

THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

# **EPE** EVERYDAY PRACTICAL ELECTRONICS

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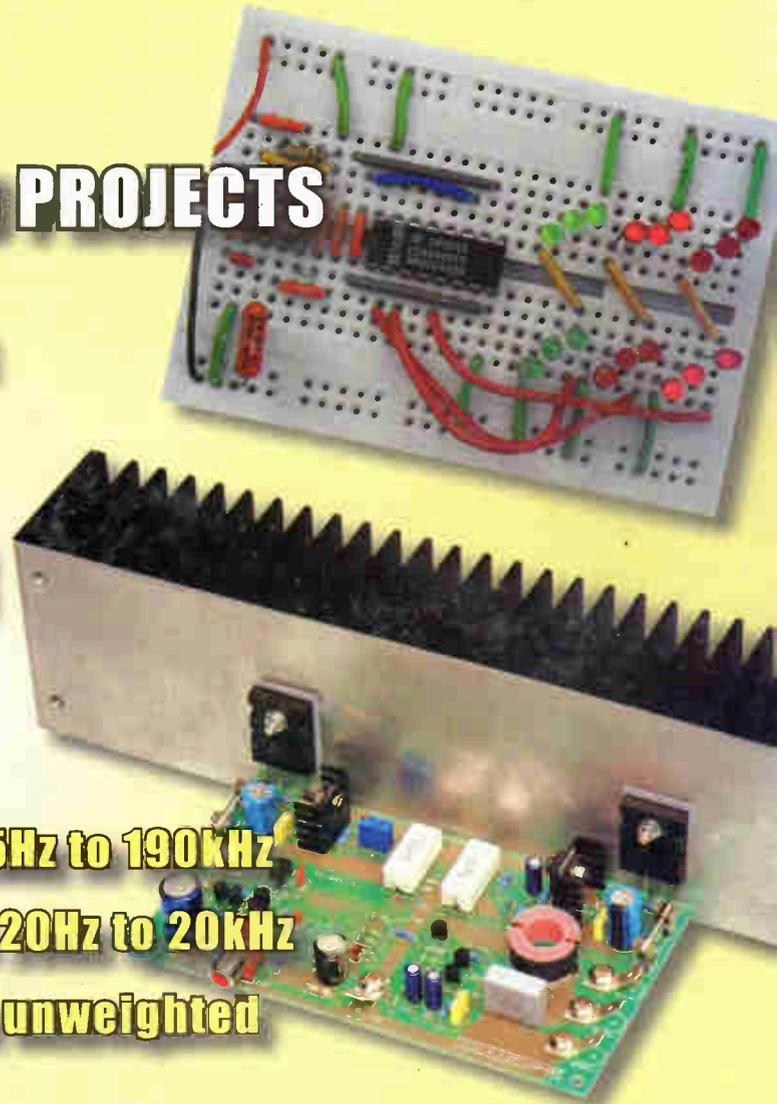
## **New Series**

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**Part 1: Introduction, plus  
Circuit Tester and Rain Check**

## **CLASS-A AMPLIFIER MODULE**

- ★ **20W into 8 $\Omega$  – pure class-A**
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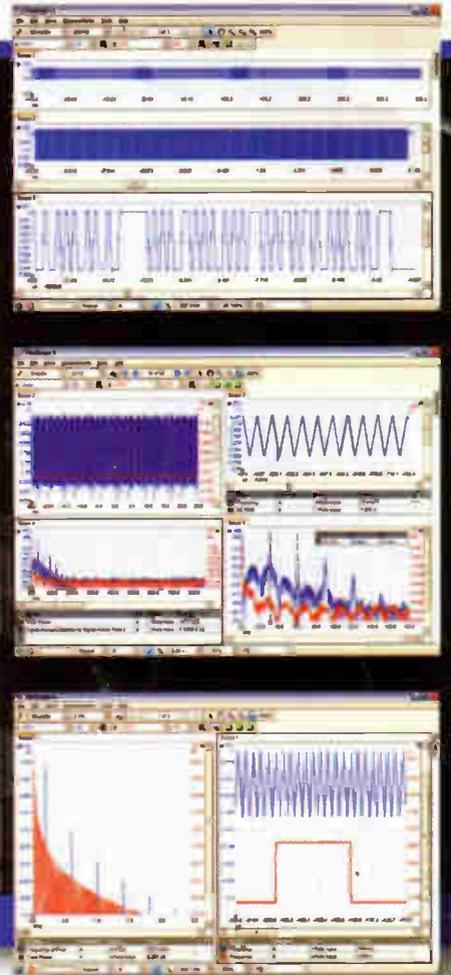
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# USB Connected High Speed PC Oscilloscopes



5000 SERIES

## PicoScope 5000 Series The No Compromise PC Oscilloscopes

With class-leading bandwidth, sampling rate, memory depth and an array of advanced high-end features, the PicoScope 5000 PC Oscilloscopes give you the features and performance you need without any compromise.

**250 MHz bandwidth**  
**1 GS/s real-time sample rate**  
**128 megasample record length**

### Advanced Triggers

In addition to the standard triggers the PicoScope 5000 series comes as standard with pulse width, window, dropout, delay, and logic level triggering.

**250 MHz Spectrum Analyser**  
**High-speed USB 2.0 Connection**

**Automatic Measurements**

**Arbitrary Waveform Generator**

Define your own waveforms or select from 8 predefined signals with the 12 bit, 125 MS/s arbitrary waveform generator.

### Waveform Playback Tool

PicoScope software now allows you to go back, review, and analyse up to 1000 captures within its waveform playback tool.

**pico**<sup>®</sup>  
Technology

3000 SERIES

The PicoScope 3000 Series of oscilloscopes from Pico Technology includes general purpose and high resolution models: With 12 bit resolution and 1% accuracy, the 10MHz PicoScope 3424 is able to detect changes as small as 0.024% (244ppm) – making it the ideal 4-channel oscilloscope for analog design and analysis. The higher speed 8 bit models in the PicoScope 3000 series feature sampling rates up to 200MS/s and up to 1 MS/s record lengths for general purpose and portable applications.



2000 SERIES

The PicoScope 2000 series oscilloscopes offer single and dual channel units that offer highly portable/low cost solutions to general purpose testing. The award winning 25MHz handheld PicoScope 2105 fits comfortably into the palm of your hand yet still includes the powerful features found in larger oscilloscopes.



VISIT [www.picotech.com/scope487](http://www.picotech.com/scope487)

to check out our full line of PC-based instruments or call **01480 396 395** for information and a product catalogue

## Projects and Circuits

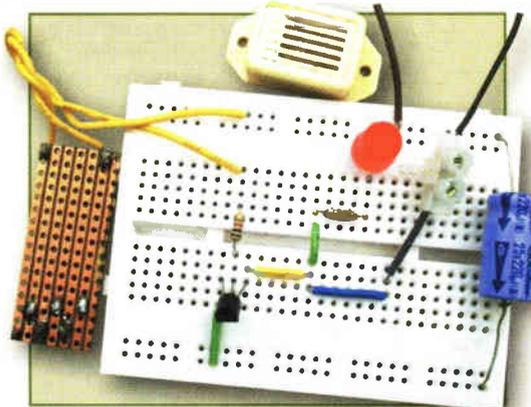
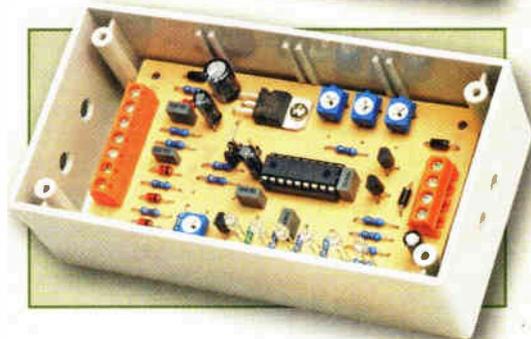
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Our November 2008 issue will be published on Thursday 9 October 2008, see page 72 for details.

Everyday Practical Electronics, October 2008

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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 (PSU010) £18.95  
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

#### NEW! 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: 3149KT - £39.95  
Assembled Order Code: AS3149 - £49.95

#### NEW! USB 'All-Flash' PIC Programmer

USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows XP Software. ZIF Socket and USB lead not incl.

Assembled Order Code: AS3128 - £44.95  
Assembled with ZIF socket Order Code: AS3128ZIF - £59.95

#### 'PICALL' ISP PIC Programmer

Will program virtually all 8 to 40 pin serial-mode AND parallel-mode (PIC15C family) PIC microcontrollers. Free Windows software. Blank chip auto detect for super fast bulk programming. Optional ZIF socket.

Assembled Order Code: AS3117 - £24.95  
Assembled with ZIF socket Order Code: AS3117ZIF - £39.95

#### 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 - £24.95  
Assembled Order Code: AS3123 - £34.95

#### 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: VK8076KT - £21.95



#### 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: VK8048KT - £22.95



Assembled Order Code: VVM111 - £39.95

### 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 PSU445 £8.95

#### 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: VK8055KT - £20.95  
Assembled Order Code: VVM110 - £39.95



#### 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 - £44.95  
Assembled Order Code: AS3180 - £54.95



#### 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 - £17.95  
Assembled Order Code: AS3145 - £24.95  
Additional DS1820 Sensors - £3.95 each



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 - £54.95  
Assembled Order Code: AS3140 - £69.95



#### 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 - £54.95  
Assembled Order Code: AS3108 - £64.95



#### 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 - £47.95  
Assembled Order Code: AS3142 - £59.95



#### 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 PSU445). Main PCB: 55x95mm. Kit Order Code: 3153KT - £24.95  
Assembled Order Code: AS3153 - £34.95



#### Telephone Call Logger

Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).

Kit Order Code: 3164KT - £54.95  
Assembled Order Code: AS3164 - £69.95



## Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

### Bipolar Stepper Motor Chopper Driver

New bipolar chopper driver gives better performance from your stepper motors. It uses a dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase is set using an on-board potentiometer. Can handle motor winding currents of up to 2 Amps per phase. Operates from a DC supply voltage of 9-36V. All basic motor controls provided including full or half stepping of bipolar steppers and direction control. Synchronisable when using multiple drivers. Perfect for desktop CNC applications. Kit Order Code: 3187KT - £29.95  
Assembled Order Code: AS3187 - £39.95



### Shaking Dice

This electronic construction kit is great fun to build and play with. Simply shake and watch it slowly roll to stop on a random number. Kit Order Code: VMK150KT - £9.95



### Running MicroBug

This electronic construction kit is an attractive bright coloured bug-shaped miniature robot. The microbug is always hungry for light and travels toward it! Kit Order Code: VMK127KT - £9.95



### Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors. Kit Order Code: VK8036KT - £19.95  
Assembled Order Code: VVM106 - £26.95



### PC Interface Board

This interface card excels in its simplicity of use and installation. The card is connected in a very simple way to the printer port (there is no need to open up the computer). Likewise there is no need to install an extra printer port, even if a printer is to be used. This can be connected to the card in the usual manner. Connection to the computer is optically isolated, so that damage to the computer from the card is not possible. Kit Order Code: VK8000KT - £59.95



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

## Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

### DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H. Kit Order Code: 3067KT - £13.95  
Assembled Order Code: AS3067 - £21.95



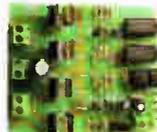
### PC / Standalone Unipolar Stepper Motor Driver

Drives any 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps max. Provides speed and direction control. Operates in stand-alone or PC-controlled mode. Up to six 3179 driver boards can be connected to a single parallel port. Supply: 9Vdc. PCB: 80x50mm. Kit Order Code: 3179KT - £12.95  
Assembled Order Code: AS3179 - £19.95



### Bi-Polar Stepper Motor Driver

Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer. Supply: 8-30Vdc. PCB: 75x85mm. Kit Order Code: 3158KT - £17.95  
Assembled Order Code: AS3158 - £27.95



### Bidirectional DC Motor Controller

Controls the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections. Kit Order Code: 3166v2KT - £17.95  
Assembled Order Code: AS3166v2 - £27.95



### AC Motor Speed Controller (700W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or single phase 230V AC motor rated up to 700 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors. Kit Order Code: 1074KT - £12.95  
Assembled Order Code: AS1074 - £18.95  
Box Order Code 2074BX - £5.95



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Also available - 30-in-1 £16.95, 50-in-1 £21.95, 75-in-1 £32.95, 130-in-1 £39.95 & 300-in-1 £59.95 (details on website)



## Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

### Two-Channel USB Pc Oscilloscope

This digital storage oscilloscope uses the power of your PC to visualize electrical signals. Its high sensitive display resolution, down to 0.15mV, combined with a high bandwidth and a sampling frequency of up to 1GHz are giving this unit all the power you need. Order Code: VPCSU1000 - £289.95



### Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use. Order Code: VHPS10 - £129.95 £119.95



See website for more super deals!



