope 6 software includes a spectrum analyser facility. In this case, the input signal is a 1kHz squarewave, which is comprised of a fundamental signal and odd order harmonics (3kHz, 5kHz etc.).

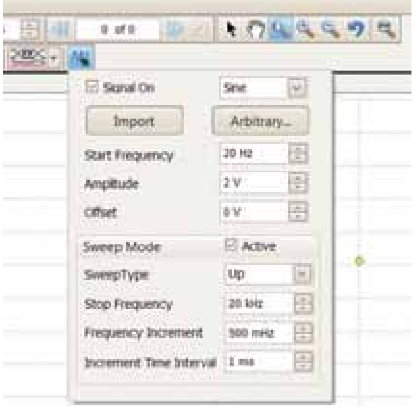

Fig.6. A dialogue box is used to control the built-in signal generator. Various preset waveforms are available, or you can design your own.

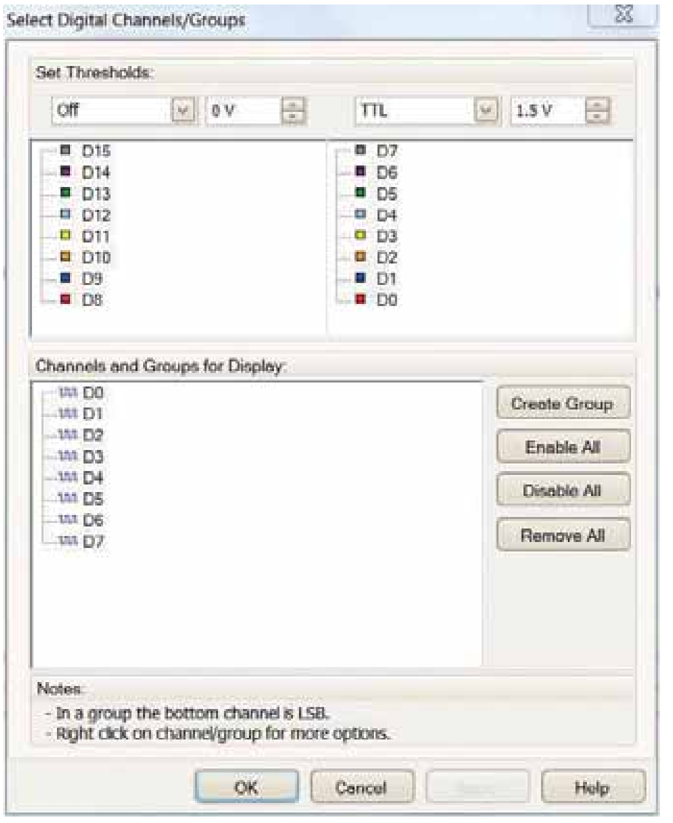

Fig.7. A dialogue box is used to select the digital inputs that will be displayed by the logic analyser function. A maximum of 16 digital inputs are available.

The button at the left end of the lower toolbar brings up a small control panel that provides access to some advanced features, the most useful of which is probably the resolution enhancement. This effectively gives an increase in the vertical resolution by using an averaging technique. The enhancement is adjustable from 8 bits to 12 bits, in 0.5 bit increments. Using resolution enhancement has some drawbacks, with the main one being some loss of high frequency detail. Therefore, the degree of enhancement used has to be a compromise between increased resolution, and overly smoothed waveforms that lack fine detail.

Triggering

The toolbar along the bottom of the screen is mainly concerned with the system's trigger function. There are on and off buttons, plus further buttons and menus that provide options such as, triggering on the rising or falling edge, auto, repetitive, or single-sweep operation, and the various trigger levels. There is also a free-running option for the timebase, and an automatic mode where the software selects the type of triggering that it deems most suitable for the characteristics of the input signal.

With no separate Sync input on the PicoScope unit, it is obviously not possible to display two waveforms while using a third signal for synchronisation. However, it is possible to display one waveform while using the second channel with an unseen synchronisation signal. It is possible to switch off the timebase altogether and display Lissajous figures (Fig.4) by opting to have the X axis controlled by the other channel.

Taking measures

The three buttons at the right end of this toolbar enable a measurement to be added to the display, removed, or edited. For example, using this feature it is possible to add the AC RMS value of the signal. The measurement is added below the waveform display, with maximum, minimum, and average levels being indicated.

A large range of measurement types are available, including frequency, fall-time, rise-time, duty-cycle, true RMS voltage, and peak-to-peak voltage. Several different types of measurement can be added for each signal if required.

The PicoScope 6 software provides some useful extras, and one of these is a spectrum analyser facility. This can have various maximum frequencies from 100Hz to 25MHz.

Fig.5 shows the result of feeding the 1kHz square-wave output of the built-in signal generator into channel A and using the spectrum analyser mode (upper display) with maximum frequency set at 20kHz. The spikes show the expected strong fundamental components and odd numbered harmonics. The lower display in Fig.5 shows the input waveform.

Signal generator

The built-in signal generator is controlled via a dialogue box (Fig.6) that is activated via a button in the lower toolbar. This offers a number of output waveforms including sine, square, triangle, two types of ramp, and white noise. A range of output frequencies from 0.03Hz to 100kHz are available. There is an optional feature that enables the output frequency to be swept up or down.

Inevitably, the quality of the output signal reduces somewhat at higher frequencies, but good quality signals are produced over the audio range and beyond. The maximum output level is 2V peak-to-peak, and a range of lower output levels down to 1mV peak-to-peak can be provided. It is possible to use the oscilloscope and signal generator functions at the same time.

Another button on the toolbar brings up a dialogue box that enables the required digital inputs to be selected (Fig.7), and if required, they can be organised into groups. This gives a simple logic analyser facility, and the digital waveforms can be displayed above or below the analogue display. I did not get a chance to thoroughly check this aspect of the unit, but with a few simple tests everything seemed to work as expected.

One of the advantages of a computer-based oscilloscope is that the results obtained can be easily transferred into other programs. The File menu has options that permit the display area to be saved in various file formats, such as BMP and TIF, and formats such as CSV for transferring data to a spreadsheet. Various copy options are available from the Edit menu. The display area can also be printed using any printer that is installed in Windows.

As I have previously installed Pico products on my PC, when loading the 2205 MSO it picked up the data logging programme called, 'PicoLog', from a previous application. In this instance it appears to be incompatible with the 2205 MSO, but it is compatible with the rest of the 2000 series, so well worth leaving on your PC.

However, I would guess that buyers of the 2205 MSO are primarily interested in its potential as an oscilloscope and its signal generating facilities, rather than data logging.

Conclusion

The PicoScope 6 software has a comprehensive range of facilities, and it has not been possible to cover all its capabilities here. For example, there is a persistence mode for use with non-repetitive waveforms. In this mode existing traces are not erased as new ones are added, and a complex display can be built up. There are also maths channels, which display additional traces such as channel A + channel B, or channel A – channel B.

A demonstration version of the program is available, and anyone contemplating the purchase of a PicoScope would be well advised to download and try this program.

One of the main advantages of a computer-based oscilloscope is that it provides a sophisticated instrument at a lower cost than a standalone unit. This assumes that a suitable host PC is available, but practically any PC running a supported version of Windows and having a spare USB 2 port should suffice.

At £349 + VAT, the PicoScope 2205 MSO is not cheap, but it offers good value for money when you consider its capabilities and the range of additional facilities it provides via the PicoScope 6 software, which is included with it. A USB lead is included in the price, but it should be noted that the analogue and digital test leads are extra. The PicoScope 2205 MSO can certainly be recommended for anyone seeking a unit of this type that includes a signal generator and a basic logic analyser facility.

A kit option is available priced at £399 which includes a digital cable, two packs of 10 test clips and two 60MHz oscilloscope probes.

For more information, contact: Pico Technology Ltd, Dept *EPE* James House, Marlborough Road, Colmworth Business Park, Eaton Socon, St Neots, Cambridgeshire, PE19 8YP. Tel 01480 396395, Fax 01480 396296, email marketing@picotech.com. More information and demonstration software is available from the Pico website at: www.picotech.com.

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

More on Altitude Display, and creating a Video Driver

Having completed last month's GPS Altitude Display with a chipKIT so quickly, we thought it would be interesting to repeat the exercise using MPALB and a 'home grown' PIC18F processor board to see what the differences are in development approach and speed.

Altitude display – take two

First, we needed a microprocessor development board to replace the chipKIT.

After an hour of digging through drawers full of old circuit boards and boxes of chips, we ended up with a small unpopulated PCB designed to take a PIC18LF2520 (and not much else.) There was enough I/O available on header pads, a PICkit 2 programming adaptor interface, and space for a 3.3V regulator, so it seemed an ideal starting point. The PIC18F2520 is nowhere near as capable as the PCI32, but our altitude display is not demanding of processor power, and this was more of an experiment in how the develop-pent approach differed, rather than trying to maximise raw processing speed.

The PIC18F2520 has a UART interface and many general purpose I/O pins, so it was a simple task finding where the GPS and LCD module should be wired up to. Once this was done, it was time to look at what software tools we would use. The obvious solution was a PICkit 2 programmer/debugger unit and MPLAB IDE, with the free C18 'C' language compiler.

Slowly does it

Just as we did last time, we crept up on the design slowly, deciding to start with toggling an I/O pin. Straightaway, we were into hardware dependencies that required us to look deeply into the datasheet: how do we configure the config bits in the device for the crystal we are using? What values should I program into the remaining config registers that I don't care about?

This took several hours of reading and experimentation, especially as the details of *how* you set the config bits in your code were buried deep within an MPLAB help file. Setting the config bits correctly is essential; without these, your code will simply not run at all (or worse, exhibit bizarre behaviour.)

Moving on, we wanted to flash an LED using a timer interrupt. We had to work out how interrupts are configured, interrupt routines written, and even how to work out what values to write to the timer registers. Each of these steps proved to be onerous (even with our own previous experience of writing applications in 'C' for this very processor!) Two more hours passed. Eventually, we had an LED flashing.

Fig.1. Part assembled Bike Altitude Display

As we now had a basic hardware setup working, it was only a few minutes later that we had the LCD backlight flashing – but, several hours longer than it took to get to the same stage with the chipKIT.

Reading GPS data

Moving forward slightly quicker, it was time to try reading GPS data from the UART. Once again, this required careful study of a number of sections in the datasheet to work out how to configure the UART, how to clear receive error conditions, and how to set the desired baud rate (which required the use of a calculator and a certain amount of head scratching.)

We even had to resort to an oscilloscope to confirm that the settings were correct, which they weren't at first. MPLAB was quite helpful here, as we could place breakpoints on the serial routines and see the correct values arriving from the GPS unit.

Now things really started speeding up. Because the SPI and LCD routines developed under the chipKIT Arduino platform were actually written in 'C', porting them to the new processor was quite straightforward, and it took only an hour to get the complete project running. With the processor board we picked being populated with surface mount components we ended up with quite a small assembly, which you can see in Fig.1.

As we really did end up attaching this to a mountain bike, we added a small lithium polymer rechargeable battery, which gave 10 hours of life between charges. (We will discuss using lithium polymer rechargeable batteries in a later article.)

Conclusions

It became clear that the Arduino development environment, with it's quick 'build – download – run' process, the example 'get me going' programs, and the range of simple to use library functions, does make the software development process much quicker and more fun. It's an ideal platform for experimenting with new ideas, or new external devices, before facing the challenges of a final project. At which point, you would almost certainly switch back to MPLAB, and start pulling out the datasheets.

While MPLAB provides greater debugging facilities, if you are trying out different user interface designs for example ('move that string two pixels to the left; no, down two') MPIDE wins hands down.

It made the author realise that there needs to be something to perhaps bridge the gap between developing in MPIDE and the full 'start from scratch' approach when developing a custom project in MPLAB. This is something that we will be take up later in the year with our new 'C for PICs' series.

Back to chipKIT – video

We go back to the chipKIT Arduino platform now to look at making an Arduino library for generating video. This is going to make use of the power of the PIC32 processor fitted to the Uno32 board. Although it will require some intensive research, and detailed study of the processor datasheet, the idea is that you write this once, and then the library can be reused in the future without need to revisit the complex 'stuff'.

We have covered video generation before with the PC24 processor, generating monochrome composite video to drive televisions. This time, we will do something different – our aim is to produce an RGB video output, suitable for driving those VGA LCD monitors that are now so readily available on the second-hand market. We say 'aim', because we do not yet know just how easy this will be to achieve.

Let's start with the basics – what the VGA standard is, and what it looks like.

The term VGA originally referred to a graphics card manufactured by IBM in the 1990s that had a display resolution of up to 640 × 480 pixels. These days VGA refers to the physical display interface, the 15-pin DE-15 connector and a range of loosely related video standards commonly called 'Super VGA' or SVGA.

SVGA covers resolutions from 800 × 600 pixels to in excess of 1024 × 768 pixels, but as we will be generating our signals from a microcontroller with a slow clock and limited memory, we already know that we will be forced to run at a relatively low screen resolution.

Factor-three

There are three factors that we have to consider: pixel resolution, colour depth and display refresh rate. On top of that, we have to decide whether we will support 'all pixels addressable' for a true graphical display, or limit ourselves to character output.

That last point is driven by a concern for how much RAM we can allocate to the display buffer; for a display resolution of 1024 × 768 pixels we would need at least 98KB of RAM, well beyond our 16KB limit.

The refresh rate of the display is how frequently the display is re-drawn. Draw too slow, and our eyes can perceive the display changing, which is at best unpleasant. The faster the refresh rate, the faster we need to write pixels to the display. Too high a refresh rate will result in the processor being unable to keep up.

Another consideration is that LCD displays have a 'preferred' display resolution, as they have a fixed number of pixels. Running at a resolution that does not match this will result in uneven shapes being displayed. Some of the older cheap displays have a native resolution of 1024 × 768 pixels; some have 1440 × 900 pixels. Normally, these LCDs will display 800 × 600 pixels acceptably, as this is one of the default resolutions for the Windows operating system.

For now at least, we will look to support this resolution at 60Hz refresh rate, as it is one of the easiest (relatively speaking!) formats to support. More importantly, the rate at which pixels are written to the display, or 'pixel clock', is 40MHz – an easy rate to generate from our chipKIT Uno32 board, as we will see.

Even at this relatively low resolution, we do not have enough RAM on the chip to support a full graphics display; it would require 38KB of RAM for a monochrome image. Instead, we will implement a character-based display. Using a standard font of 5 × 7 pixels per character, at a resolution of 800 × 600 pixels, we will be able to display 133 × 75 characters.

We will store the characters to display in a RAM buffer, which will require only 9KB of memory. With this approach, our video driver will read the character data from the screen text buffer, look up the 5 × 7 pixel data from a font table, and then write the font data to the physical interface.

VGA physical interface

The VGA standard is an analogue one, just like composite video. There are two control signal pins, VSYNC and HSYNC, which pulse when the end of a display line and end of the screen occur. Synchronised to these are the red, green and blue colour signals for the pixel colour.

The colour signals range in value from 0.0V for 'no colour' to 0.7V for 'full colour intensity'. So, for example, when the three colour pins are at 0V, the pixel will be black, and if all three pins are at 0.7V, the pixel will be white. An example of the video signals on all pins can be seen in Fig.2.

Clearly, we will need some kind of digital-to-analogue converter to translate 0V/3.3V signal levels on our I/O pins to the 0V/0.7V levels required by VGA.

The final question we have now is the colour depth: How many colours will we support?

This will depend on how many pins we can drive simultaneously in time with the pixel 'clock' rate. As each pixel signal lasts for only 39.7ns, we do not have the time to do this in software; it would have to be handled automatically by whatever hardware peripheral is driving the colour pins.

So what methods do we have for outputting these five signals (vertical sync, horizontal sync and the three colours) quickly enough? Software controlled 'bit-bashing' is out of the question, as the instruction time of the processor is too slow. We will have to make use of one or more of the processor's hardware peripherals. Reading the datasheet suggests the following peripherals support the control of I/O pins – The SPI interface, Output Compare and the Parallel Port interface.

We will start, as always, by creeping up on the problem. It should be possible to generate just the horizontal and vertical sync signals, leaving the three colour signals at a low level, and a monitor should happily lock to this. As most recent monitors have a built-

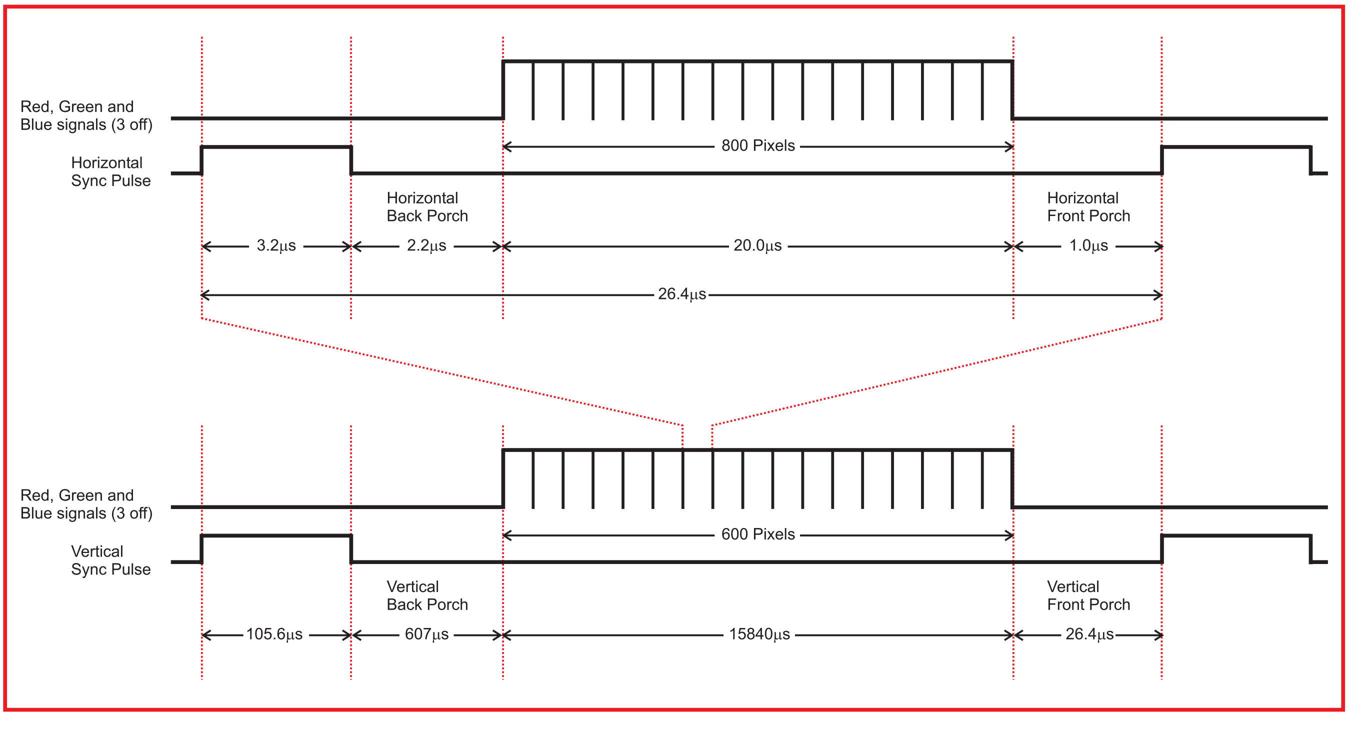

Fig.2. VGA signals, 800 × 640 resolution, at 60Hz

in diagnostics option that can display information about the input signal, we should be able to get an indication that our output is conforming to the correct timing. The screen will be blank, but that's fine for a starting point.

Before that, we need to create the correct physical interface between our microcontroller and the VGA connector. Fortunately for us, interfacing digital logic circuits to VGA displays has been done many times before, in particular by FPGA engineers (who, we would like to point out, have a simpler task than us in approaching this problem. FPGAs are ideally suited to generating fast video signals.)

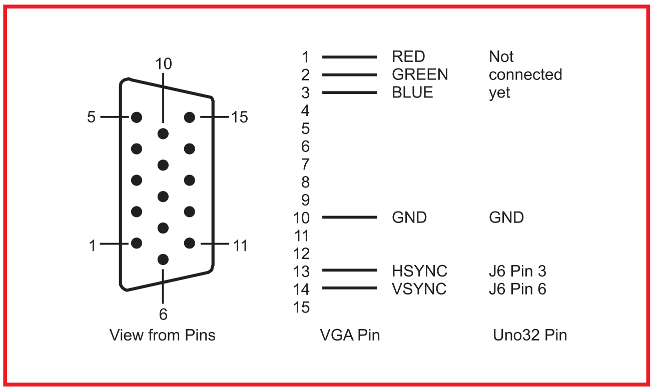

Fig.3. Initial video interface

A quick search on the Internet revealed a simple potential divider DAC VGA interface circuit that could be adapted to our needs. Our initial test connection can be seen in Fig.3.

In the VGA standard, the horizontal and vertical sync signals are TTL level inputs to the monitor, and so the 3.3V CMOS outputs from the chipKit can drive these directly. The colour signals are more complicated, because they are analogue levels ranging from 0V to 0.7V, but we are ignoring these for now as we test the synchronisation signals.