[www.QuasarElectronics.com](http://www.QuasarElectronics.com)

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# EVERYDAY PRACTICAL ELECTRONICS FEATURED KITS

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.

## Jaycar Electronics

October '08

### GALACTIC VOICE KIT

**KC-5431 £13.25 plus postage & packing**

Refer: EPE Magazine August 2008.

This galactic voice simulator kit has effect and depth controls to allow you to vary the effect to simulate everything from the metallic-challenged C-3PO, to the hysterical ranting of Daleks. The kit includes PCB with overlay, enclosure, speaker panel and all components.

- Requires a 9V battery.
- As published in EPE Magazine August 2008



### STARSHIP ENTERPRISE DOOR SOUND EMULATOR

**KC-5423 £11.75 + postage & packing**

This easy to build kit emulates the unique noise made when the cabin doors on the Starship Enterprise open and close. The 'shut' noise is also duplicated. The sound emulator can be triggered by switch contacts (normally open) which means you can use a reed magnet switch, IR beam or PIR detector to trigger the unit. Kit includes PCB with overlay, case and all electronic components with clear English instructions.

- Requires 9-12VDC power
- As published in EPE Magazine June 2008



### MINI THEREMIN SYNTHESIZER KIT

**KC-5426 £43.50 plus postage & packing**

AS USED IN THE  
"GIRL BOYS  
CLASS" KIT "GOOD  
VIBRATIONS"



The Therman is a musical instrument that was invented in the early 1900s and is still used today. By moving your hand between the metal antennas you can create unusual sound effects like those used in science fiction movies. Kit includes stand, PCB with overlay, machined case with silkscreen printed lid, loud speaker, pitch and volume antennas & all specified electronic components.

- Requires 12VDC power supply
- As published in EPE Magazine May & June 2008

### SPEAKER BASS EXTENDER KIT

**KC-5411 £6.00 plus postage & packing**

Most audiophiles know that loudspeaker enclosures have a natural frequency roll off which is inherent in their design. The bass extender kit boosts the level of the bass to counteract the natural roll off of the enclosure, producing rich, natural bass. It gives an extra octave of response, and is sure to please even the most avid audiophiles.

- Kit supplied with PCB and all electronic components
- As published in EPE Magazine March 2007



### COURTESY INTERIOR LIGHT DELAY KIT

**KC-5392 £5.95 plus postage & packing**

This kit provides a time delay in your vehicle's interior light, for you to buckle-up your seat belt and get organised before the light dims and fades out. It has a 'soft' fade-out after a set time has elapsed and has a universal wiring kit. Supplied with PCB with overlay, all electronics components and clear English instructions.

- As published in EPE Magazine February 2007



### SMART CARD READER PROGRAMMER KIT

**KC-5361 £15.95 plus P&P**



Program both the microcontroller and EEPROM in the popular gold, silver & emerald wafer cards. Card used needs to conform to ISO-7816 standards, which includes ones sold by Jaycar. Powered by 9-12 VDC wall adaptor or a 9V battery.

Instructions outline software requirements that are freely available on the internet. Kit supplied with PCB, wafer card socket & all electronic components.

- PCB measures: 141 x 101mm
- As published in EPE Magazine May 2006

### 50MHz FREQUENCY METER KIT WITH LCD

**KC-5369 £16.00 plus postage & packing**



This compact 50MHz Frequency Meter is low cost and invaluable for servicing and diagnostics. This meter is autoranging and displays the frequency in either Hz, kHz or MHz. Features compact size (130 x 67 x 44mm), 8 digit LCD display, high and low resolution modes. 0.1Hz resolution up to 150Hz, 1Hz resolution maximum up to 150Hz and 10Hz resolution above 16MHz. Kit includes PCB, case with machined and silk-screened lid, pre-programmed PIC and all electronic components with clear English instructions.

- Requires 9VDC wall adaptor (Maplin #GS74R £9.99)
- As published in EPE Magazine September 2006

### AC/DC CURRENT CLAMP METER KIT

**KC-5368 £8.75 plus P&P**

It uses a simple hall effect sensor and iron ring core setup, and connects to your digital multimeter. It will measure AC and DC current and has a calibration dial to allow for any magnetising of the core. Kit supplied with PCB, clamp, case with silk-screened front panel and all electronic components with clear English instructions

- As published in EPE Magazine January 2006



### THEREMIN SYNTHESIZER KIT

**KC-5372 £55.95 plus postage & packing**

The Studio 350 power amplifier will deliver a whopping 350WRMS into 4 ohms, or 200WRMS into 8 ohms. Using eight 250V 200W plastic power transistors, it is super quiet, with a signal to noise ratio of -125dB (A) at full 8 ohm power. Harmonic distortion is just 0.002%, and frequency response is almost flat (less than -1dB) between 15Hz and 60kHz! Kit supplied in short form with PCB and electronic components. Kit requires heatsink and +/- 70V power supply (a suitable supply is described in the instructions)

- As published in EPE Magazine October 2006



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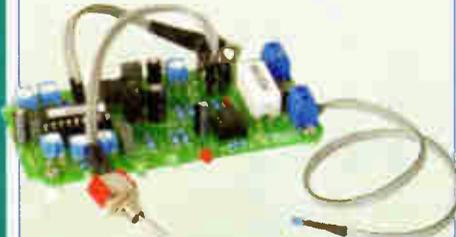
www.jaycarelectronics.co.uk

# POPULAR KITS FOR ELECTRONIC ENTHUSIASTS



## FAST NI-MH BATTERY CHARGER KIT

**KC-5453 £11.75 plus postage & packing**



A truly versatile charger, capable of handling up to 15 of the same type of Ni-MH or Ni-Cd cells. Build it to suit any size cells or cell capacity and set your own fast or trickle charge rate. It also has overcharge protection including temperature sensing. Ideal for R/C enthusiasts who burn through a lot of batteries.

- Kit includes PCB and all specified electronic components.
- Case, heatsink and battery holder not included.

## AMPLIFIER MODULES



**NEW FOR 08 KC-5470 £26.25 plus P&P**

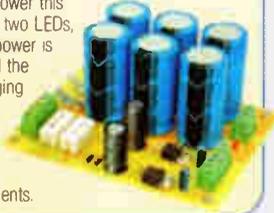
This ultra low distortion amplifier module uses the new ThermalTrak power transistors and is largely based on the high-performance Class-A amplifier. This improved circuit has no need for a quiescent current adjustment or a Vbe multiplier transistor and has an exceptionally low distortion figure.

- Kit supplied with PCB and all electronic components.
- Heatsink and power supply not included.
- Output Power: 135WRMS into 8 ohms and 200WRMS into 4 ohms
- Frequency Response at 1W: 4Hz to 50kHz
- Harmonic Distortion: <0.008% from 20Hz to 20kHz

**KC-5471 £16.00 plus post & packing**

The amp module (KC-5470) is powered using an unregulated rail only. This power supply kit is specifically designed to provide a balanced +/- 55VDC supply to power this fantastic amp kit. It has two LEDs, which illuminate when power is present on the rails and the assist in slowly discharging the filter caps when power is switched off.

- Kit includes PCB and all electronic components.



## IMPROVED LOW VOLTAGE ADAPTOR

**KC-5463 £4.50 plus postage & packing**

This handy regulator will let you run a variety of devices such as CD, DVD or MP3 players from your car cigarette lighter sockets, even a digital camera or powered speakers from the power supply inside your PC. This unit can supply 3V, 5V, 6V, 9V, 12V or 15V from a higher input voltage at up to four amps (with suitable heatsink).

- Kit includes screen printed PCB and all specified components. Heatsink not included.



## POWERTOOL BATTERY CHARGER KIT

**KC-5436 £11.75 plus postage & packing**

Enhance the performance of the charger supplied with your power tool with this controller. It incorporates charge timeout, min and max temperature monitoring, Delta charge detection, power and charge LED indicator, adjustable Delta V, temperature settings, and optional adjustable trickle charge. Suits both Ni-Cd and Ni-MH cells.

- Kit includes PCB with overlay, case, all electronic components and clear English instructions.

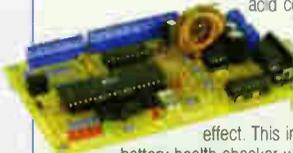


## BATTERY ZAPPER KIT MK II

**KC-5427 £29.00 plus postage & packing**

This kit attacks a common cause of failure in wet lead acid cell batteries: sulphation. The circuit produces short bursts of high level energy to reverse the damaging sulphation effect. This improved unit features a battery health checker with LED indicator, new circuit protection against badly sulphated batteries, test points for a DMM & connection for a battery charger.

- Kit includes case with screen printed lid, PCB with overlay and all electronic components with clear English instructions.
- Suitable for 6, 12 and 24V batteries
- Powered by the battery itself



## TOOLS & ACCESSORIES

**QM-1323 DMM £10.00 plus postage & packing**

A budget priced meter with everything you need - capacitance, temperature and 10A on AC and DC, compact and light weight with rugged moulded case.

- Data hold
- Temp range: -20° to 760°C
- Case included
- Category: Cat III 600V
- Display: 4000 count
- Ave/RMS: True RMS
- 137(H) x 65(W) x 35(D)mm
- For full specs see our website



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10 x 12"	£9.59	£11.70	£12.64	£11.83
12 x 12"	£9.68	£11.77	£12.87	£12.25
100 x 160mm			£2.81	£3.12
203 x 114mm			£4.05	£4.06
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26 Woy	£0.26	£13.94
34 Woy	£0.34	£18.22
40 Woy	£0.40	£21.44
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60 Woy	£0.64	£33.92
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Going back to my opening comment, the reason paper's downfall has been so regularly predicted is of course the Internet. In fact, the truth is, web and paper versions of EPE complement rather than replace each other, and the good news is that it is even cheaper to download your copies from our website at [www.epemag3.com](http://www.epemag3.com) – the cost for a year's subscription is about £9.50 (\$18.99 US). You get all the same content without us having to print it and post it, or give the major newsagents a 'promotion' payment!

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# NEWS

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



## Cherry Blossom Talks

Barry Fox Reports on the Fujitsu Technology Forum

**W**HEN cherry blossom talks, Japan's electronics industry should listen. That was the message from Dr Kazuo Murano, President of Fujitsu Laboratories at the Fujitsu Technology Forum held in London recently. Murano, along with Richard Christou, chairman and chief executive of Fujitsu EMEA plc, was talking to a small group of journalists before addressing an invited audience of around 150 top-level managers from the public and private sector.

"In Japan", said Murano, "cherry blossom is very important to us. Over the last fifty years it has arrived earlier and now on average is 4.2 days early each year. We have to take notice of that sign of global warming."

### Power management

Says Christou: "People don't turn their computers off. They often don't enable power management. We will soon start shipping a green monitor which has light sensors so that it adjusts the screen brightness to suit the room brightness. It also consumes zero watts in sleep mode."

The green monitor screen brightens when a light is shone on the sensors; a watt meter shows a zero reading when the PC connected to it is shut down or put into sleep mode.

Whereas most monitors remain in standby when the PC is idle, Fujitsu uses capacitor storage and relay control so that the power can be completely disconnected when the screen is not needed.

### Fingerprinting

Although Fujitsu has a range of security systems such as PC password control based on fingerprint recognition, Murano believes the new technology of palm vein recognition is a better bet.

"When you pick up a glass you leave a fingerprint which can be copied" he says. Fingerprinting is good for criminal investigation but not for security. Palm vein recognition is more secure. The

reader needs no contact with the hand. This makes it ideal for hospitals, for better hygiene, or where there are religious or cultural objections to fingerprinting'.

The palm is held 3 to 7cm over a near infra-red light source, while a camera captures and maps the pattern of veins which contain oxygen-reduced blood that absorbs the IR. Because there is no contact, no copiable trace is left. The system is as accurate as iris recognition, but without the rejections that spectacle-wearers experience at UK airports which offer the option of iris passport control. What's more, the blood must be flowing, so a severed hand will not be recognised!

### No tailgating

To prevent tailgating – where an unauthorised visitor slips in behind an authorised visitor or forces them to open a door – six cameras over a secure zone refuse to open the door if more than one person is near the palm reader. Identification and rejection takes only a couple of seconds.

Say Murano and Christou: "Of course we would like to see palm vein used more widely. But the EU has effectively mandated fingerprint technology. It's used in the US for immigration; and the system is often tied to criminal fingerprint records. In the future, there may be more multi-authorisation, with fingerprint and vein recognition".

Fujitsu also showed real-time temperature measurement in optic fibre data networks. Light scatter caused by temperature differences along the fibre are detected by an infra-red pulse test signal and used to map the temperature under the floor or in the ceiling. So air conditioning can be targeted to save energy.

### Colour electronic paper

The most impressive demonstration was of colour electronic paper. The

'paper' is a 0.8mm thick triple layer of LCDs, with red, green and blue cells separated by transparent electrodes and backed by an opaque layer. The cells are bi-stable; when switched on and off by electric signals they remain switched until fresh pulses are applied. When daylight or room light falls on the sheet it displays a passive coloured image. Contrast can be heightened by applying the switching pulses in a series of three steps. A line 'wipes' across the screen making the image more legible. Even with one wipe the image is clear enough to read comfortably.

The demonstration screen was A5 size, in a rigid frame, but Fujitsu promises 40-inch displays with a re-write taking three seconds and using only three watts – compared to over 300 watts for an equivalent size plasma.

The paper can be used for travel signs and price labels that are remotely changed by sending electric signals down a line or over the air. Security and visitor tags can be written and later erased. Resolution is 162 ppi and contrast 4:1 – compared to newspaper at 8:1 or 10:1.

Browse <http://jp.fujitsu.com/group/labs/en/business/activities/activities-4/e-paper.print.html>

### Precision screwdriver

Computer and electronic engineers, hobbyists and technicians will welcome Kamasa's latest precision ratchet screwdriver (55936) with a bit set integrated into the auto-extending handle.

Within the auto-extending handle there are three nickel chromium molybdenum bits supplied: Phillips (PH00/PH0/PH1), two flat (2.5/3.0 mm) and five star bits (T6 – T10).

For further information on the Kamasa brand or to find out nearest stockists/online stockists visit [www.kamasa.co.uk](http://www.kamasa.co.uk), or contact The Tool Connection Ltd, Kineton Road, Southam, Warwickshire, CV47 ODR, [www.toolconnection.co.uk](http://www.toolconnection.co.uk).

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Everyday Practical Electronics and Microchip have teamed up to offer you the chance to buy a PICKit 2 Debug Express Kit (DV164121) at an unprecedented discount price! In the November issue of *EPE*, find out how to purchase this kit via microchipDIRECT at an unmissable price of only £9.99 – including VAT and delivery to UK addresses! As this is an unprecedented price, the offer is limited to one per household, UK addresses only.

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PICKit 2 is a pocket-sized complete programmer and debugger which allows easy in-circuit development of selected PIC

microcontrollers. Any personal computer can become a development station using the supplied MPLAB IDE development tool for writing code, debugging and programming devices. A single USB port is used to interface with the PICKit 2 and control your PIC project, enabling you to halt, single-step and breakpoint your code on your target board.

The Kit includes Microchip's 44-pin PIC16F887 Flash microcontroller demo board, the PICKit 2 programmer, USB cable and software CDs, including Microchip's MPLAB IDE integrated development environment, CCS PCM Midrange C Compiler Demo for PIC16F887 and HI-TECH PICC LITE C Compiler – enabling new users to easily get started with an embedded control design.

To find out more about how to buy your PICKit 2 Debug Express Kit at this special price, make sure you buy the November issue of *EPE*!

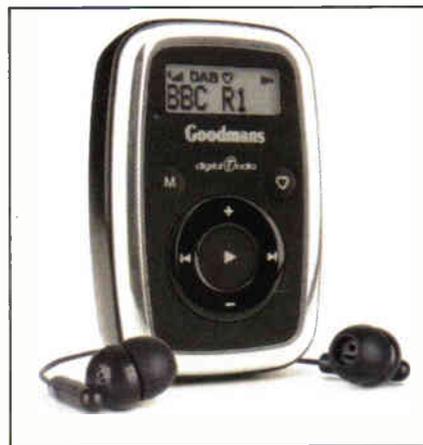
## END OF THE SHORTWAVES?

Local QRM man-made interference is becoming an increasing threat to reception over the whole of the shortwave spectrum, and for many amateurs and shortwave listeners, reception is fast becoming an impossibility. There is a conflict between the desire to link up all sorts of gadgets in the home and the ability to listen to low level signals. One fast-growing threat is the use of domestic mains electricity wiring to distribute data signals around the home. This technology uses devices known as power line adapters (PLA).

Many see this in the context of a number of onslaughts on shortwave operation. These include, cheap unfiltered computer power supplies that carry the CE mark and are now flooding the UK; badly filtered switch-mode power supplies in TVs, set-top boxes, running modems, chargers, light dimmers, etc. The issue of power line adapters really is a wake-up call, unless we push for improved standards and best practice we will lose the shortwaves – they will be sunk under an ever increasing tide of QRM.

While the RSGB does a good job of representing licensed amateurs on EMC issues at national and international levels, it is not mandated to represent other non-professional users of the shortwave bands. Up to now, there has been no representation that embraces the concerns of shortwave listeners as well as radio amateurs. Enter UKQRM – a new group formed to campaign on the issue of PLA QRM. The group, which has over 300 members, is open to anyone concerned with these issues and can be found at <http://tech.groups.yahoo.com/group/UKQRM/>.

See [www.radiowymsey.org/qrm.htm](http://www.radiowymsey.org/qrm.htm) for more information and links.



### WORLD'S SMALLEST POCKET DAB RADIO

This dinky new hand-held radio is currently the smallest stand-alone DAB/FM radio in the world. Avid radio listeners will love the convenience of its size and its high quality sound performance. Concealed under its minimalist stylish black and chrome casing lies the heart of the radio – a clever, miniature chip that delivers the latest state-of-the-art radio technology. Smaller than a mobile phone or wallet, and lighter than a set of keys or loose change, this new pocket radio won't take up much room while on the move as it measures only 69.5 × 44 × 21.4mm and weighs a mere 48g.

It comes with quality headphones, which double up as the aerial, and requires just two AAA size batteries to provide over 10 hours of DAB radio listening or 15 hours of FM, depending on your station preferences. Its stylish fascia has a blue backlit display panel, clearly showing station name, volume level, favourite icon, signal strength and battery level. Radio controls are simple with a button to access the menu and a button to store up to 10 of your favourite radio stations.

The new Goodmans GHDAB 101 is retailing at just £44.99. DAB radio has much to offer, giving access to around double the number of FM radio stations, opening up a whole new radio experience. More than 90% of the UK population is now covered by a DAB signal and in London alone there are more than 50 DAB stations from which to choose.

## From Bletchley With Love

On 24 July 2008, a visit to Bletchley Park by Their Royal Highnesses The Prince of Wales and The Duchess of Cornwall, marked the official opening, in Hut 12, of a very special new exhibition about Ian Fleming and Real Spies, Double Agents and Bletchley Park. The Royal couple, along with some specially invited guests, such as members of the Fleming family and Bletchley Park veterans, admired the new exhibition and listened to a presentation in Hut 12 by Mavis Batey, Bletchley Park codebreaker, on Ian Fleming's war.

Ian Fleming's favourite Churchill quote was, 'In the high ranges of Secret Service work the actual facts in many cases were in every respect equal to the most fantastic inventions of romance and melodrama. Tangle within tangle, plot and counter-plot, ruse and treachery, cross and double cross, true agent, false agent, gold and steel, the bomb, the dagger and the firing party were interwoven in many a texture so intricate as to be incredible and yet true'.

Knowing the enemy's secrets and keeping your own is a real war winner. In World War Two codebreaking and the special intelligence derived from it played a major role in the allied victory in Europe. Ian Fleming, NID 17F, acted as liaison officer between Bletchley Park and the Director of Naval Intelligence throughout the war. The brand new 'From Bletchley, With Love' exhibition shows for the first time his involvement with the secrets of ENIGMA and ULTRA, which he was never able to reveal, but which formed the inspiration for the fantasy world of James Bond. Among other fascinating Fleming insights, the exhibition makes the startling revelation of who was Ian Fleming's real-life 'M'.

Truth really is stranger than fiction. This exhibition also tells the story of the subversive wartime world of double-cross agents. Espionage and counter-espionage. Deception and intrigue. Sabotage and extortion. And how it was all achieved with the help of intelligence gleaned from Bletchley Park.

Admission to the *From Bletchley With Love* exhibition is included in the normal admission price.

- Cost of the annual season ticket for Bletchley Park is: adults: £10, concessions: £8 (Over 60s and students with valid ID card) and £6 (children aged 12 to 16), children under 12 admitted free of charge. Family Ticket: £22.50 (two adults and two children aged 12 to 16). Tickets include a guided tour (subject to availability) and/or the use of an audio tour. Onsite parking is £3 per car.

- Bletchley Park is open during 2008 every day except Christmas Eve, Christmas Day, Boxing Day and New Year's Day.

# CORDLESS POWER CHARGER CONTROL

**Protect your investment and extend the life of your power tool rechargeable batteries. Add this Power Tool Charger Controller and never cook a NiCad again!**

**W**HILE battery-powered tools have many virtues, we are not so enthusiastic about their battery charging systems. Most low-cost power tools include a very basic charger: a plugpack to supply power and a resistor to limit the current flow into the battery pack. There is nothing to prevent overcharging: no timer to switch off charging when the time has elapsed and no full-charge detection.

At best, this type of basic charger will shorten the battery pack life, so that it will require replacing after relatively few charges. At worst, the basic charger can cause destruction of the battery pack the very first time it is used!

Destruction of the battery pack can happen if the charger is left on for too long after the battery pack has reached full charge. And it is all too easy to forget to switch the charger off at the required time. The result is serious overcharging.

You cannot even rely on the fact that charging requires a certain time period and the charger can be switched off after that, because the time period required to reach full charge depends on the state of charge of the battery pack at the start of charging.

Overcharging can destroy the battery pack because of the characteristics of the cells that make up the battery pack, which are usually based on NiCad

(Nickel Cadmium (NiCad)) or NiMH (Nickel Metal Hydride) chemistry. The two types tend to have fairly similar characteristics and overcharging will severely shorten the life of both.

One of the main differences between the two, as far as users are concerned, is that NiCads can develop a 'memory', where if they are only partially discharged then charged again, eventually they will 'remember' this as their

charge point (also known as the end-point) the temperature and internal pressure rapidly rise and the voltage initially rises and then falls.

Continual overcharging will damage the cells due to elevated temperature. This accelerates chemical reactions that contribute to the ageing process. In extreme cases during overcharging, the internal pressure can cause the cells to open their safety vents to release the pressure. The vents should re-close after the pressure is released, but sometimes the cells are deformed by the heat and permanent damage occurs.

## What should happen?

A well-designed charger will not allow overcharging; in fact, it will switch off the main charge when the cells reach their 'end-point'.

Some chargers will just include a timer to switch off charging after a certain period has elapsed. This is not ideal for the reasons already mentioned, and the timer should really only be included as a fail-safe device; a backup to stop charging should the 'detection of full charge' fail.

Full charge of the battery pack can be determined in one of two ways. One way is to monitor the voltage across the battery pack and detect the point where the voltage begins to rapidly rise and then fall.

## MAIN FEATURES

- **Charging timeout**
- **Minimum and maximum temperature monitoring**
- **dT/dt charged detection (temperature/time - see text)**
- **Over and under-temperature detection**
- **Power, charging and thermistor out indicator LEDs**
- **Adjustable timeout limit**
- **Adjustable dT/dt setting**
- **Optional and adjustable top-up and trickle charging**
- **Start switch**
- **Charging resumes after blackout**

entire charge/discharge limit and, therefore, significantly reduce the amount of power available. NiMH batteries do not have this characteristic. However, NiCads are more suited to the heavy discharge currents of power tools and are usually supplied instead of NiMH cells.

## On charge

To see what happens when a battery charges take a look at Fig.1. This shows the typical voltage, temperature and internal pressure rise with charge. Once charging goes past the 100%

# TOOL ROLLER



By JOHN CLARKE

This form of end-point detection is called  $dV/dt$ , or the change in voltage with respect to time. In practice, this voltage change can be difficult to detect, especially with NiMH cells, which do not show a marked voltage change at full charge.

The second (and more reliable) method is to detect the *temperature* rise of one or two cells within the battery pack. When charging, the incoming electrical power is converted into stored energy via chemical reactions within each cell. These reactions are reversible – when an electrical load is connected they deliver electrical power.

While charging at normal rates, the cells do not rise much in temperature because most of the incoming power is converted into useful stored energy. However, once the cells become fully charged, no more useful chemical reactions can occur.

But, if the charger stays connected, power is still being forced in and this energy is converted to heat. Therefore, the cells rise quickly in temperature. Detection of this change at the charging end-point is called  $dT/dt$  (detection), or the change in temperature

over time. The temperature rise is in the order of  $2^{\circ}\text{C}$  per minute.

At the end-point (where the cells are fully charged), charging is normally switched off to prevent the cells overcharging. Some chargers include a top-up charge after the end-point to deliver a lower current to the cells to ensure they are fully charged. After top up, the cells are 'trickle-charged' to maintain their full charge.

The trickle charge can be maintained indefinitely because the cells are safely able to dissipate the small amount of heat generated.

## Charger controller

The Cordless Power Tool Charger Controller uses the tool's existing plugpack and battery charging unit/base. It simply connects in series between the two and therefore can control the charging process (see Fig.2).