There are two techniques for connecting to a monitor; cut the end off a VGA cable and solder header pins to the wires, or wire up to a VGA connector. A connector can be easily 'ratted' from an old video card, but as we didn't have one to hand we purchased a cheap VGA cable from the local supermarket and cut one end off. This proved to be the more convenient option of the two, as the lead could then be re-used on other breadboard circuits, and is less cumbersome.

Generating sync signals

With the VGA cable suitably modified for use, the next question was the tricky one: how to generate the signals in the first place. Initially, the parallel port interface seemed a good choice, but on further investigation there was insufficient control available for generating the very specific pulse times we need.

The Output Compare peripheral, however, hit the spot. It works in conjunction with a timer module configured in counter mode, which is used to specify the count values at which an output pin will go high and low. Once configured, this operates without further interaction from the CPU.

Following the instructions in the datasheet, and with the aid of an oscilloscope as confirmation, we very quickly arrived at the code shown in Fig.4.

At this stage, while we are still developing the software, we keep the code organised as a simple project, as we did last month. It's only once we have the completed video interface working (which will be next month) that we think about moving the code off to a library.

Now we move onto the vertical sync signal. As can been seen in Fig.2, this signal is significantly slower and has a wider pulse, as it only occurs once for every screen full of data, rather than once per line as for the horizontal sync signal.

We take advantage of this slower timing by generating the signal in an interrupt routine attached to the horizontal sync timer, as the interrupt routine provides a 'hook' in which we can add display update code – all of which will become clear next month. Within the interrupt routine, we simply count the number of horizontal lines that have been generated, and toggle the vertical sync pin for the appropriate number of horizontal line counts.

The Timer 3 interrupts are firing quite frequently – once every 26µs – but there is very little code executed in the interrupt routine, so the CPU utilisation will not be too high. Our only concern (that will not be resolved until we start displaying real image data,) is that the slight timing variations, caused by delays in calling the interrupt routine, might result in jitter on the display. As the processor is running at 80MHz we believe that this jitter will be inperceptible, but we will have to wait to next month to find out.

Hooking the chipKit up to an LCD monitor resulted in a black display – a good start – and then, on opening the monitor's built in diagnostics display, it confirmed that it was locked to a resolution of 800 × 600 pixels at 60Hz. Success!

Next month, we discover how we can generate the pixel data, expand the software to provide a simple to use interface, and finally store the files as a library for future use. The partly constructed source code that accompanies this month's article can be found on the *EPE* website; see Library, Project Code Library.

```
// Configure Output Compare peripheral OC1
// Connects to pin 3 on chipKit Uno32 header J5
OC1CON = 0x0d;     // Setup is 16 bit, using Timer3, +ve edge
OC1R =   0;        // Positive edge at count 0
OC1RS =  256;      // Falling edge 256 counts later

// Timer 3 setup, to support OC1
PR3 = 2111;        // Timer will restart after 2111 counts
T3CON = 0;         // Disable timer while configuring it
TMR3 = 0;

// Enable an interrupt to occur on each line. We will
// use this later to help generate the vertical sync
IFS0CLR = 0x1000; // Clear timer interrupt status flag
IEC0SET = 0x1000; // Set interrupt enable on Tmr3

// Specify the interrupt priority
IPC3CLR = 0x1F;
IPC3SET = (_T3_IPL_IPC << 2) | _T3_SPL_IPC;

// Start the timer and output compare peripheral
T3CONSET =  0x8000;
OC1CONSET = 0x8000;
```

Fig.4. Horizontal sync code listing

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Circuit Surgery

Regular Clinic

by Ian Bell

On the buffers

EPE Chat Zone contributor ***afferrari*** posted a series of question related to output buffer amplifiers.

I am about to build an output stage for a sine generator. I ran across several circuits of AB class amplifiers, but in spite of lot of reading I still have many basic doubts. My questions are:

1) A buffer output is expected to have a gain by itself? In other words, what defines the gain in a push-pull configuration?

2) Several function generators seem to set their output impedance just by using a series resistor of 50Ω/75Ω/600Ω at the output. Is that all is needed?

3) Instead of building an AB stage, the LH0033 (or similar buffer), would be a better (if expensive) solution?

4) When reading about AB amps, it seems that those specifically for audio and those used as an output stage of signal generators share different necessities. Besides the obvious low impedance loads in audio, is there anything else that makes them so different?

5) Walter Jung in his IC Op-amp Cookbook *describes a circuit that has an output impedance of 10Ω [this has a class AB amplifier, and an op amp in a feedback loop]. What determines that value? How could I change it, if possible?*

6) I read somewhere in a forum that diodes [used for biasing] are old use; that a V_{be} multiplier should be used instead. Can anyone elaborate?

Gracias *for any help to understand this a little more.*

Need for buffers

This question raises a variety of topics – the need for buffers and what their characteristics should be, class AB amplifiers and their biasing, and output impedance in general. We will start by outlining why buffers are needed and what their gain should be, and then look in detail at issues relating to output impedance.

Output buffers are used in a wide variety of applications as the final stage in the signal path before the load or equipment output connection. Circuits with similar topologies also occur in systems such as audio power amplifiers, where the term 'buffer' may not used, but the basic principles are the same.

Circuits such as voltage amplifiers (standard op amps, audio preamps) and signal generators (oscillators, test instruments) often do not have much current output capability. They produce a voltage signal with (hopefully) exactly the required waveform shape and magnitude, but cannot drive low impedance loads. The output buffer or power amplifier produces a copy (same voltage) of the output of the signal processing or generating circuit with a much higher current drive capability behind it.

Output buffer gain

Output buffers, therefore, usually have a voltage gain of 1, or –1, but a significant power gain. Other low voltage gains, for example ×2 may be appropriate in some circumstances, but still it is the power gain or drive capability which is crucial.

Thus, in answer to the first question, the output buffer is not expected to have anything other than unity voltage gain in most cases. The fact that a buffer outputs the same voltage as its input leads to the term 'voltage follower' being used in the context of these circuits.

The exact value of this gain is important in some applications, for example in signal generators and other test equipment where the required output voltage is specified. If the initial stages of the circuit have produced exactly the output voltage required, but the buffer has a gain of 0.9 instead of 1, there may be a problem. This issue is usually referred to as 'gain accuracy' when comparing the performance of buffers.

In other applications, the gain accuracy may not be important, for example an audio circuit driving a speaker or headphones can be adjusted by the user to the required perceived volume without the need for good gain accuracy in the buffer (power amplifier).

Output impedance

The second question refers to output impedance, and this is indeed an important issue in the design and use of output buffers. The idea of representing the output of a complex circuit, such as amplifier or filter, by a single voltage source and resistor (or impedance) is based on Thévenin's theorem, which is named after Léon Charles Thévenin (1857–1926), who was a French telegraph engineer.

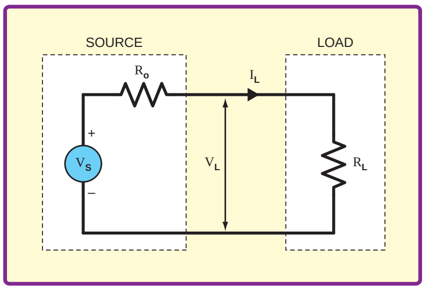

Fig.1. Concept of output impedance

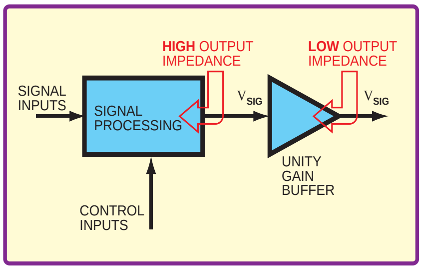

Fig.2. Output buffer providing impedance transformation

Thévenin's theorem states that a linear electronic circuit that comprises any combination of voltage sources, current sources and resistors, with two output terminals, is electrically equivalent to a single voltage source, V_S, and a single series resistor, R_O (see Fig.1). The theorem also applies to circuits in which the sources are AC (sinewave), all at the same frequency and the other components are impedances (resistance, capacitance inductance).

Fig.1 shows a source connected to a load resistance. The two resistances (source and load) are in series and form a potential divider. The current through the resistors (output current or load current) is therefore $I_L=V_S/(R_S+R_L)$. Thus, the voltage across the load is given by this current times the load resistance:

$$V_L = \frac{R_L}{(R_S + R_L)} V_S$$

From this equation, we see that if we want V_L to be as large as possible, or as close as possible to V_S, then R_L must be much larger than R_S. If R_L is very much larger than R_S, then the load voltage is effectively equal to the source voltage.

This implies that the output buffer should have very low output impedance (resistance) and indeed we can think of the buffer as providing 'impedance transformation'. That is, it takes the signal from the high output impedance source of the signal processing/generating stage and provides a much lower output impedance version. This is illustrated in Fig.2.

In general, both the load and source characteristics may not be simply resistance, but may also have capacitive and/or inductive components. Thus, we often refer to output and load impedance; however, for illustrating the most basic principles it is simpler to just use resistors. We must, of course, remember that things are not always so simple and, for example, capacitive loads may cause some buffer circuits difficulty.

Matching up

In some situations we might want to match the source and load resistances (impedances) $R_S=R_L$. This is potentially useful because maximum power is transferred from source to load when source and load are matched. For example, consider an output buffer producing a 3V RMS signal with R_S =1Ω; the power into loads of various impedances are listed in Table 1. The power is calculated using I^2R, where R is R_S or R_L as required and I is given by $I_L=V_S/(R_S+R_L)$, as above.

The maximum power in this example is obtained for a load of 1Ω – matching the source impedance. The maximum power delivered to the load is *half* of the power taken from the source at that point (50% efficiency). As the load impedance increases a greater proportion of the source's power ends up in the load (the efficiency increases), but the actual power delivered decreases.

In many cases efficiency is more important than maximum power transfer, as is the ability to drive load impedances, which varies with frequency. So, a low output impedance is used. However, this is not the whole story, and there are other reasons why we might want specific output impedances for a signal generator, as implied in the second question.

Transmission lines

When wiring up small circuits operating at relatively low frequencies and currents, we often think of wires as being perfect conductors that do not have much influence on the circuit. One step on from this, we may remember that a real wire has some resistance, so it might drop some voltage if we pass a high current through it, or we might realise the wire has some capacitance or inductance, which may influence circuit performance in some way.

If this is the case, we can regard the wire as a single resistor or capacitor and take this into account. For example, Fig.3 shows Fig.1 redrawn for a situation in which the wire connecting the source and load has significant resistance.

The view of a non-ideal wire being equivalent to, say, a single resistor, capacitor, or combination of these works fine at relatively low frequencies and for relatively short wires. However, for very long wires, or very high frequencies for shorter wires, the signal takes a significant time to travel down the wire compared to one cycle of the signal's waveform. When this happens, we can no longer lump the impedance of the wire into a single component as in Fig.2, because different parts of the signal 'see' different parts of the wire at different times.

For high frequencies, or long wires, a signal behaves like a wave travelling in a pipe, and the wire is referred to as a 'transmission line' (see Fig.4). How long a wire has to be before transmission line effects become significant decreases with increasing frequency.

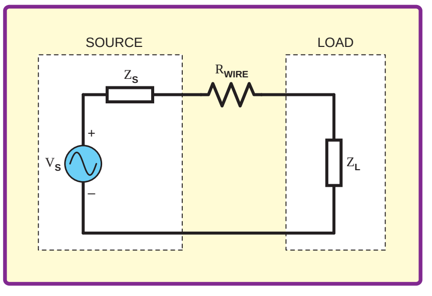

Fig.3. The wire connecting source and load may need to be taken into account

Instead of single lumped impedance, transmission lines are described by their characteristic impedance, which is the ratio of voltage to current at any point on the wave travelling down the line. Coax cables are often used in applications where they behave as transmission lines. They typically have characteristic impedances in the range 50Ω to 100Ω.

Impedance matching

Impedance matching is important when transmission lines are involved because unmatched connections cause part of the wave on the line to be reflected. It then travels back down the wire in the opposite direction and causes interference, which distorts the signal.

The reflection, of course, also reduces the amount of power delivered to the load. In order to prevent signal loss and distortion, the characteristic impedance of a transmission line must be equal to the load and source impedances. Transmission lines must be terminated correctly, even if the final end of the wire is not connected to a circuit input.

To fully analyse the behaviour of transmission lines in detail requires some advanced mathematics; however, you can get a feel for what is happening by imagining a wave travelling down a channel filled with water. If we connect this channel to another of exactly the same width and depth the wave will carry on as if nothing has happened (the channels are matched).

However, if we connect one water channel to another which is much wider or narrower the wave will get reflected off the edges or corners of the channels at the join, causing interference and loss of power in the wave that continues in the original direction.

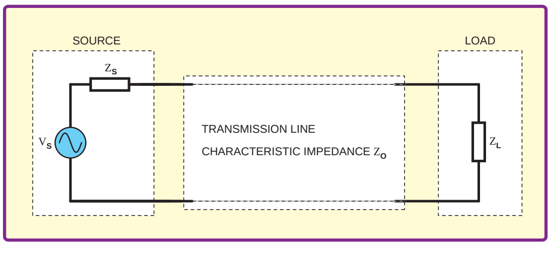

Fig.4. The wire connecting source and load may behave as a transmission line, in which case it should be matched to the source and the load. For matching $Z_S = Z_0 = X_L$

Table 1: Effect of relative R_S and R_L on power transfer and efficiency

Load/Ω	*RMS Power in Load/W (1Ω source at 3V RMS)*	*Efficiency/% (% of total power in load)*
0.25	1.4	20
0.5	2.0	33
1 (matched)	2.3	50
1.5	2.2	60
2	2.0	67
3	1.7	75
30	0.3	97

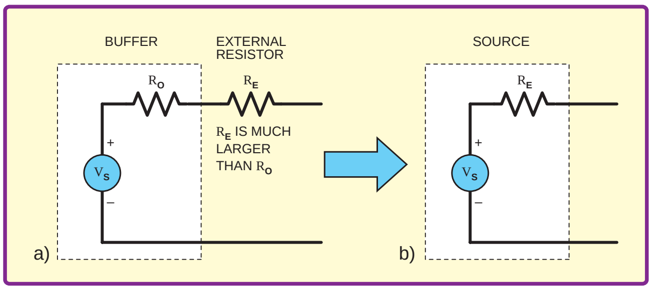

Fig.5. (a) Setting the output impedance for matched-line driving using a back termination resistor, (b) Thévenin's equivalent circuit

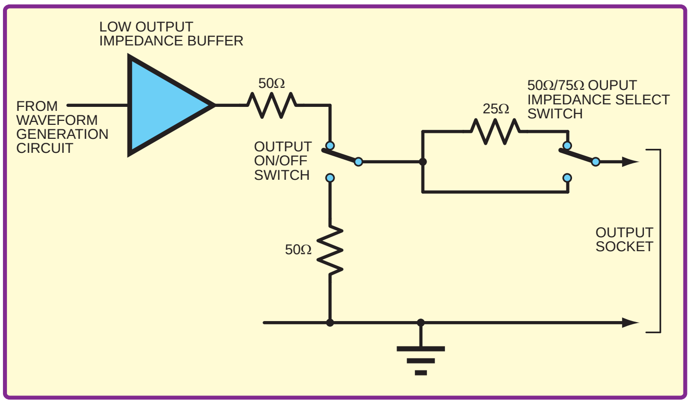

Fig.6. Possible signal generator output circuit with impedance selection

If we have a low impedance buffer, and add an external resistor, R_E, as shown in Fig.5, then a simple application of Thévenin's theorem shows that we have a source with an output impedance R_E. This assumes that the buffer's output impedance, R_O, is much lower than R_E.

This approach is commonly used for matching to a load connected via a transmission line, such as in video applications (the video cable acts as a transmission line). In such cases, the resistor R_E is referred to as a 'back-termination resistor'.

The answer to the second question is, yes, the output impedance of a signal generator can be set by switching in an appropriate resistor. This approach is useful in general purpose scenarios such as lab test equipment, but if fixed impedance is required it may be better designed directly into the buffer circuit rather than as an add-on resistor.

Fig.6 shows a possible setup for a signal generator output with 50Ω/75Ω output impedance selection. The output can also be switched off, in which case the generator's output socket will present 50Ω or 75Ω looking back into the equipment, terminating the cable correctly. The switching can be achieved by using small mechanical relays under control of a microcontroller or PC, or whatever is used to implement the signal generator's user interface.

Feedback

When an output buffer or power amplifier stage is used with a high gain amplifier (such as an op amp), the buffer can be included in a feedback loop. Fig.7 illustrates two scenarios, one in which an amplifier with feedback is simply connected to a buffer's input, and one in which the buffer is included in the feedback loop. The latter circuit is a general form of the design by Walter Jung mentioned in question 5, and is widely used.

Including the buffer in the feedback loop provides the buffer with the advantages that negative feedback brings, including lower output impedance. The output resistance of the circuit in Fig.7b with feedback, R_{OF}, is related to the output resistance without feedback (open loop), R_{OO}, by:

$$R_{OF} = \frac{R_{OO}}{1+\beta A}$$

where A is the open-loop voltage gain of the amplifier and buffer combined. Assuming the buffer has a voltage gain of 1, this is simply the voltage gain of the amplifier. β is the feedback fraction, that is the proportion of the output signal that is fed back to the input (subtracted from the input signal). β is less than or equal to 1.

High gain amplifiers with buffers inside the feedback may have difficulties when driving capacitive loads. This may cause peaks in the frequency response and even oscillation of the circuit. The problem is caused by the output of the buffer behaving like an inductor at high frequencies. This combines with the load capacitance to form an LC circuit, with 'peaky' or resonate behaviour. These effects can be compensated for by adding a resistor, R_{ISO}, known as an isolation resistor, to the output, as shown in Fig.8.

This month, we have started to answer afterrari's series of questions about output buffer circuits. We've taken an abstract overview so far and concentrated on issues related to gain and output impedance. Next month, we will continue this topic and look at some circuits in more detail.

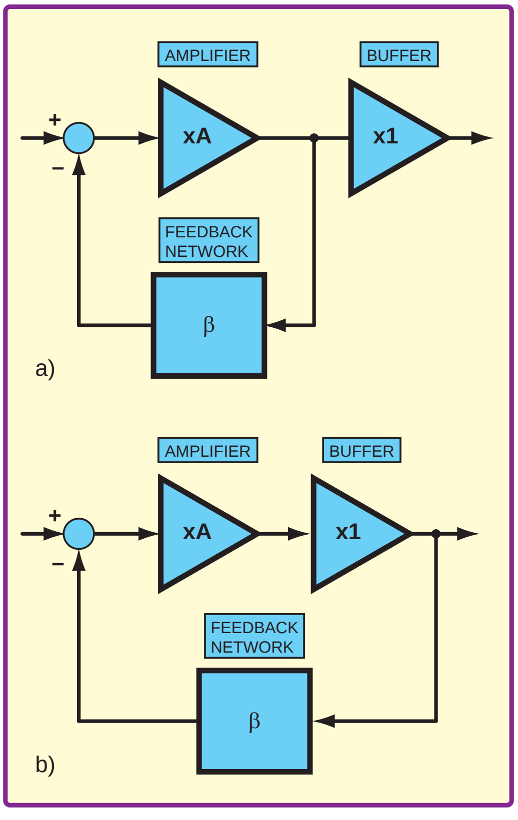

Fig.7. Adding an output buffer to an amplifier (a) Buffer outside feedback loop (b) Buffer inside feedback loop

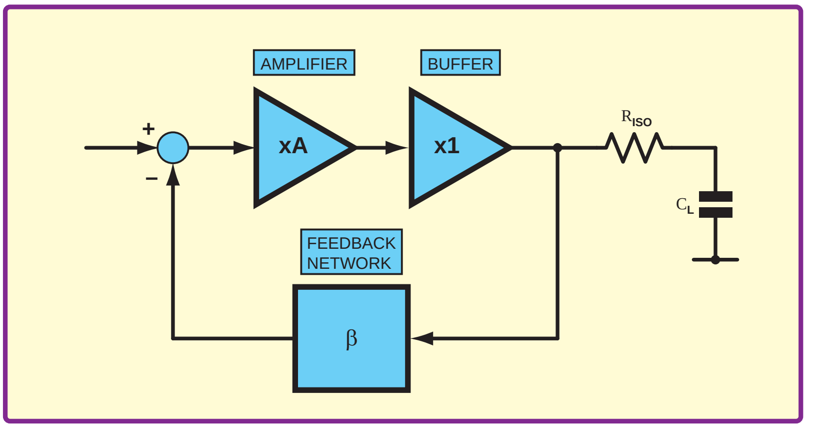

Fig.8. Amplifier and output buffer with isolation resistor for stability when driving capacitive loads

Max's Cool Beans

By Max The Magnificent

Earlier this year, I spent a week in Norway. First I gave the keynote presentation at the *FPGA Forum*, which was held in Trondheim. Then I caught a train down to Oslo to give a guest lecture at the Department of Informatics at the University of Oslo (**www.ifi.uio.no**). I arrived at the lecture hall (a monster auditorium with tiered rows of seats that looked like a film set) 20 minutes before my lecture was scheduled to start. You can imagine my surprise to find the place jam-packed with people … then the bell rang and they all got up and left (sad face). Happily, my audience then started to roll in, and I ended up with a full house of my own.