Note that because the Charger Controller does not connect directly to the battery pack, it cannot measure the battery voltage. Instead, it utilises  $dT/dt$  detection to stop charging at the end-point.

For this temperature measurement, the charger controller requires that a small NTC (negative temperature coefficient) thermistor is installed within the power tool battery pack, with the two leads brought out to a 3.5mm jack socket.

As a backup, we have included a timer that will switch off charging after

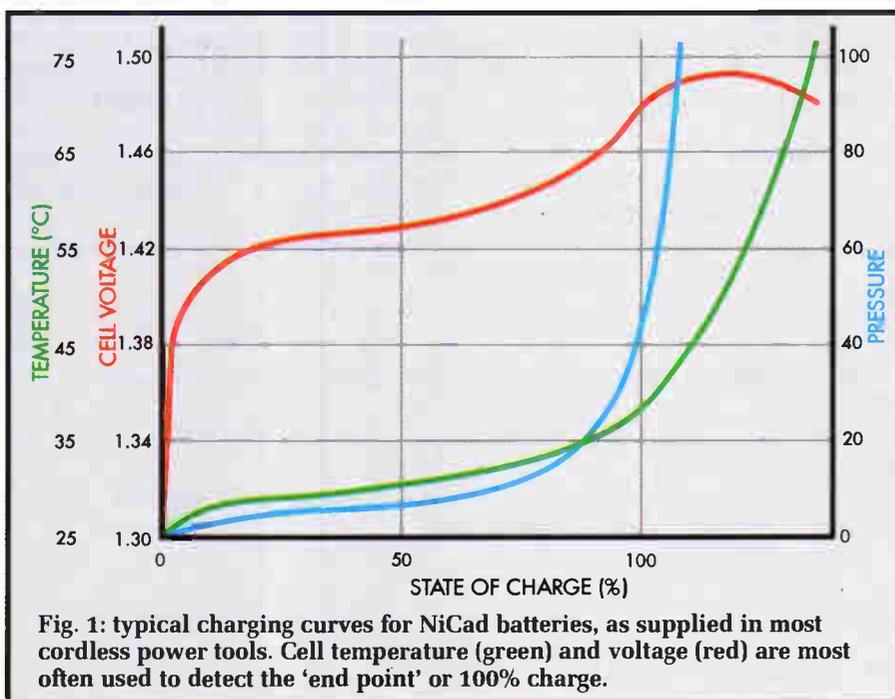
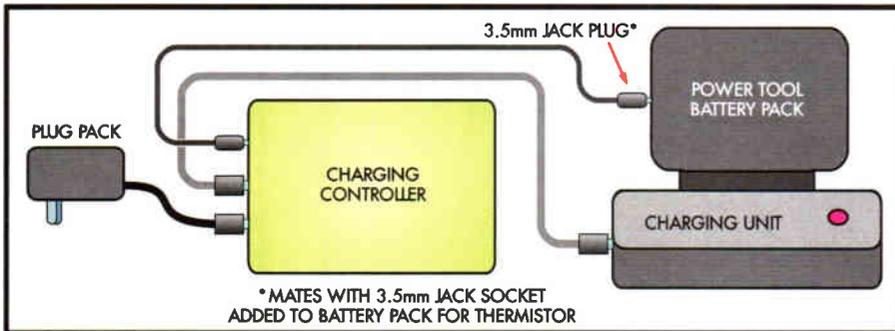


Fig. 1: typical charging curves for NiCad batteries, as supplied in most cordless power tools. Cell temperature (green) and voltage (red) are most often used to detect the 'end point' or 100% charge.

# Constructional Project



**Fig.2: the Cordless Power Tool Charger Controller connects between the original plugpack's low-voltage output and the power tool's charging base. A separate thermistor connection is also required, with the thermistor mounted on one of the new battery cells.**

a preset period should the thermistor end-point detection fail.

## More safeguards

Further safeguards to protect the cells are also included. Charging is initiated with the start switch (S1). However, charging will not start if the NTC thermistor is disconnected or if there is an over-temperature or under-temperature detection. The over-temperature setting is at 70°C, while the under temperature setting is at 0°C.

If the NTC thermistor is connected and the cell temperature is within the 0 to 70°C range, then charging will start. Charging will halt should the temperature fall below 0°C or if the thermistor is disconnected.

Charging will resume when the temperature range is correct or the NTC thermistor is re-connected. However, if the temperature goes over 70°C, full charging will cease and will not automatically resume.

If a 'blackout' (power-cut) occurs during charging, then charging will resume with the return of power. The timeout period will also resume from where charging was interrupted.

Charging will cease at the point where the  $dT/dt$  value is exceeded, or if the timeout period expires. Pressing the start switch will resume charging from the start of the timeout period. You can also stop the charging process at any time by pressing the start switch.

## Reduced charge

In its simplest form, the Charger Controller includes just the features mentioned earlier. However, you can also include top-up and trickle charging if you wish. The top-up feature provides a reduced charge (typically at 400mA) for an hour to ensure full charge is reached after the main charge cycle. The trickle charge (at typically 100mA) continues after the top-up to maintain battery charge.

As mentioned earlier, trickle charging does not generate a lot of heat, so the battery can be left on trickle charge, ready for use at a moment's notice. There's nothing worse than picking up a drill to find that the battery has self-discharged – which they can do!

## Adjustments

Both the timeout period and  $dT/dt$  values are adjustable. Timeout can be

set up to 25 hours, while  $dT/dt$  can be selected between 0.5°C rise per minute to 5°C per minute.

The trickle charge rate must be adjusted if the top-up and trickle charge option is selected. More details concerning the adjustments are included later in the setting-up section.

## Indication

Three LEDs indicate the status of the charger controller: Power, Thermistor and Charging.

The power LED is lit whenever power is applied to the charger controller. The thermistor LED lights whenever the thermistor is disconnected. When connected, the LED will be off unless there is an over-temperature or under-temperature condition. In these cases, the thermistor LED flashes at a 1Hz rate when it measures over temperature and at a 0.5Hz (once every two seconds) rate when it measures under temperature.

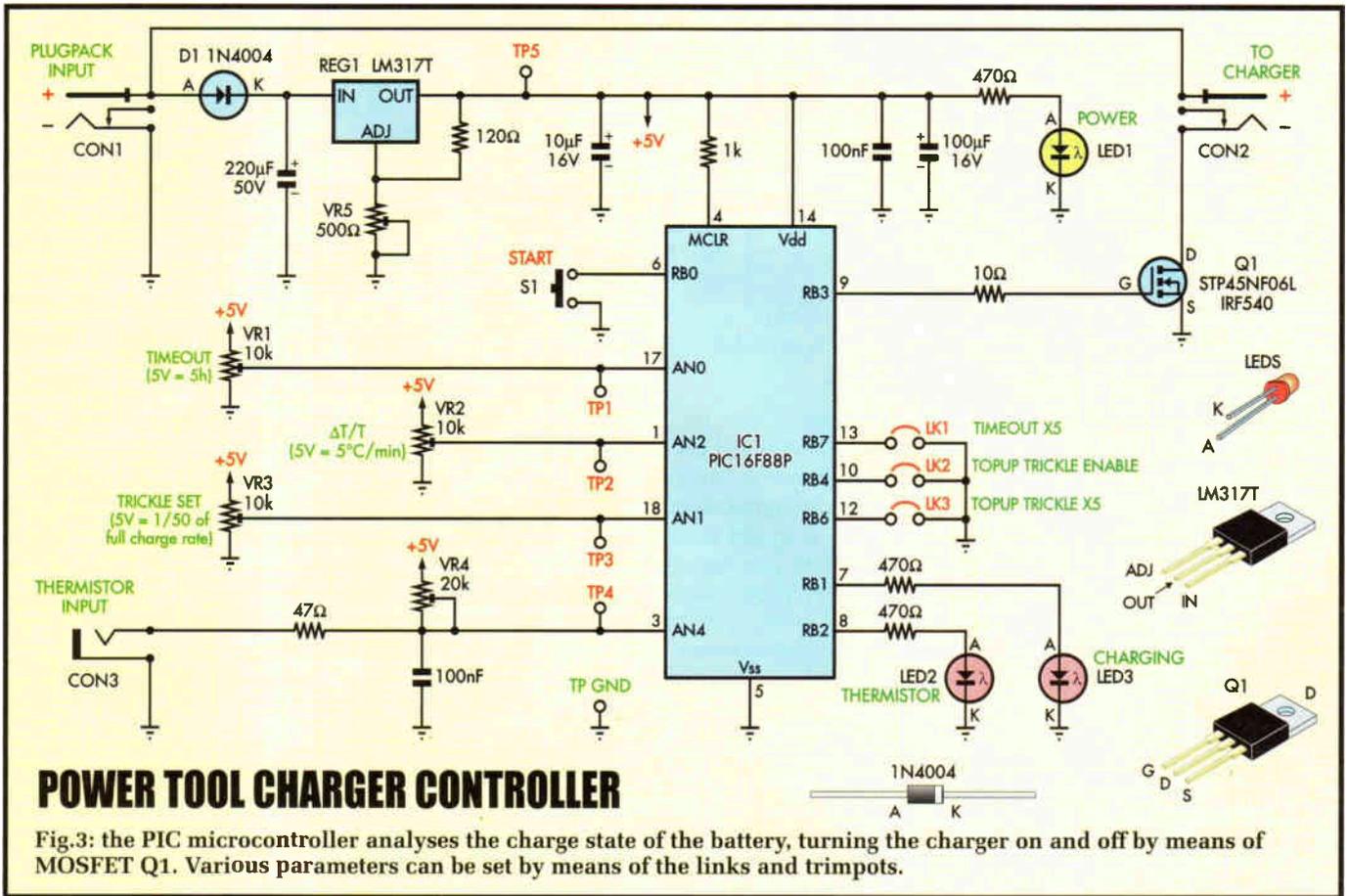
The charging LED is continuously lit during the main charging cycle and switches off when charging is complete. If top-up and trickle charging is selected, the charging LED will flash at a 1Hz rate during top-up charge and will flash at a 0.5Hz rate during trickle charge. When the thermistor LED is lit or flashing, the charging LED will be off.

## How it works

The circuit for the Cordless Power Tool Charger Controller (Fig.3) is based around a PIC16F88 microcontroller. This performs all the logical decisions required to control the charging and runs a software program specifically for this charger controller application. Apart from the PIC, there is not really much else to the circuit.

## Specifications

<b>Maximum Current</b> .....	5A
<b>Timeout adjustment</b> .....	From 0 to 5 hours, corresponding to 0 to 5V from VR1 at TP1. 0 to 25 hours with ×5 link installed (LK1)
<b>dT/dt adjustment</b> .....	From 0.5°C to 5°C rise/minute, corresponding to 0.5V to 5V from VR2 at TP2.
<b>Top up and Trickle Charge</b> .....	Available when LK2 is installed
<b>Trickle Charge adjustment.</b> .....	From 100% to 1/50th of main charge current corresponding to 0 to 5V from VR3 at TP3. 100% to 1/250th with ×5 link installed (LK3)
<b>Top-up charge</b> .....	4 x trickle setting for 1 hour
<b>Top-up and trickle switching rate</b> ..	30Hz.
<b>Over temperature cutout</b> .....	70°C
<b>Under temperature detection</b> .....	0°C
<b>Current consumption</b> .....	20 to 26mA, depending on status LEDs



When the thermistor is plugged into its socket (CON3), it forms a voltage divider in conjunction with trimpot VR4 across the 5V supply. VR4 is set so that the voltage across the thermistor is 2.5V at 25°C.

The voltage across the thermistor is monitored by the PIC's AN4 input (pin 3) via a 47Ω stopper resistor and a 100nF filter capacitor. These are included to remove any RF signals and noise that could be present due to the thermistor being connected remotely from the circuit.

The voltage at the AN4 input is converted into a digital value by the

software and this is compared against the over- and under-temperature values and for dT/dt changes.

Trim pots VR1, VR2 and VR3 set the timeout, dT/dt and trickle charge current respectively. They are each connected across the 5V supply. The wipers (moving contact) of each trimpot connect to one of the PIC's AN0, AN2 or AN1 inputs. The voltages are converted to a digital value within IC1, so that the settings can be processed in software.

Note that the trim pots can be monitored via test points (TP1, TP2 and TP3) using a multimeter.

For example, setting VR1 to give 4V at TP1 will set the timeout to four hours. The timeout value can be multiplied by a factor of five if jumper link LK1 is installed. With LK1 out, pin 13 is pulled to 5V via an internal pull-up resistor within IC1. With LK1 in, pin 13 is tied to ground (0V).

Links LK2 and LK3 work in a similar manner, with LK2 enabling the top-up and trickle charge when inserted. LK3 increases the top-up and trickle current setting by a factor of five when inserted.