Following my presentation, I was given a grand tour of the department. I saw some amazing things that boggled my mind, and I'm sure I will be waffling on about many of these things in future columns. For the moment, however, I shall restrain myself to talking about the work of postdoc Kyrre Glette, who is researching adaptive robotics techniques. One experiment that particularly caught my eye was a spider-like robot that was learning to walk. The reason this was of interest to me was that Kyrre was using genetic algorithms as part of his evolutionary learning techniques.

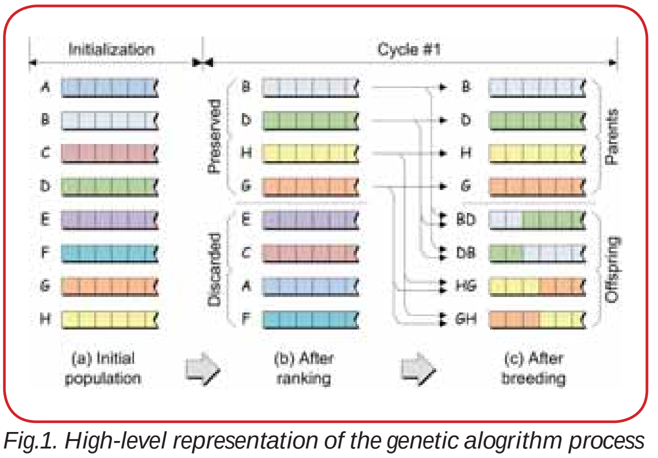

Fig.1. High-level representation of the genetic alogrithm process

It's all in the genes…

Let's assume that we have a really complex problem involving lots of input signals, internal states, and output signals, and that all of these signals and states have complex interactions with each other. For example, increasing the value of input A may cause the value on output X to increase or decrease depending on the states of other inputs and/or outputs. The end result is that the optimal solution that gives the best overall results may be almost impossible to determine using conventional problem-solving techniques.

And so we come to 'genetic algorithms'. The underlying concept is to mimic evolutionary processes in the natural world; specifically, those of natural selection based on the 'fitness' of individuals in a population that evolves by exchanging genetic material and also by random mutations. The principles underlying genetic algorithms are actually quite simple, and were first described by J H Holland in the early 1970s.

First of all, we manipulate the problem under consideration in such a way that its variables can be represented as a string of 0s and 1s. Then we 'seed' our environment with an initial 'population' of randomly generated strings; that is, strings containing random sequences of 0s and 1s, as illustrated in Fig.1(a).

Next generation

Next, we evaluate each string in our population by testing any measurable quantities in our system to see how close we came to some desired result. We use the results of this evaluation to assign a 'fitness' to each string, then we rank the strings in order of this fitness, as illustrated in Fig.1(b). Low-ranking strings may be discarded, while high-ranking strings represent the individuals that will be permitted to 'breed'; that is, the strings that ranked the highest will be permitted to generate the offspring that will form part of the next generation.

Now, here's the clever part, because the strings that will act as the parents for the next generation undergo a process known as 'crossover,' in which we emulate the natural process of exchanging genetic material in order to create 'offspring' strings, as illustrated in Fig.1(c). Observe that the original parent strings remain part of this new population, because we don't want to discard the best solutions we've obtained thus far. The ranking and breeding process may be repeated for thousands of cycles.

Of course, we've only shown a small initial population and the mating of two pairs of strings; in reality, we would have a much larger population pool and there would be many such unions. Furthermore, some algorithms allow strings to 'mate' in proportion to their fitness, in which case a high-ranking string will be allowed to mate with more strings than a lower-ranking companion. Thus, we see that a key feature to genetic algorithms is 'survival of the fittest,' whereby the fitter strings generate more offspring and therefore have a higher chance of passing their 'genetic information' on to future generations.

Another important component of genetic algorithms is that of mutation. Following crossover, every bit in each of the new strings has some finite chance of undergoing mutation (that is, our algorithm might decide to flip its state from a 0 to a 1, or vice versa). The probability of mutation is maintained at a very low level (say a chance of 1 in 10,000) … but it's enough to make life interesting (pun intended).

Although the whole concept of genetic algorithms might seem a bit nebulous, their use of pseudo-natural selection and mutation manages to direct the search towards regions of high potential in the solution space. These mechanisms also allow genetic algorithms to explore a greater range of potential solutions than do more conventional search techniques, and to converge on optimal results in complex solution spaces faster and more efficiently than other approaches.

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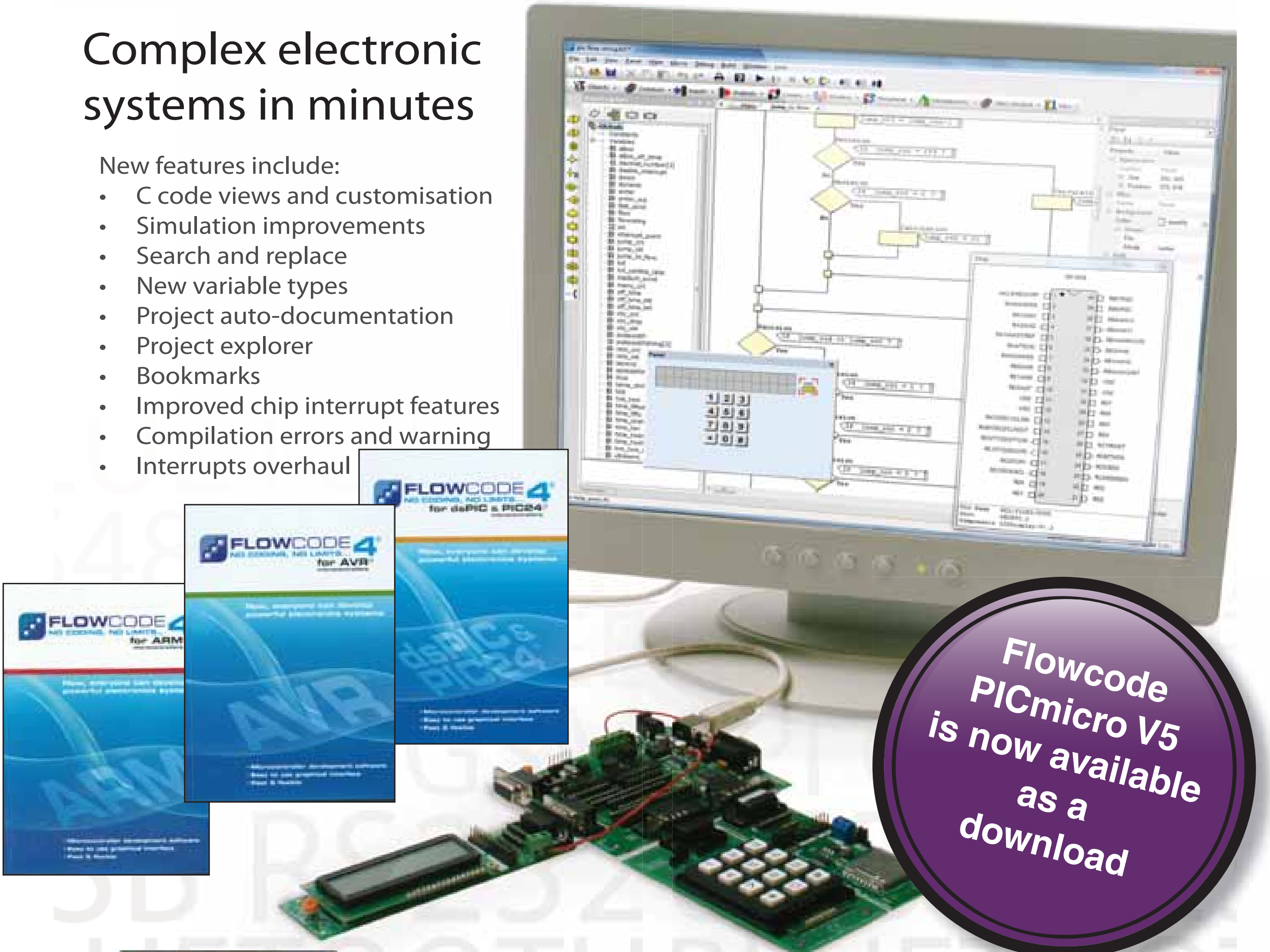

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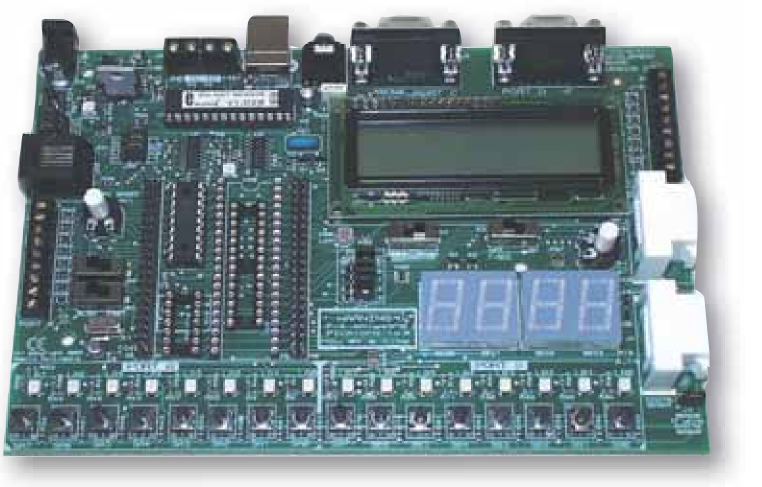

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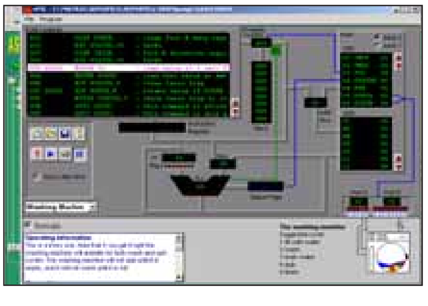

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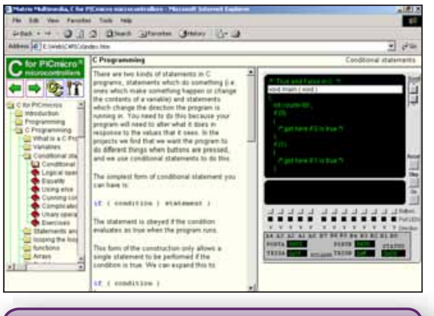
● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible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



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

FLOWCODE FOR PICmicro V5 (see opposite page)

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

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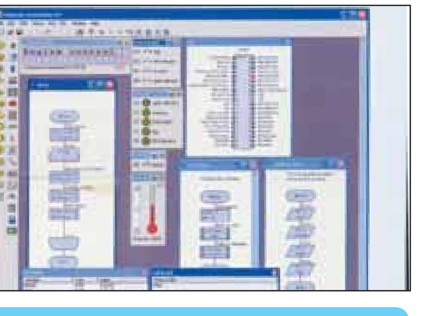

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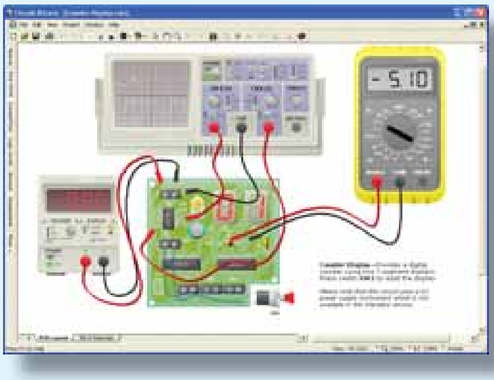

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INTERFACE

By Robert Penfold

LM335Z Temperature Sensor

THE previous *Interface* article featured a simple temperature sensor and a matching analogue-to-digital converter. The latter was actually a slightly modified version of the analogue interface featured previously, and together with the temperature sensor it provided a range of 0 to 127.5°C with a resolution of 0.5 degrees, or 0 to 150°C with a resolution of one degree. The temperature sensor used was an LM35, but there are many other temperature sensors that can be used with the same analogue interface circuit, or a slightly modified version of it.

Low temperatures

With its output potential of 10 millivolts per degree Celsius (10mV/°C), the LM35 is easy to use, but only when positive temperatures are to be measured. It can actually handle negative temperatures, and it only requires a negative supply plus a pull-down resistor at the output in order to achieve this. The obvious problem with this is that negative temperatures produce negative output voltages that cannot be handled by the simple analogue-to-digital converter interface in use here.

This problem is not insurmountable, and it simply requires the use of some signal conditioning circuitry to provide a suitable output voltage range to drive the input of the converter circuit. However, there are other and probably simpler ways of doing things that avoid the need for a negative supply rail.

The LM335Z temperature sensor is similar to the LM35 in that it provides an output potential equal to 10mV (0.01 volts) per degree, but its output voltage is per degree Kelvin rather than per degree Celsius. In other words, its output potential is 10mV per degree above absolute zero.

The output voltage is rather like that of the LM35, but with a built-in offset of just over 2.73V. To be precise, the actual offset is 2.7315V, but in practice it will vary very slightly from one sample to another. The calibration process compensates for any error in the offset voltage, and in the sensitivity of the particular component used. Here, we will keep things simple and assume an offset 2.73V.

The operating temperature range of the LM335Z is from –40 to +100°C, giving a nominal output voltage range of 2.33V to 3.73V. Unlike the LM35, it does require at least one discrete component, and in some applications two external components are required. Fig.1 shows leadout details for this chip, and the circuit for a LM335Z temperature sensor is given in Fig.2. It is used rather like a Zener diode in a shunt regulator circuit, and R1 is the load resistor.

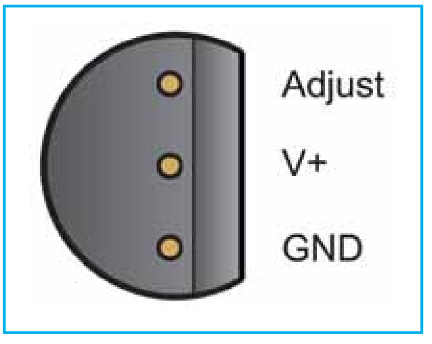


Fig.1. Leadout details for the LM335Z temperature sensor. This is a base view

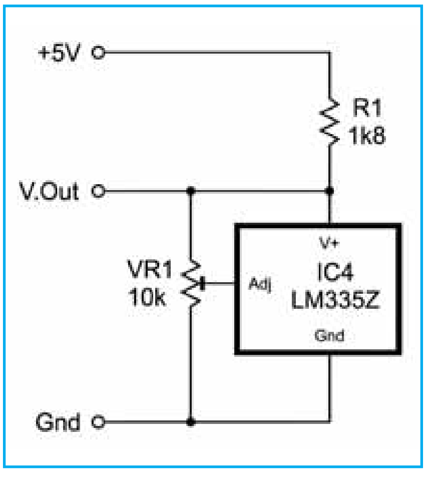


Fig.2. The circuit for a temperature sensor based on an LM335Z. Calibration potentiometer VR1 is optional, and if included it is adjusted for an output potential of precisely 10mV per degree Kelvin

Performance of the LM335Z is quoted in the data sheet as being constant with supply currents from 450µA to 5mA. As with any semiconductor temperature sensor, a low supply current is preferably in order to avoid problems with self-heating.

The specified value for resistor R1, in conjunction with a 5V supply, ensures that the supply current is kept just above the 450µA minimum at the highest operating temperature, but is still less than one milliamp at the minimum operating temperature.

Preset potentiometer VR1 is an optional calibration control. This can be adjusted to correct errors in the output voltage of the LM335Z itself, and, if necessary, it can compensate for minor errors elsewhere in the system as a whole. Alternatively, it can be omitted, and the system as a whole can be calibrated by varying the full-scale value of the converter circuit, as in the temperature interface featured previously.

Scaling the heights

Using a sensor that can handle negative temperatures without providing negative voltages makes life easier, but matters are not problem-free when trying to get the scaling of the temperature sensor to match that of the analogue interface. The output of the sensor changes at 10mV/K, and the basic resolution of the converter is 19.607843mV (5V divided by 255).

A small amount of attenuation at the input of the converter could be used to reduce its resolution to 20mV, and the system would then accommodate the full –40 to +100°C range of the sensor. However, in terms of degrees Celsius the resolution of the system would be just two degrees, which is far from ideal. It would not really be adequate for even the most basic of temperature measuring applications.

It is possible to set the resolution of the converter at 10mV using the modified version featured in the previous *Interface* article. On the face of it, this would give a much more useful resolution of 1°C, and would still enable the full temperature range of the sensor to be accommodated.

However, in practice it would not work at all well. The problem is that the input voltage range of the sensor would be 0V to 2.55V, but the output voltage range of the sensor is 2.33V to 3.73V, as explained previously. Only temperatures from –40 to –18°C would fall within the input range of the converter.

In order to obtain a useful temperature range from the system, it is necessary to remove all, or a large part of the 2.33V offset. This can be achieved using suitable signal conditioning circuitry, but the additional stages would have to be carefully designed in order to avoid inaccuracies being added into the system. The ADC0804LCN converter chip used in the analogue interface provides a much simpler solution, and that is probably a better way of handling things as well.

Vive la différence

The ADC0804 chip is mainly used as a simple analogue-to-digital with having a single input, but it does actually have differential inputs. The voltage converted by the device is the potential difference across its inputs, and in most applications the '–' input is simply connected to the 0V supply rail.

The converted voltage is then the difference between the 0V rail and the '+' input, and normal (single input) operation is thus obtained. However, supplying a positive voltage to the negative input effectively results in that voltage being deducted from the input potential at the positive input, with readings being reduced by a corresponding amount.

In the present application, using an input potential of 1.18V at the negative input would give an input voltage range of 1.18V to 3.73V and would reduce the effective output voltage range of the sensor to 1.15V to 2.55V. Either way of looking at it, this would bring the output of the sensor fully within the compass of the converter. The resolution obtained would be 1°C, and the full temperature range of the sensor would be accommodated.

As usual with this type of thing, some simple mathematics in the software is all that would be needed in order to give readings directly in degrees Celsius. In fact, it would just be a matter of deducting 155 from readings in order to convert them to corresponding temperatures.

In practice, it would be better to use a slightly higher offset voltage of (say) 1.2V, with 157 being deducted from the raw readings. It would then be possible for readings both above and below the valid range to be produced. The importance of this is that it is then clear to the user when an out of range, and therefore unreliable reading is being obtained. There would otherwise be no way of knowing whether a maximum in-range reading was valid or produced by an excessive temperature and input voltage.

Listing 1

```
Imports System
Imports System.IO.Ports

Public Class Form1
   Dim WithEvents port As SerialPort = New _
    System.IO.Ports.SerialPort("COM8", 9600, Parity.None, 8, StopBits.One)

   Private Sub Form1_Load(ByVal sender As Object, ByVal e As _
                  System.EventArgs) Handles Me.Load
      CheckForIllegalCrossThreadCalls = False
      If port.IsOpen = False Then port.Open()
   End Sub

   Private Sub port_DataReceived(ByVal sender As Object, ByVal e As _
     System.IO.Ports.SerialDataReceivedEventArgs) Handles port.DataReceived
      TextBox1.Text = (port.ReadByte - 157)
      If port.ReadExisting.Length = 0 Then
      End If
   End Sub
End Class
```

Modified circuit

The circuit diagram for the modified version of the analogue-to-digital converter is shown in Fig.3. This is the same as the interface featured in the April'12 issue, apart from the addition of resistor R7 and preset potentiometer VR2. These provide a voltage to the negative input of converter chip IC1 that can be varied from zero to nearly 2V.

The component used for VR2 should be a good quality multiturn type. As before, VR1 enables the full-scale sensitivity of the circuit to be altered; and in this case, it is a full-scale value of 2.55V that is required.

Listing 1 shows the modified version of the Visual BASIC program for the temperature interface, and the screen dump of Fig.4 shows it in action. This is the same as the program featured previously, apart from the fact that 157 is deducted from readings before they are displayed via the textbox. In order to match this figure, the interface should be set for an offset potential of 1.2V.

It is probably best to use the interface with the basic version of the temperature sensor. Including its calibration control is pointless since the system can be calibrated via VR1 and VR2 in the analogue interface.