Switch S1 is a normally-open push-button type. When open, input RB0

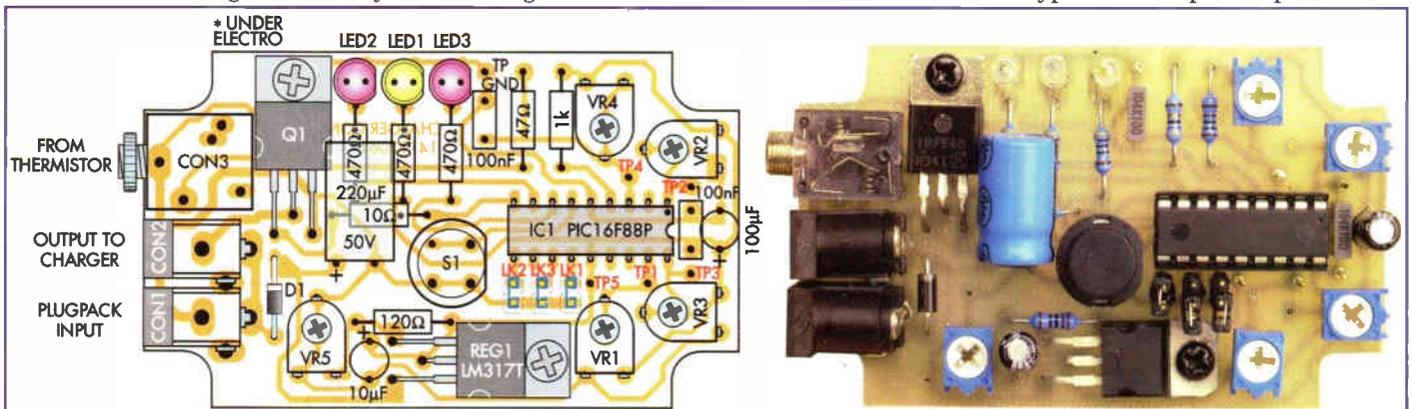
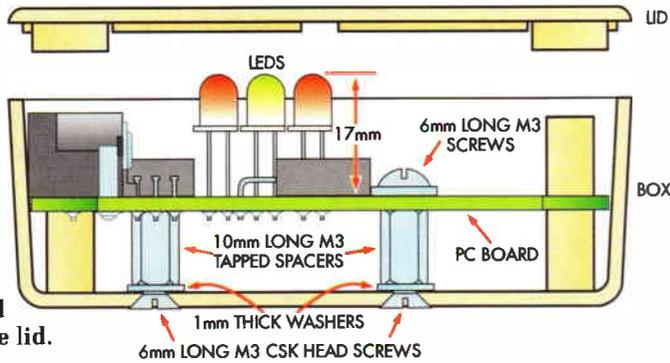


Fig.4: with the exception of the thermistor (which must be installed in the battery pack) everything fits onto one small PC board. The photo at right is reproduced same size to match the component overlay at left.

# Constructional Project

Fig.5: the PC board sits 11mm up from the bottom of the case with the tops of the LEDs 17mm above the board so they just poke through the lid. The 'start' pushbutton switch (not shown here) is below the lid surface, accessed through a hole in the lid.



is pulled high via an internal pull-up resistor. When the switch is pressed, RB0 is taken low (0V) and the charge timing begins its cycle.

The software code provides switch debouncing, mainly to prevent a false initiation of the charge cycle. When RB0 is taken low, there is a short delay before the port is checked again. If it is still low, then the software waits for a further delay and rechecks. If it is still low, the software assumes that the switch has been pressed. If RB0 is at 5V after any of the delay periods, it is assumed that the switch was not pressed.

Outputs RB1 and RB2 drive the charging and thermistor LEDs respectively, via 470Ω resistors. The power LED is driven directly from the 5V supply via its 470Ω resistor.

MOSFET Q1 is driven from IC1's RB3 output via a 10Ω gate resistor. When Q1 is on, the cells can be charged because the negative side of the charger is effectively connected to ground.

During the main charge, RB3 is taken to 5V and Q1 is always switched on. However, during the Top-up and Trickle charge modes, RB3 can provide a PWM (pulse width modulation) signal with a reduced duty cycle, so that MOSFET Q1 is only switched on for a small proportion of the time and hence the average current is reduced. RB3 is pulsed at about 30Hz.

The specified STP45NF06L MOSFET is a logic-level device that is fully switched on with a 5V gate voltage (most standard MOSFETs require around 10V of gate voltage in order to fully switch on). An IRF540 MOSFET could also be used because it switches on fully for gate voltages over 4.5V.

Power for the circuit is taken directly from the original plugpack supply for the charger via diode D1. This provides reverse polarity protection for the following 220μF capacitor and for regulator REG1.

Note that diode D1 does not protect against reverse charging of the battery

– therefore the original charger (ie, as supplied with the cordless tool) should be used.

As shown on Fig.3, the plugpack's output is connected to the plugpack input socket of the Charger Controller and the 'to charger' output socket is connected to the charger base. In this way, power for the Charger Controller is taken from the plugpack. If the connections are reversed, the Charger Controller will still operate, but the battery will be discharged over time because it will be supplying power to the Charger Controller.

## Regulated supply

An LM317T (REG1) is used to supply a regulated 5V supply. This was chosen in preference to a standard 5V regulator for two reasons.

First, this adjustable regulator can be adjusted to supply a precise 5V to make the settings of VR2 and VR3 more accurate. Second, the LM317T can accept a 45V input (when the output is 5V) compared to 35V for a standard 5V regulator.

The extra input voltage that the LM317T can accept may be needed for an 18V battery pack. A high voltage is also specified for the 220μF capacitor at the IN terminal of REG1.

In operation, REG1 has a nominal 1.25V between its OUT and ADJ (adjust) pins. If a 120Ω resistor is connected between these pins then there will be a current flow of about 10.42mA. This current flows into VR5 and will raise the output voltage to 5V when VR5 is set at 360Ω. This is because  $10.42\text{mA} \times 360\Omega = 3.74\text{V}$ . When we add this voltage to our original 1.25V between the OUT and ADJ terminals, we get 5V.

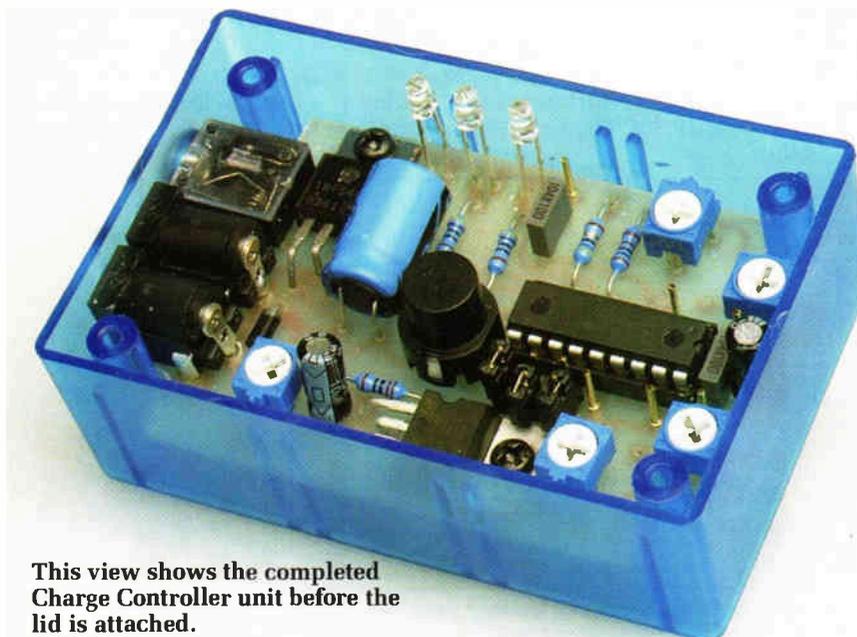
Note that the tolerance of the regulator output to adjust pin voltage is between 1.2V and 1.3V. Also, a nominal 50μA current flows out of the adjust pin and this can affect the output voltage. These factors can be trimmed out with VR5 to set the output to precisely 5.00V.

## Software

The software files are available for free download via the EPE Downloads site, access via [www.epemag.co.uk](http://www.epemag.co.uk). Pre-programmed PICs are available from Magenta Electronics – see their advert in this issue for contact details

## Construction

The Power Tool Charger Controller is built on a PC board, measuring just 78



This view shows the completed Charge Controller unit before the lid is attached.

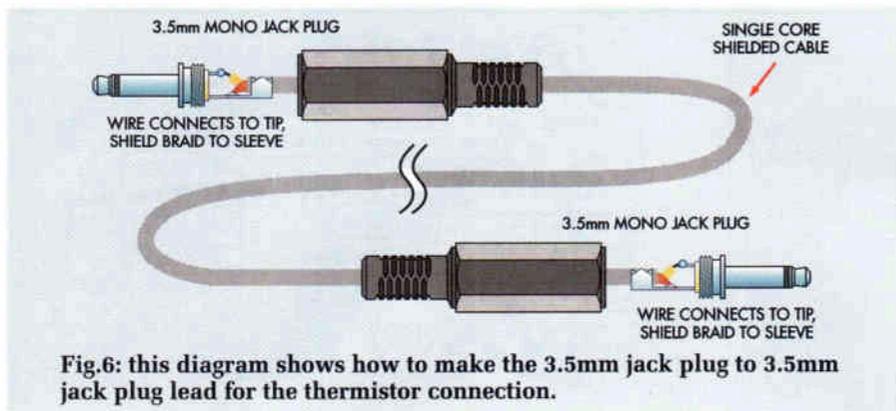


Fig.6: this diagram shows how to make the 3.5mm jack plug to 3.5mm jack plug lead for the thermistor connection.

× 46mm. This board is available from the *EPE PCB Service*, code 686.

The topside component layout is shown in Fig.4. A full-size copper foil master pattern is given in Fig.8.

Begin construction by checking the PC board for any defects such as shorted tracks, breaks in the copper and incorrect hole sizes. Enlarge the holes for the DC sockets and the 3.5mm jack socket if necessary.

Install the resistors first. You can, if you wish, use a digital multimeter to check each resistor before inserting it into the PC board. Solder each lead and cut the leads short against the underside of the PC board.

Now solder in the diode and IC socket, taking care to orient them with the correct polarity. (Do not insert the PIC at this stage). The capacitors can go in next. Note that the electrolytic types must be oriented with the polarity as shown. The large 220µF capacitor needs to be mounted on its side (see photo) so that the assembled board will fit inside the box.

LEDs 1 to 3 need to be mounted so that the tops of each LED is 17mm above the surface of the PC board. Orient each LED with its anode (longer lead) towards the left of the PC board. LED1 is green while LED2 and LED3 are both red.

Switch S1 must mount with its flat side towards IC1. When placing the trimpots, make sure the correct values are in each position. The link headers can also be installed for LK1, LK2 and LK3.

Voltage regulator REG1 and MOSFET Q1 are installed so that they lie flat on the PC board, with their leads bent down by 90° so that they go through their matching holes. During installation in the box, they are secured to the PC board with an M3 screw. Finally, install the DC power sockets and the 3.5mm jack socket.

## Installing it in a case

The completed PC board is housed in a small translucent plastic case measuring 83 × 54 × 31mm.

The first job is to drill a hole for the 3.5mm jack socket. That done, clip the PC board into the integral side pillars of the box and mark out the positions for the screw holes in the base of the case for the Q1 and REG1 mounting supports – see Fig.5. Drill these holes to 3mm diameter and countersink the holes on the underside of the box.

Next, install the two 10mm tapped standoffs and the 1mm spacers as shown in Fig.5 and secure the PC board in place. You can then mark out the positions for the DC socket holes in the side of the box and for the three LED holes and switch S1 in the box lid. Drill these holes out. The switch surface will be slightly below the panel lid, so its hole will need to be large enough for your finger to reach in and push.

## Setup

Initially, leave IC1 out of its socket. Apply power from the plugpack to the DC input socket (positive to the centre of the plug) and check that the power LED lights. If it does, connect a multimeter between TP5 and TP GND and adjust VR5 for a reading of 5.0V.

Now check that there is 5V between pin 14 and pin 5 of IC1's socket. If this is correct, switch off and install IC1.

## Adjustments

Trimpot VR4 is adjusted so that the voltage between TP4 and TP GND is 2.5V when the thermistor is at 25°C. Alternatively, set the trimpot for 2.2V at 30°C or 2.8V at 20°C.

Both the timeout and dT/dt values are adjustable and these are changed using

## Parts List – Power Tool Charger Controller

- 1 PC board, code 686, available from the *EPE PCB Service*, size 78 × 46mm
- 1 plastic utility box, size 83 × 54 × 31mm
- 1 momentary pushbutton PC mounting switch (S1)
- 1 3.5mm PC-mount stereo jack socket
- 1 3.5mm panel mount mono jack socket (installed within power tool for the NTC thermistor)
- 2 3.5mm mono line jack plugs
- 2 2.5mm DC line plugs
- 2 2.5mm DC power sockets, PC mounting, CON1,2
- 1 18-pin IC socket
- 1 3-way DIL header
- 3 jumper shunts
- 1 NTC thermistor, 10kΩ @ 25°C (installed in battery pack)
- 2 10mm M3 tapped brass spacers
- 2 5mm M3 countersunk screws
- 2 M3 screws
- 2 1mm spacers (washers)
- 1 1m length of single-core shielded cable
- 1 1m light-duty figure-8 cable

### Semiconductors

- 1 PIC16F88P microcontroller (IC1), programmed with CHRGCONT.ASM
- 1 STP45NF06L logic-level MOSFET (or IRF540 – see text) (Q1)
- 1 LM317T 1.5A adjustable voltage regulator (REG1)
- 2 3mm red LEDs (LED2, LED3)
- 1 3mm green LED (LED1)
- 1 1N4004 1A diode (D1)

### Capacitors

- 1 220µF 50V PC electrolytic
- 1 100µF 16V PC electrolytic
- 1 10µF 16V PC electrolytic
- 2 100nF MKT polyester (0.1µF)

### Resistors (0.25W, 1%)

- 1 1kΩ      3 470Ω      1 120Ω
- 1 47Ω      1 10Ω
- 1 500Ω trimpot, horizontal (VR5)
- 3 10kΩ trimpots, horizontal (VR1 to VR3)
- 1 20kΩ trimpot, horizontal (VR4)

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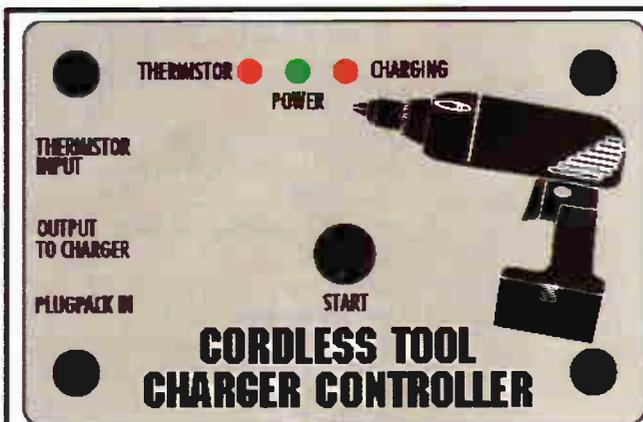


Fig. 7: this is the full-size artwork for the front panel label. It can be cut out and attached to the case lid.

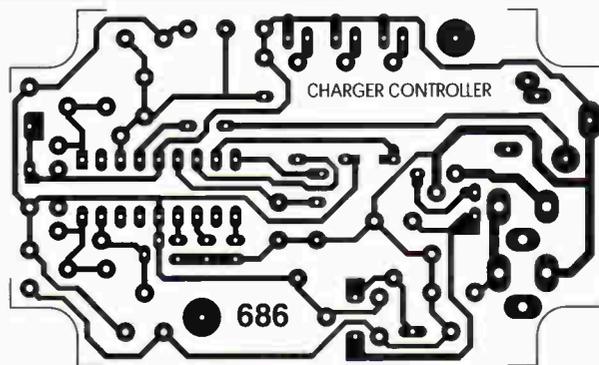


Fig. 8: Full-size PC board, copper master.

trimpots VR1 and VR2. Test points have been included to allow easy measurement of these trimpot settings.

The timeout is easily set anywhere from 0-25 hours. In its simplest arrangement, the voltage at TP1 gives the timeout in hours. So, for example, if VR1 is set to provide 5V at TP1, then the timeout is five hours.

If you need a timeout longer than this, install LK1. This link acts as a  $\times 5$  multiplier. So, for example, with LK1 installed and with VR1 set so that TP1 is at 5V, the timeout will be 25 hours.

Similarly, if TP1 is 1.2V then the timeout will be six hours ( $5 \times 1.2$ ). Most chargers that come with battery-powered tools will state the required charge time.

Temperature rise detection ( $dT/dt$ ) can be adjusted from between  $0.5^\circ\text{C}$  per minute to  $5^\circ\text{C}$  per minute. This is adjusted using VR2 and by measuring at TP2. The negative connection of your multimeter connects to TP GND.

There is a direct correlation between the voltage and the setting. So, for example, a setting of 2.5V at TP2 will set the  $dT/dt$  value to a  $2.5^\circ\text{C}$  per minute rise. Initially, set VR2 so that the voltage at TP2 is 2.5V.

## Charging options

Top-up and trickle charge is enabled by installing link LK2. If this option is selected you will need to set the trickle charge rate. The top-up charge is fixed at four times the trickle charge. The trickle charge is set using VR3 and link LK3. If LK3 is not installed, then VR3 allows the trickle charge to be set from unity to  $1/50$  of the main charge current.

With link LK3 installed, the ratio is multiplied by a factor of 5. The trickle charge requirement is calculated by

## USING THIS CONTROLLER

(1) This controller can be used with a NiMH or NiCad battery pack of up to 15 cells (18V).

(2) The minimum rated voltage battery pack that the unit can control is 6V (five cells).

(3) This controller **MUST NOT** be used to control the 230VAC input to any drill charger. It must only be used to control low-voltage circuits.

dividing the amp/hour rating of the cells by 20. If the cells are 2400mAh, then the trickle current should be 120mA.

To set VR3 you need to know the charge current of your charger. This is usually quoted on the charger. It can also be measured with a multimeter connected in line between the plugpack and charger when the battery pack is charging. Trimpot VR3 (and link LK3) provide the division ratio required to reduce the charge current down to the trickle value.

For example, if the main charge current is 3A and we want a 120mA trickle charge, the division required is  $3/0.12$  or 25. So VR3 should be set to 2.5V. If a ratio of more than 50 is required, link LK3 can be installed to allow the value to be increased by five to a maximum of 250.

## Connection

As shown in Fig. 2, the Cordless Power Tool Charger Controller simply connects in-line between the charger's plugpack and the charging base. This means that the plugpack supplied with the cordless tool connects directly to the charger controller.

A separate lead connects between the charger controller and the original charger. You will need to make up this lead using a length of 2-way wire (figure-8 wire) and two DC plugs. Similarly, you will need a 3.5mm jack plug to 3.5mm jack plug lead for the thermistor connection. Fig. 6 shows how to do this for the 3.5mm jack lead.

The power tool must have a battery pack that has the specified thermistor installed and a 3.5mm jack socket added to the battery pack for connection to the Power Tool Charger Controller. Note that some battery packs have a thermistor already installed. This should be replaced because it may not have the same resistance characteristics as the one we specify.

It may also connect the negative side of the battery pack to one side of the NTC thermistor. Our circuit requires an isolated thermistor connection to avoid bypassing the MOSFET Q1.

Firstly, remove enough insulating covering on one cell so that the specified thermistor can make intimate contact with the cell wall. Mount the thermistor on the cell, it can be glued in position using a dab of super glue.

## Setting up

Depending on settings, the charger may stop before full charge or it may tend to overcharge the batteries.

Undercharge will be evident if the charging period appears to be too short and the power tool does not run for the usual period before recharging is required. In this case, turn VR2 further clockwise to increase the  $dT/dt$  value. Alternatively, if the battery pack appears to get hot after full charge has been reached, adjust VR2 anticlockwise for a lower  $dT/dt$  value. **EPE**



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# Light fantastic

**Did the title make you think of LEDs? Not a bad guess. In fact, however, we're tripping the light fantastic (dancing the night away) and if that leaves you confused, please read on. Mark Nelson elucidates.**

**E**ven if we're not supposed to consider our profession/pastime/hobby as 'playing', I don't think it makes us bad people to admit a sneaking jealousy of the fun that youngsters enjoy. So when I see the sparkly red lights of some children's footwear I have to suppress a pang of envy, wondering why we couldn't have had exciting shoes that flickered red every time we walked.

The answer's simple: LEDs had not been invented. So that's the end of this train of thought – or is it?

## Blood trackers

Actually it's not. Generating electricity from people's footfall is a truly fascinating prospect, not just for the notion of free power, but also the challenge to electronicists to make it truly happen. We'll examine this and other novel sources of free energy in a moment, but before we forget the flashing footwear, let me just point you to a website called <http://yesled.com/>.

This enterprising firm has assembled a host of LED-based products for your car and household, including 'aftermarket' flashers to attach to your shoes (recommended for horse riders), ultra-violet flashlamps for checking electrical insulation among other things, and all manner of LED clusters to substitute for normal bulbs in your car (in ten different colours or mixed/changing). There are even blood-tracking flashlights designed for hunters to brightly illuminate red blood trails while tracking (police officers might find them useful too). No, this is not a commercial, just a random find on the Internet that might help you enjoy wasting five minutes.

Retrofit LED lights for cars are hardly new, but until recently few vehicles had LED headlights fitted from new. One of the first to have these is the Cadillac *Escalade Platinum*, a gas guzzler SUV with a 6.2-litre V8 engine. In automotive applications the dominant factor is not cost but power efficiency, especially with the move towards hybrid and all-electric vehicles. In terms of electrical load, headlights are second only to heating, air-conditioning and ventilation, and if you factor in side and rear lights plus interior lighting, it's obvious that high-brightness LEDs win hands-down over incandescent bulbs.

## Spin-off

Just before we leave the subject of LED lighting, a recent interview in trade paper *Electronic Engineering Times Europe* gave an interesting update on the status of LED lighting in the home. Lemnis is a spin-off

of Philips and whereas Philips made its first fortunes from producing incandescent lamp bulbs, Lemnis hopes to do the same with LED lighting, basing its sales pitch on affordability and 'no toxic waste'. But how affordable is the LED lamp bulb right now?

Joint founder Frank Otten told the publication, 'Where you have a 40W bulb now, you can use an LED bulb.' Right now this lamp sells for just under £20, with the advantage that it will not need replacing for 30 years or after 50,000 hours use, whichever comes first. It's certain that this price will fall to truly affordable levels within four years, so there's no need to rush out to buy them yet. Incidentally, Lemnis is also involved in a pilot LED street lighting trial in London.

## Stepping out to save the world

Back to the plot. How can tripping the light fantastic save the planet? Dr. Earth has a manifesto for the salvation of planet Earth and its inhabitants, which was launched in July at Club4Climate headquarters at Bar Surya in London's King's Cross. Party power is the answer, using a sprung dance floor resting on blocks made of piezoelectric crystals. These generate electricity (OK, a minute amount) when subjected to pressure.

The club's owner, Andrew Charalambous, claims that harnessing the pounding of clubbers' feet could generate 60 per cent of the building's energy requirement. A similar system is in use at Rotterdam's Sustainable Dance Club, while a gym in Seattle is trying to capture the excess energy of customers working out in the same way.

## Military fatigues

Not convinced by pico-power? There are other forms of kinetic energy that are looking increasingly promising, particularly as a way to create small amounts of energy for individual devices. Heel strike generators are a promising example, embedded within a boot or shoe heel and actuated by the constant up-down motion of a footstep. Currently (no pun!) they can achieve up to 6W of power output. The technique has a military origin, funded chiefly by the Defense Advanced Research Projects Agency (DARPA) in the United States. The trigger was the need to reduce the capacity, and hence weight, of the rechargeable batteries carried by soldiers for essential communication devices.

Similar generators embedded in buildings have potentially vast civilian applications too, and news website *Inhabitat* reports on a story carried by several papers in June concerning a proposal from David Webb

of consultancy Scott Wilson. He speaks of installing miniature 'heel-strike generators' in public places with a heavy footfall and calculates that the 34,000 passengers passing through London's Victoria station every hour could generate enough energy to light 6,500 light bulbs. "We can do something useful with that energy," he says.

The Scott Wilson consultancy is in talks with Network Rail to develop the idea and the idea is equally applicable to large stores, street pavements and other public places. Another 'captive audience' is at the 170m (560ft) Spinnaker Tower viewing platform in Portsmouth, where he plans to collect the energy of every person walking up and down the stairs. Ultimately Webb would like to install them in every public place.

## More people power

Another devotee of harvesting people power is Claire Price, director of the Facility architecture practice in Bermondsey, south London. "One day when you use a staircase at a tube station, it might be a step towards saving the planet," she says, adding that capturing environmental energy that would otherwise be wasted could save \$200 billion a year in the United States alone.

Her firm claims years of experience in environmental architecture, including an entire building created from recycled materials and a school that doesn't require heating. Sister company Facility:Innovate develops devices to convert the mechanical movement associated with footsteps or transport vibration into electricity.

Applications for these free energy techniques include powering traffic lights through the vibrations produced from passing traffic, feeding the floodlights of Wembley from spectators climbing the stadium staircases and driving the plasma screens at the local gym while people exercise.