The first step in the calibration process is to use a digital multimeter to measure the voltage at pin 7 of IC1 so it can be set at 1.2V. With the sensor at a known temperature

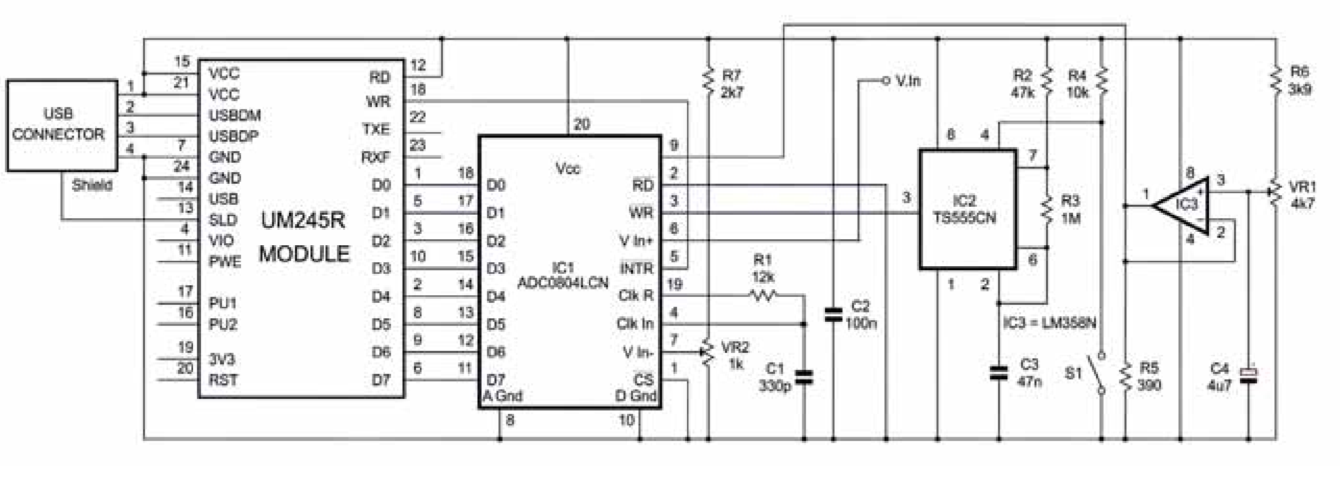


Fig.3. The modified analogue interface circuit for use with an LM335Z temperature sensor. VR2 provides an adjustable offset voltage that can be varied from 0 to just under 2V

that is equal to or close to the 100°C maximum, preset VR1 is set for the correct reading.

Next, the sensor is taken to a known temperature that should be 0°C, or any lower temperature that is within the range of the system. If necessary, VR2 is then adjusted to give the right temperature reading. This process should be repeated a few times until no further adjustment of VR1 or VR2 is needed.

Of course, the sensor must be housed in a probe assembly that is waterproof and can handle temperatures of 100°C or so if it is used with hot liquids. Bear in mind that some plastics melt at less than 100°C.

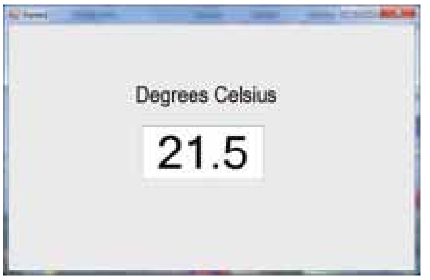


Fig.4. A screen dump showing the modified temperature program in operation

Obviously, due care should be taken when the calibration process involves the use of hot liquids, and (or) very cold materials.

NET WORK

by Alan Winstanley

Blackberry way…

ONE of the trickiest soldering jobs I undertook recently was to replace the badly-scraped touchscreen of my loyal TomTom satellite navigation unit. I needed to resolder some microscopically-thin wires of the touch digitiser (the transparent wafer-thin capacitive film placed over the colour screen) and connect them to the LCD ribbon cable itself. Luckily, I'd bought a couple of replacement digitisers via eBay for next to nothing, so after a practice-run with the first screen (a failure) I'm happy to say the repair was successful a second time, helped along by a reflow soldering technique and some crossing of fingers.

The TomTom screen reminds me that touch technology is here to stay, and a day seldom passes without a new touch device being launched in one shape or another. In previous columns, I outlined some of the latest hardware developments in consumer tablets and smartphones, including the short-lived but appealing HP WebOS-based Touchpad tablet (see *Net Work,* Nov 2011) which was strangled at birth by HP and sold off at knock-down prices.

Today, the rumour mill is buzzing with speculation of a possible foreign buy-out of Canada's Research in Motion, the name behind Blackberry. The Blackberry Playbook tablet (*Net Work*, Sept 2011) seems to be heading the same way as HP's Touchpad, in terms of price anyway, after eight months of lacklustre sales. Previously handicapped by its inability to handle email natively, a recent OS update has made the Playbook more usable as an email device that connects via your Blackberry. The Playbook 16GB is now less than half price on Amazon, at about £190, so if you enjoy tweeting or emailing via a Blackberry, then now is the time to hunt one down and grab a bargain.

Back in the Dec'11 issue, I mentioned the new Amazon Kindle Fire, a 7in. colour tablet with movie, ebook, email and web capabilities. At the time of writing, it's yet to be released in the UK, it's only on sale in the US, the price of $199 being unchanged. The Fire runs the Amazon Silk web browser and claims to deliver web-based content in a smoother, more predictive manner by processing downloads through Amazon's cloud, which acts as a cache. Many news and media websites contain a ludicrous number of adverts streamed in from third-party ad. servers, which cripples a web page's loading times, so Amazon's approach sounds very appealing.

Blackberry's Playbook is now less than half price and benefits from a recent OS upgrade

Amazon in the UK has been busily growing its Kindle range, and the new Kindle Touch is available on pre-order at £109.00. It still has the impressive high visibility e-ink screen (6in. diagonal) that avoids the glare, heat and eyestrain of a backlit LCD, but it's now touchscreen-enabled. The Kindle Touch has Wi-Fi, and e-books can be downloaded in 60 seconds, claims Amazon. As before, you can email your own PDFs and documents to your Kindle to view them on the go (fees apply). Still available are the classic Kindle ebook reader (£89) and a keyboard version (£149).

For readers wanting to access the web or email on the go, several years ago a new family of 'netbook' mini laptops appeared that offered a 10in. or 12in. colour screen and a proper dinky-sized keyboard in a folding laptop-like style. Many use solid-state drives (SSDs) and there is no optical drive, and various other specifications have been pared down, as befits the tiny form factor. They mostly run Windows 7 Starter Edition and cost around £250.

Many users still find a netbook adequate for a particular task or for taking on holiday, or for use by youngsters. Another option is devices called 'chromebooks', which are dumb-terminal netbooks using the Google Chrome OS (a Linux derivation, see *Net Work,* Sept 2011). Chromebooks require an always-available Internet connection to access the Google cloud-based applications and documents that they work with. Basic programs including a browser and media player are included, but not much else

The art of Zenbooks

A netbook or chromebook can soon be found wanting for everyday Internet use, and they are gradually being over-shadowed by the latest generation of touchscreen devices. An option that is less cumbersome than a laptop, and less dainty than a tablet, is the latest range of so-called 'ultrabooks'. These pricey ultra-portable devices are super-thin and near silent, with folding screen and QWERTY keyboard, using SSDs to host Windows 7. Aping the style of the svelte MacBook Air, benefits of an Intel-based ultrabook include their high degree of portability, rapid wake-up (typically two seconds) and tablet-like ergonomics. They are typically only 15mm thick, with some models tapering down to just a few millimetres at the front lip.

Several dozen models are now available from the best known names. Ones that stand out include the Asus Zenbook UX21, which is crafted out of a sliver of aluminium, with webcam, SSD, USB3 and Bluetooth, for about £760. The larger-screen Asus UX31 is £1,100 to £1,600. The Samsung

Series 5 ultrabook (£779) has a 13.3in. screen and a claimed six hour battery life, and Samsung's eagerly anticipated Series 9 (£1,200) has super-slim styling. Apple's MacBook Air ultra portable is also Intel powered, with an 11in. or 13in. screen, from £849.

None of these gadgets is cheap, and there is no denying the trend towards mobile Internet usage, especially via smartphones (choose between Windows, Android or Apple's iOS). Alternatives to ultrabooks or tablets include the new Samsung Galaxy Note, a smartphone-style phone/tablet with 5.3in. (diagonal) HD screen running Android in a coat-pocket sized 146mm housing. It has an 8 megapixel camera and touch screen or stylus input and high specification LCD. The novel Asus PadFone is a 4.3in. screen Android phone with a separate 10.1in. PadFone tablet into which an Asus PadFone slides; due soon.

The NATPC 7in. M009S Android 4.0 touch tablet offers everything needed for everyday casual use, with 8GB of storage, Flash compatibility (YouTube, BBC iPlayer), 802.11n Wi-Fi, webcam, HDMI, USB and MicroSD; about £100.00

A cheap alternative, that will be perfect for many home users, is a 7in. Android 4.0 touch tablet, which can be had for about £100 or so. A striking example is the NATPC M009S with Android 4, capacitive touch screen, Flash 11 (enabling animated Flash sites, YouTube, BBC iPlayer etc to be viewed natively, unlike an iPad), 802.11n Wi-Fi, HDMI out, Micro SD, webcam and USB. It's under 1cm thick and is currently £110 on Amazon. For a few tens of pounds more, a 10in. screen tablet can be bought, such as the highly-rated Zenithink ZT-280 imported from www.ebellking.com.

Smaller Android tablets are now within easy reach. There's more choice than ever, so it's worth browsing around and comparing reviews and prices online

Still in the slow lane

These new ultraportable devices and tablets are all very well, but the frustration for many of us is not the tantalising new hardware, but the fact that a decent, high speed network is still beyond reach after all this time. Ten years ago, I was bemoaning the dire state of dial-up Internet and the lack of ADSL, but today we endure the frustration of a patchy mobile network (I have never managed to make a 3G video call in my life), and slow broadband speeds that are in every way handicapping our use of this increasingly essential medium.

It's claimed that 50% of UK homes have access to a 'superfast' 50Mbps service, but this doesn't take account of Britain's geography. In my own locality, broadband speeds have barely doubled in the past ten years, and they frequently struggle at four megabits per second over an arthritic telephone line, based on a copper network cobbled together 30 or 40 years ago.

Superfast broadband is on the horizon though, and 90% of premises in the UK are promised 25 Mbps by 2015 as part of the Government's 'Broadband Delivery UK' (BDUK) programme. This £0.8 billion network upgrade comes under the umbrella of the Dept. of Culture, Media and Sport (DCMS), which has the lofty ambition of 'providing the best superfast broadband network in Europe by 2015'. The BBC 2013/14 licence fee will contribute a £300 million slice of the cost.

Fibre optic links are being laid to supply high speed broadband access around the country, and there is the possibility of broadband 'community hubs' being created to allow bandwidth to be purchased at market rates rather than being force-fed by BT. The acronym 'FTTC' stands for fibre to the cabinet, meaning fibre optic data delivered to a roadside cabinet, with copper cable delivering data the last mile or two, while 'FTTH/P' delivers directly to the home or premises. The way in which a future-proof high speed network can be built across the UK is still being hotly debated. The BDUK programme promises to be technology neutral, and at the extreme fringes of broadband access, satellite services may play a part.

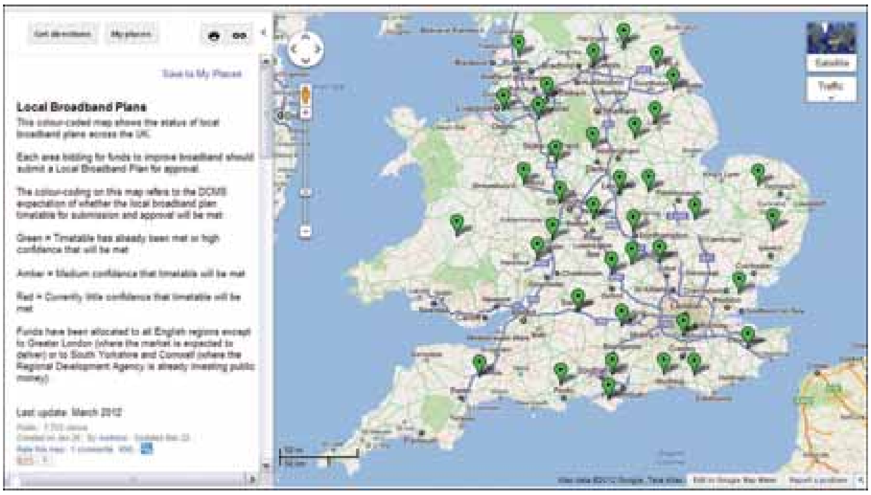
You can learn more about the DMCS's broadband programme at: www.culture.gov.uk/what_we_do/telecommunications_and_online/7763.aspx and you can see how well your own region is faring at the moment by zooming in on this map (2011): http://maps.ofcom.org.uk/broadband/. How the Local Broadband Plan will affect you can also be viewed at: http://g.co/maps/yxnwx

Home is where you hang your @

Some regular *EPE Chat Zone* forum users (www.chatzones.co.uk) might have noticed a new *Net Work* area dedicated to Internet-related topics. You might also have seen links to my personal website, which includes a mystery tour of my own constructional projects that appeared in *Everyday Electronics* over the years, starting with my first-ever project (Mains Delay Switch) of 1977 vintage.

I'm revisiting my original prototypes, which are being re-photographed in colour and published online for the first time. You'll be able to download my original constructional article as a PDF with some personal background notes about the prototype. I'd like to think I have come a long way in 35 years (some may disagree!) and readers are welcome to visit www.alanwinstanley.com and take a look around.

In tandem with this is www.epemag.net, a website that I host in support of *EPE*. Among other resources, it has the legacy PIC microcontroller and other source code files from the mid 1990s to the early 2000s, and my Network Best of the Net A-Z listing has also been revived after an absence of many years. A web-enabled reprint of my article *From Pipelines to Pylons – the story of electricity generation* will also be found there. That's all for this month – you can email me at alan@epemag.demon.co.uk or write to the editor at editorial@wimborne.co.uk



This optimistic map shows the planned roll-out of high speed broadband across the UK. How does your region fare?

READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say?

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All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

Leakage current measurement

Dear editor

The system of Jim Rowe for capacitor leakage measurement (*EPE*, Apr 2012) was interesting. I have been using capacitors under conditions where their leakage current was potentially of significance, but not having the above type of system, I used a different technique to measure the effective leakage resistance. The obvious technique is to use a sensing resistor and measure the voltage drop across it caused by the capacitor leakage current, as used by Jim. In my case, I was using electrolytic capacitors well below their maximum rated voltage, consequently very low currents in the nanoamp range were involved.

Measurement of current in this range is a bit tricky. Instead of using a sensing resistor, I use a different approach. By measuring the rate of decay of charge of the capacitor caused by leakage, the effective leakage current can be obtained from the expression $I = CdV/dt$. The capacitance is known and the voltage on the capacitor has to be measured at some time and again at some time later. Measurement of voltage cannot be done without the effect of the input impedance of the voltmeter loading the capacitor; but fortunately, it is only the voltage at the start of the timed period and at the end of it that is of interest.

I used a digital storage oscilloscope (Picoscope) with a ×10 probe having an input impedance of 10M. The DC supply and probe were connected to the capacitor and then both removed, leaving the capacitor open-circuited. Some time later, the probe was touched on the capacitor to read the voltage. The DSO showed the voltage when source and probe were removed and the voltage when the probe was reapplied, so that the drop in voltage and the time interval could be read off. The time interval was adjusted so that a small but measurable decay in voltage could be detected.

This technique is not a particularly accurate measurement, but is very simple. It is useful in cases where only an assessment of leakage current is needed.

Ken Naylor, by email

Matt Pulzer replies:

Thank you for your email Ken. I enjoyed reading about your technique for measuring leakage current. I often feel that the I = CdV/dt equation is not given the prominence it deserves by hobbyists, possibly because some are put off by differential equations. But as you point out, with a little though it can be used to yield useful information.

In other circuits, sawtooth or triangle waveforms are especially handy with capacitors, since the dV/dt component of the equation is simply a constant (the gradient of the waveform); the equation then reduces to I = kC, where k is the gradient. In other words, the current is directly proportional to the capacitance.

Digital RF & Power Meter

Dear editor

I have made a small deviation from the original project design (*EPE*, Dec 2010) by re-arranging the 470µF 16V radial electrolytic capacitor from a vertical to horizontal position and cutting away a section of the main PCB to allow a 9V PP3 battery to be placed at the top of the main LCD module. This results in a more comfortable hand-held unit, rather than the clumsy but robust unit in the original design. I have also added the LCD backlight switch and removed the head-end plastic wire retaining clip and locating screw.

I have used the *Digital RF & Power Meter* on four occasions since its completion and found it to be of immense value, especially considering that a commercial unit of the same type would cost £300. I built mine for £60 thanks to *EPE*.

I hope readers find my associated website of interest: http://m3xod-2e0xod.webplus.net.

Ian Donnelly, by email

Matthew Pulzer replies:

Many thanks for your mod explanation Ian, and good luck with the website.

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

editorial@wimborne.co.uk

EHT probe – be careful!

Dear editor
I just want to drop you a line to say that I thought the EHT sensor project was dangerous.

I know you published a long warning, and it is reasonable to assume that people involved with TVs are aware of the dangers of working with live CRTs. However, the design requires that the earth lead connection is fool proof, otherwise the full EHT will be transmitted to the meter – and possibly to a person touching it. In the photograph, the earth lead is secured by means of a croc clip onto a thin sheet of earthed metal chassis. If the user is distracted by looking for a fault and perhaps adjusting the brightness or contrast controls, that crock clip could easily 'pop off'.

In my view, it should be made clear that the earth lead should be bolted to the chassis under test. This is not as quick, and it takes some time to find a place, but it's safer.

Last, I want to finish on a positive note – the WIB series has been great fun and has kept me quiet for hours.

Keep up the good work!

Mike Boyden, by email

Matt Pulzer replies:

Mike, thank you for your useful observations.

If used properly, I do think the EHT probe is safe, but like much equipment in engineering, if one is distracted and ceases to pay careful attention then a hazard is certainly possible.

That said, I do think your suggestion is sensible and I am grateful for your further warning to those using it and to encourage extra safety where possible.

I'm delighted to hear you are enjoying the WIB – it's a really popular project.

Dear editor
In my opinion the EHT probe is rather too dangerous for everyday use, bearing in mind that most readily available (cheap) multimeters have very modest insulation capabilities.

Is it not possible to design a really safe probe? I am thinking along the lines of an optical interface between the high and low sides. Not standard opto-isolators, but two or more components separated by a short piece of optical fibre giving safe 50kV or better isolation. As an example, I have a 30kV electric fence energiser where control between the HV and LV sides is achieved by two 5mm LED's interconnected by means of a 75mm length of drinking straw!

The primary side could be battery powered to drive a sender LED. Access to the battery and primary side circuitry will be possible only by opening the unit. Battery drain will ideally be near zero when not in use.

A properly earthed primary will give a sensible readout, whereas an unearthed primary will give no readout, or some randomly floating values.

I am, nevertheless, going ahead with your project – but why would the constructional cost be £40?

Leon van der Merwe, South Africa, by email

Matt Pulzer replies:

Hi Leon, if constructed carefully and accurately, and used properly by an experienced amateur or professional – something we do really hammer home in the article – I do believe our probe is safe to use. That said, there is more than one way to skin a cat, and there is always room for improvement, as your interesting suggestions highlight.

The probe costs more than one might think because correctly rated (high voltage) resistors are not the 'cheapo' components we are used to in most other areas of electronics. Normally, I would not worry about constructors choosing any substitute components that they felt were up to the task. In this case, I would urge all constructors to be very conservative in selecting (and just as important, sourcing) components. The result is a modest price hike.

Do let me know how you progress with your EHT probe and best wishes to you 'down' in South Africa.

...and a little more on leakage detection

Dear editor
From time to time I pick up your magazine when there's an article of personal interest. Your Nov 2011 Leakage meter 'sparked' my interest. I thought about building it, but decided that it was far too complicated for the few times that I'd require it. So I came up with a much simpler version, which requires a variable DC voltage source, a DVM, a 10k resistor and an SPST pushbutton switch (NC contacts). It works as follows.

Connect the DC source, 10k resistor, capacitor under test and the switch in series – observing polarity. Put the DVM across the supply and monitor voltage output as you adjust it to match capacitor rating. Switch the DVM over to the capacitor leads and watch the voltage stabilise. When it does, connect the current meter of the DVM across the switch and open the switch contacts. The meter reading will give you the leakage current – simple.

In a follow up, could you include more leakage current values for capacitors above 4700μF; ie, 6800μF, 10,000μF and 15,000μF. I have some of these and would like to know what to expect in the way of leakage readings.

Joe Wdowiak, by email

Matt Pulzer replies:

Hi Joe, there is no simple answer to your question about the magnitude of leakage current in the larger capacitors you mention. At the very least, you would need to know the capacitor technology and its voltage rating.

That said, I have found Farnell's online catalogue to provide useful data: ***http://uk.farnell.com/capacitors***

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

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

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The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

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PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)

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CD-ROM

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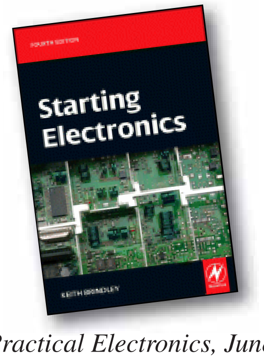

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Next Month

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Dual Tracking 0-±19V Power Supply – Part 2

In the current issue, we introduced our new Dual Tracking ±19V Power Supply and explained how it works. Next month, we show you how to build the PC boards, install them in a case, wire it all up and get it going. Both the mains-powered and plugpack-powered versions will be covered.

Jump Start

In the July issue, Mike and Richard Tooley build a 'Battery Voltage Checker', the third project in our new series dedicated to newcomers, or those following courses taught in schools and colleges.

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