If the applications sound a bit 'pie in the sky', then the consultancy's technologies are closer to *terra firma*. For harvesting power from footsteps they use a flooring system that incorporates a matrix of hydraulic compression cushions. The energy harvested from every footstep pushes fluid through a micro-turbine, generating power that is stored in a super-capacitor. This electricity is then utilised locally. To harvest power from vibrations they use a magnetic beam and coil arrangement to power light fittings. The beam resonates in tune with ambient transport vibration within the generating coil. This electricity is then used to power LED emitters within the self-contained units.

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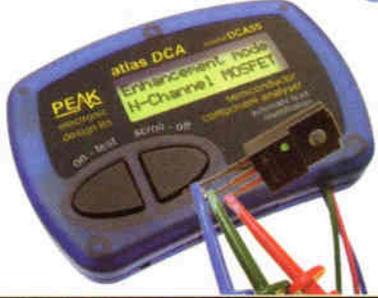
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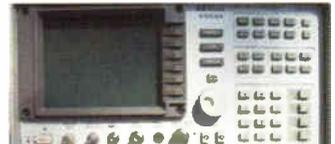
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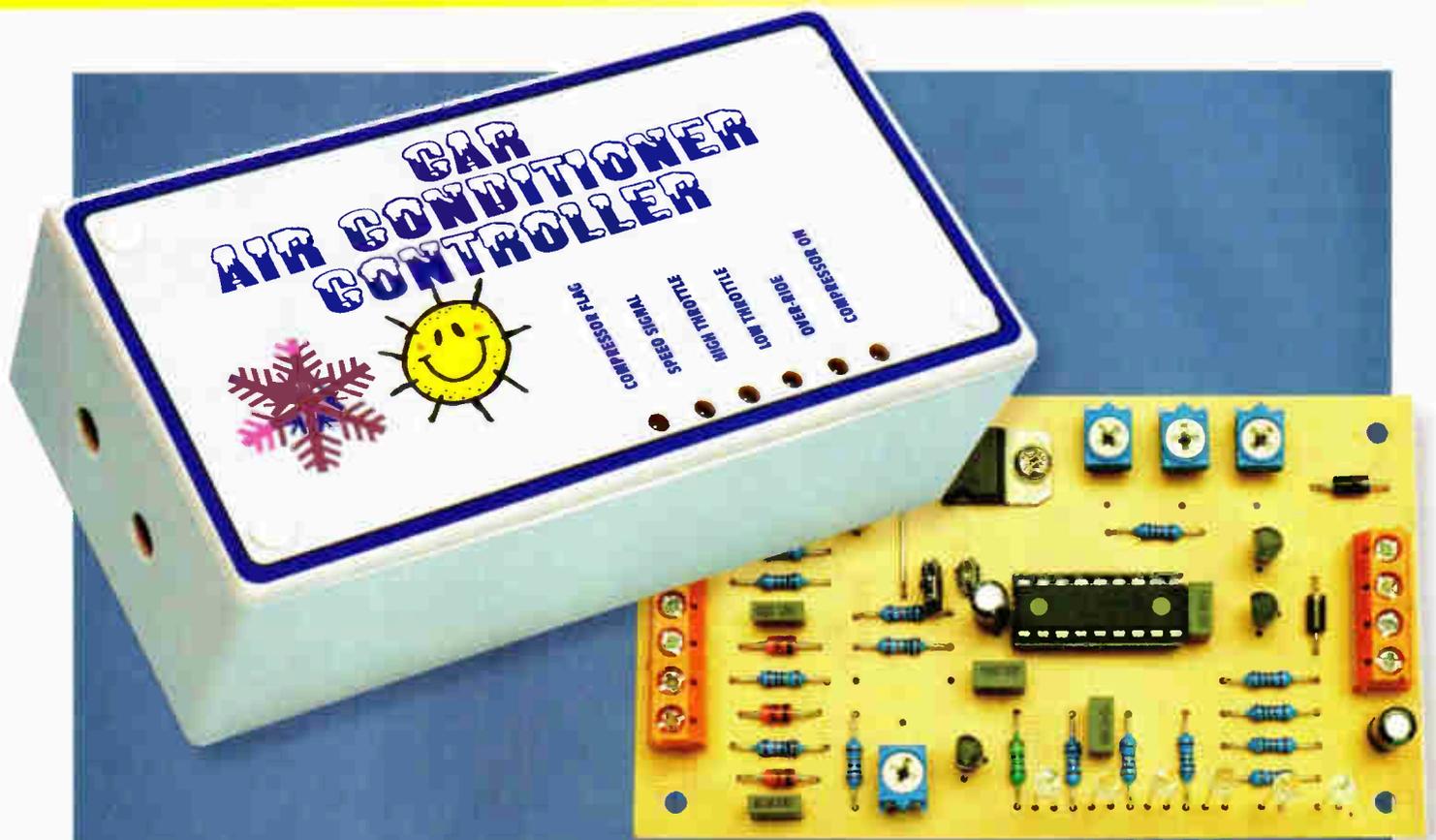
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# Intelligent Car Air-Conditioner Controller

This simple device stops the air-conditioner in your car from sapping engine power when going up hills or during overtaking, while still maintaining comfortable temperature levels inside the cabin. It's based on a PIC microcontroller and is easy to build.

By **JOHN CLARKE**

**D**URING hot summer periods, your car's air-conditioner works quite hard to keep cabin temperatures cool. As a result, fuel consumption increases due to the extra load imposed on the engine by the air-conditioning system – or more specifically, by its compressor.

But that's not all – the extra load imposed on the engine by the compressor is readily noticed when travelling up hills, particularly in smaller four-cylinder cars.

In order to get around this problem, many drivers manually switch off the air-conditioner to ensure extra power during hill climbing or when overtaking. It's almost like giving the car a mini 'turbo boost'. On some new cars, this can even happen automatically. These cars have a 'wide open throttle' (WOT) cutout relay and this automatically switches off the air-conditioner's compressor during high throttle conditions.

If you wanted to maximise engine performance, you would only turn the air-conditioner on when going down hills or when slowing down. That way, the air-conditioner compressor could be used as a brake that converts the energy into cooling the cabin rather than being wasted as heat in the brakes or via engine braking.

In practice, of course, it's quite impractical for the driver to continually switch the air-conditioner on and off. In any case, the compressor would also have to run for at least some of the time on a relatively flat road in order to keep the cabin temperature at a comfortable level on very hot days.

## Doing it electronically

But what if the switching could be done electronically? Well, that's just what this clever little circuit does.

Based on a microcontroller, it's connected to various sensors in your car and automatically switches the air-conditioner off when the car is accelerating or going up hill. It then allows it to switch on again (if needed) when the car is slowing down or going down hill, or when the engine is only lightly loaded (eg, when travelling on the 'flat').

The concept is really quite simple. The circuit overrides the existing air-conditioner control system to turn the compressor off when the engine is heavily loaded. It then allows the air-conditioner to operate normally

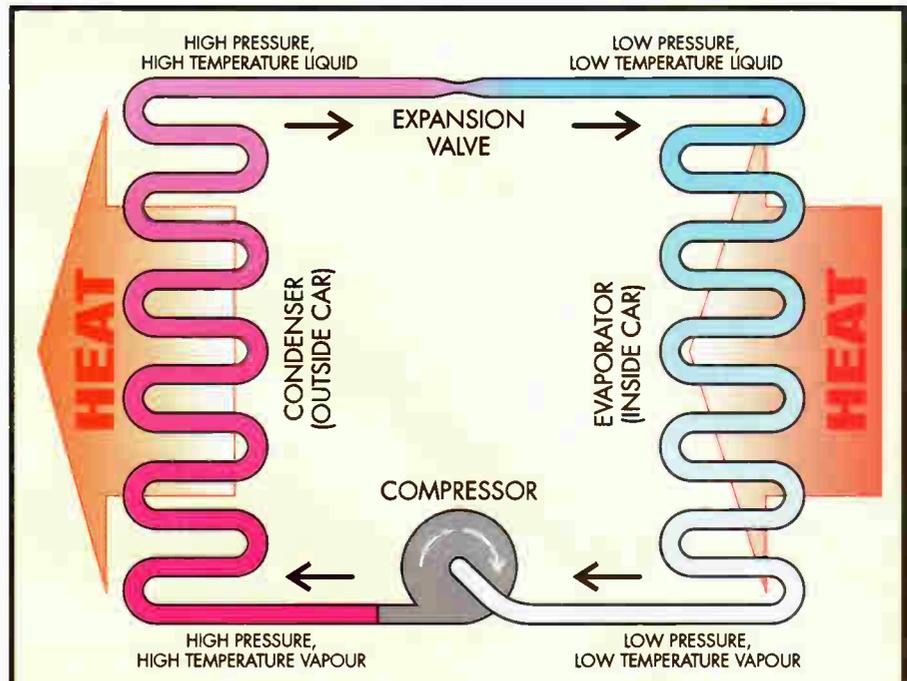


Fig.1: the basic elements in a car air-conditioning system.

## How an air-conditioner works

Fig.1 shows the basic elements of the air-conditioning cycle. The system comprises condenser and evaporator coils, a compressor and an expansion valve. In operation, the compressor compresses the refrigerant gas. This causes the gas to become hot and it is then passed through the condenser (essentially a large radiator) to cool.

In the process of giving up heat, the refrigerant becomes a liquid (ie, it condenses). This liquid is then passed through an expansion valve and this causes the liquid to expand into a low-pressure gas, significantly cooling it in the process.

Following the expansion valve, the low-pressure refrigerant is passed through the evaporator coil. Any air that passes over this coil will be cooled, due to heat absorption by the cold evaporator.

This cooling process also reduces the air's capacity to hold moisture and so this condenses to form moisture on the evaporator coil. As a result, the air is also dehumidified.

Lower air humidity allows the human body's cooling system to work more efficiently by allowing water evaporation from the skin to occur more readily. Along with the lowered air temperature, this reduced humidity gives an additional cooling benefit.

when engine loads are light. In addition, the system can be set up to switch off the compressor when the vehicle is stationary (engine idling).

## In control

That's the basic concept, but in practice there's a lot more control 'intelligence' built into the system as we shall see. In theory, this improved control should also reduce fuel consumption. However, we have not done any tests to confirm this.

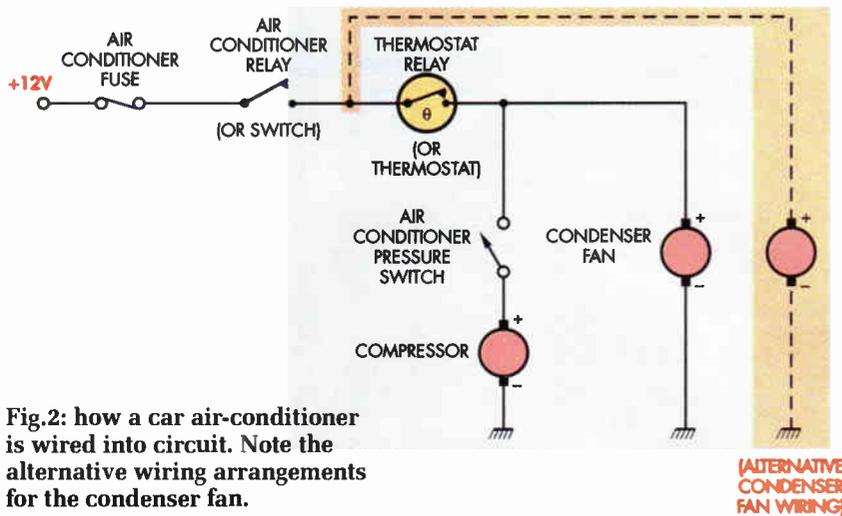
In order to understand how we can improve the operation of the air-con-

ditioner, let's take a look at how we control it. If you are not sure how air-conditioning works, refer to the above panel entitled 'How an air-conditioner works'.

## Temperature control

Most older air-conditioners control the cabin temperature using a thermostat located in the cabin. This simply switches the compressor on or off, depending on the temperature.

By contrast, modern climate control systems are much more complex in their operation. They generally use a



**Fig.2: how a car air-conditioner is wired into circuit. Note the alternative wiring arrangements for the condenser fan.**

thermistor to monitor temperature. Its output is fed to an electronic control circuit, which then acts to direct air (via vents) over the evaporator, controls the air-flow speed, maintains humidity levels and controls the compressor.

Our controller works with both types of air-conditioner systems.

## Override control

One possible drawback to our controller is that the cabin temperature could rise uncomfortably high during extended hill climbs. As a result, we've included an optional override switch. By pressing this switch, the controller is disabled for a preset period, so that the air-conditioner operates normally. This preset period can be set anywhere from 2 to 10 minutes, with each switch press giving a two-minute increment.

In addition, the unit can (optionally) be set so that the compressor comes on for longer that it normally would during deceleration. In other words, the cabin is cooled more than normal. The idea here is that the compressor won't

have to come on as much as usual on level stretches of road.

Of course, this extended cool-down period also causes wider than normal temperature fluctuations in the cabin temperature, although this can be adjusted to suit individual preferences. Alternatively, you can dispense with this feature altogether, depending on the settings chosen during the set-up procedure.

## Three operating modes

The firmware allows the user to select one of three different operating modes when setting up the Air-Conditioner Controller; these are:

- (1) **Full mode** – this includes the high-throttle compressor switch off, the low-throttle extended cool-down period (compressor on) and compressor switch-off when the engine is idling.
- (2) **Medium mode** – this is the same as the full mode, but does not include compressor switch-off when the vehicle is stationary. This mode does not require a speed signal to be connected.

- (3) **Low feature mode** – used if you only want the controller to provide high-throttle compressor switch off.

## Inputs monitored

In operation, the Intelligent Air-Conditioner Controller monitors the car's throttle position sensor in order to gauge engine load. In addition, there's a speed signal input, a compressor 'flag' input and the above-mentioned override switch input.

The speed signal input applies mainly to city driving conditions, where vehicles invariably spend a lot of time sitting at traffic lights, or in traffic jams. This input (derived from the speedometer signal) allows the controller to automatically switch off the compressor when the vehicle is stationary.

Alternatively, if most of your driving is in the country, you may not wish to use this feature, since the engine won't spend much time idling. In that case, it's simply a matter of leaving the speed input disconnected.

## Compressor flag input

The compressor flag signal is normally used to directly drive the compressor. It goes high (+12V) to turn the compressor on when the cabin requires cooling and low (0V) when the temperature setting is reached.

In this application, however, the compressor flag is used as an input. Its job is to indicate to the controller whether the compressor would normally be on or off. Basically, the controller intercepts the compressor signal and processes this along with the other inputs. It then switches the compressor on and off via an external relay.

Fig.2 shows how the compressor is normally wired, while Fig.3 shows the wiring with the Air-Conditioner Controller installed.

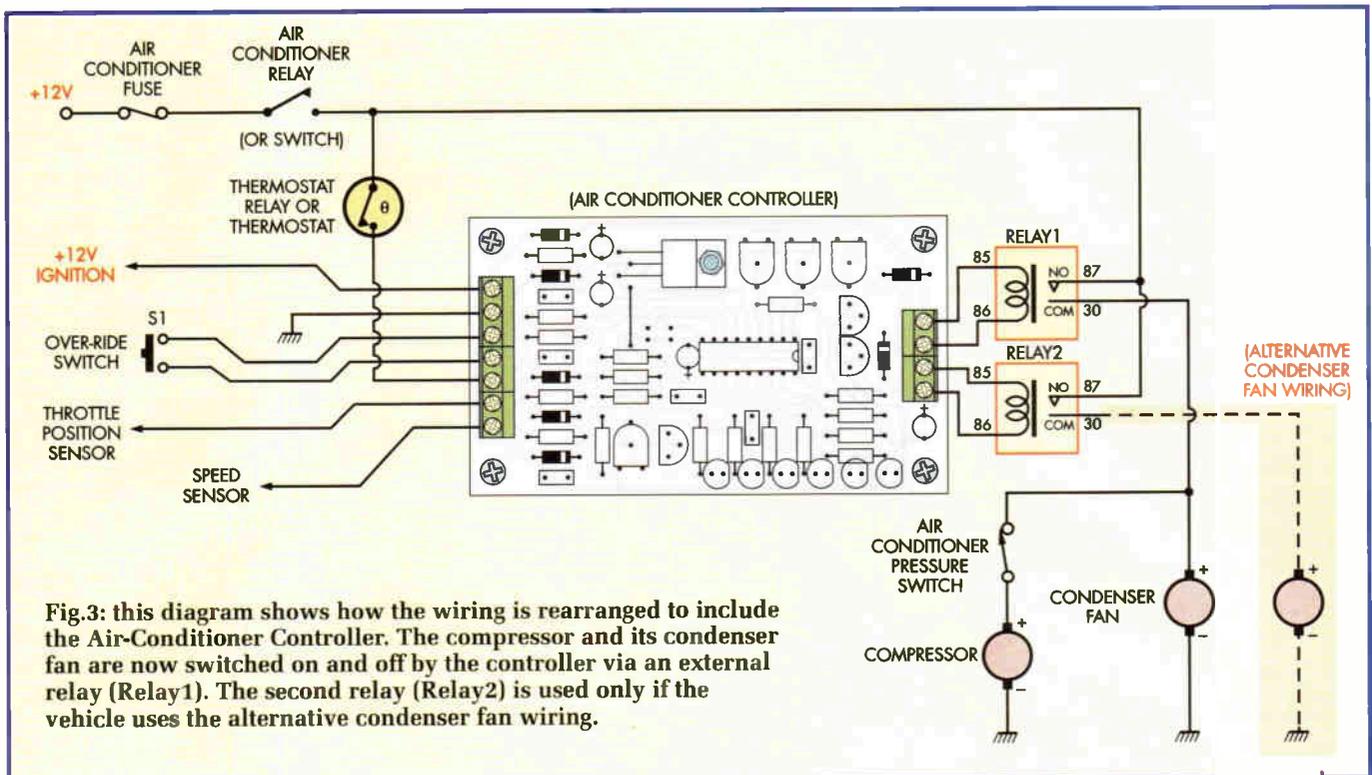
## Logging the flag signal

In operation, the on/off duty cycle of the flag signal is logged by the controller. This is done so that it can determine the necessary extra compressor turn-on period during deceleration and braking. The flag signal isn't logged continuously though, as this would give an erroneous indication of the overall duty cycle. Let's take a closer look at this.

First, the flag signal isn't logged if it goes high during high engine load

## Main Features

- Automatically switches compressor off when car is accelerating or travelling up hill (high throttle)
- Compressor may run with low throttle even when the cabin temperature setting has been reached
- Automatically switches compressor off when car is stationary
- Standard compressor operation with normal throttle position
- Override switch
- Optional speed signal input
- LED indicators for main functions



conditions. That's because the controller will have disabled the compressor and this in turn can cause the flag signal to go high (in a vain attempt to turn the compressor on) for much longer periods than normal. As a result, the duty cycle would be quite unrealistic if it was to be measured.

Conversely, we do log the flag signal when it is low during high engine load conditions, since it is no longer affected by the actions of the controller.

That's not the end of it. Again, for low-throttle positions, the flag signal is not logged if it is low and the compressor is running, as the controller is again effectively overriding the flag signal. Similarly, there's no logging when the engine is idling and the compressor flag is high, because the controller prevents the compressor from running.

Basically, logging only takes place when the controller is not overriding the flag signal and the air-conditioner is operating 'normally'. If there is an intervention one way or other by the controller, the logging ceases.

Any logging that does take place, only begins after the compressor flag signal goes low and then high again, indicating the start of normal thermostatic control by the air-conditioning system. Any logging before then (ie, immediately after the air-conditioner

has been turned on) would again give a false result.

In operation, the compressor flag signal is actively logged over a period that can be set from 1 to 16 minutes. This logging time excludes those periods when logging is paused. The extended cool-down function only becomes fully operational when there is a satisfactory log of the flag signal for processing by the PIC microcontroller (IC1).

The default length of the extended cool-down period is set by the multiplier adjustment.

### Other settings

Apart from the multiplier adjustment, there are three other main settings: the adaptation setting, the logging period and the retrigger period.

The adaptation setting modifies the length of the cool-down period according to the driving pattern. At its minimum setting, the extended cool-down period is the same each time it is activated. By contrast, at higher settings, the extended cool-down period is progressively reduced according to the number of times the vehicle slows down (or decelerates) in a given time period.

The idea here is that we can afford to reduce the length of the extended cool-down periods if they are occurring quite frequently.

The logging period can be set anywhere between 64 seconds to 16 minutes in 64s steps. However, the total number of samples in the whole logging period is always 128.

Generally, a 4 to 5 minute logging period will be suitable (ie, the compressor flag will be sampled approximately every 2.5s). However, if the compressor normally switches on and off at a fast rate, it may be necessary to use a shorter logging period to correctly sample the compressor flag signal.

Finally, the retrigger setting sets the minimum delay between switching the compressor off and then on again (and vice versa). It only comes into effect during high-throttle switching (compressor off), low-throttle cool-down switching (compressor on) and idle switching (compressor off).

Basically, the retrigger period functions as a timer to prevent the compressor from being switched on and off at a rapid rate. It can be set anywhere from 0 to 15s, although a 2 to 3s setting will generally be suitable.

The retrigger setting does not affect the time taken to switch the compressor off under high throttle settings. It is also disabled when the compressor is behaving normally in response to the flag signal, since it will be operating within the manufacturer's specifications.

## Specifications

- Compressor monitor period: adjustable in 64-second steps from 64s to 16 minutes.
- Compressor sampling period: selected with monitor period from 0.5 to 7.5s
- Multiplier effect: adjustable in 0.8% steps from x1 to x2
- Adaptation adjustment: from standard to full in 16 steps
- Throttle input range: 0 to 5V with R1 out; 0 to 14.8V with R1 in
- Low throttle adjustment: 0 to 5V, or 0 to 14.8V
- High throttle adjustment: 0 to 5V, or 0 to 14.8V
- Compressor retrigger period: adjustable in 1s steps from 0 to 15s (with 0.5s uncertainty)
- Compressor flag input: 0 to 15V.
- Speed signal input sensitivity: 1.2V (VR4 fully clockwise) to 3V (VR4 at two thirds anticlockwise).
- Override period: adjustable from 2 to 10 minutes with two minute increments per switch press.
- Current consumption: 200mA with all LEDs lit and compressor relay on

### Condenser fan drive

As shown in Fig.2, car air-conditioning systems run an electrically operated condenser fan to help transfer heat from the condenser to the ambient air. This fan can be wired so that it either runs only when the compressor is on or so that it runs permanently whenever the air-conditioner is turned on, regardless of whether or not the compressor is running.

The controller caters for both types of fan wiring. In the first case, the condenser fan is left connected across the compressor and both are controlled via the same output from the controller.

In the second case, the fan is driven via a separate controller output (and external relay). This is done because the controller may run the compressor once more after the air-conditioner has been switched off to implement the extended cool-down function.

### Circuit details

The full circuit diagram for the Intelligent Car Air-Conditioner Controller is shown in Fig.4. Its operation may sound complicated (thanks to the software options) but the circuit itself is really very simple.

PIC microcontroller (IC1) is the heart of the circuit. This accepts the various input signals, runs the software program to perform the various functions and drives the relays and several LED indicators. The software is quite

involved, with about 1500 lines of code. Much of the programmed code provides the decision logic for the extended cool-down feature.

In its basic form, IC1 is programmed to monitor inputs from the speedometer signal, the throttle position sensor and the compressor flag signal. It processes these inputs and drives the compressor (via Relay1) according to the software logic.

In addition, there are inputs from trimpots VR1 to VR3 and the override switch (S1), with further options provided by links LK1 and LK2 – see Tables 3 and 4.

The main outputs from IC1 appear at RA0 and RA1 (pins 17 and 18) and these drive NPN transistors Q2 and Q3, along with indicator LED6 (Compressor On). Additional outputs at RB5, RB7, RA6 and RA7 drive LEDs 2 to 5 respectively.

As shown, the speedometer signal is fed to the base (B) of transistor Q1 via a voltage divider consisting of 10k $\Omega$  and 1k $\Omega$  series-connected resistors and trimpot VR4. Zener diode ZD2 clamps any voltages above 16V, while the associated 10nF capacitor shunts unwanted high-frequency signals.

Trimpot VR4 functions as a sensitivity control for the speed sensor signal. When VR4 is set to maximum (10k $\Omega$ ), Q1 switches on when the speed sensor signal goes above 1.2V and off when the signal goes below this threshold.

Setting VR4 to a lower resistance value attenuates the signal fed to Q1's base, which means that the speed signal (and thus the vehicle's speed) must be higher for Q1 to turn on.

Transistor Q1's collector (C) is normally held high (at +5V) via a 10k $\Omega$  resistor. When Q1 turns on, the collector voltage is pulled low to about 200mV. A 1nF capacitor provides further high-frequency filtering before the signal is applied to the RB1 input (pin 7) of IC1.

The override switch S1 connects to the RB0 input (pin 6) of IC1 via a 1k $\Omega$  resistor. This resistor and its associated 100nF capacitor provides RF filtering, to keep unwanted noise out of the RB0 input.

The RB0 input is normally held high via an internal pull-up resistor. However, when S1 is closed, RB0 is pulled low (towards 0V) and this is detected by the software. As a refinement, the software includes a routine that makes sure that very short switch closures or transients are ignored.

### Throttle position

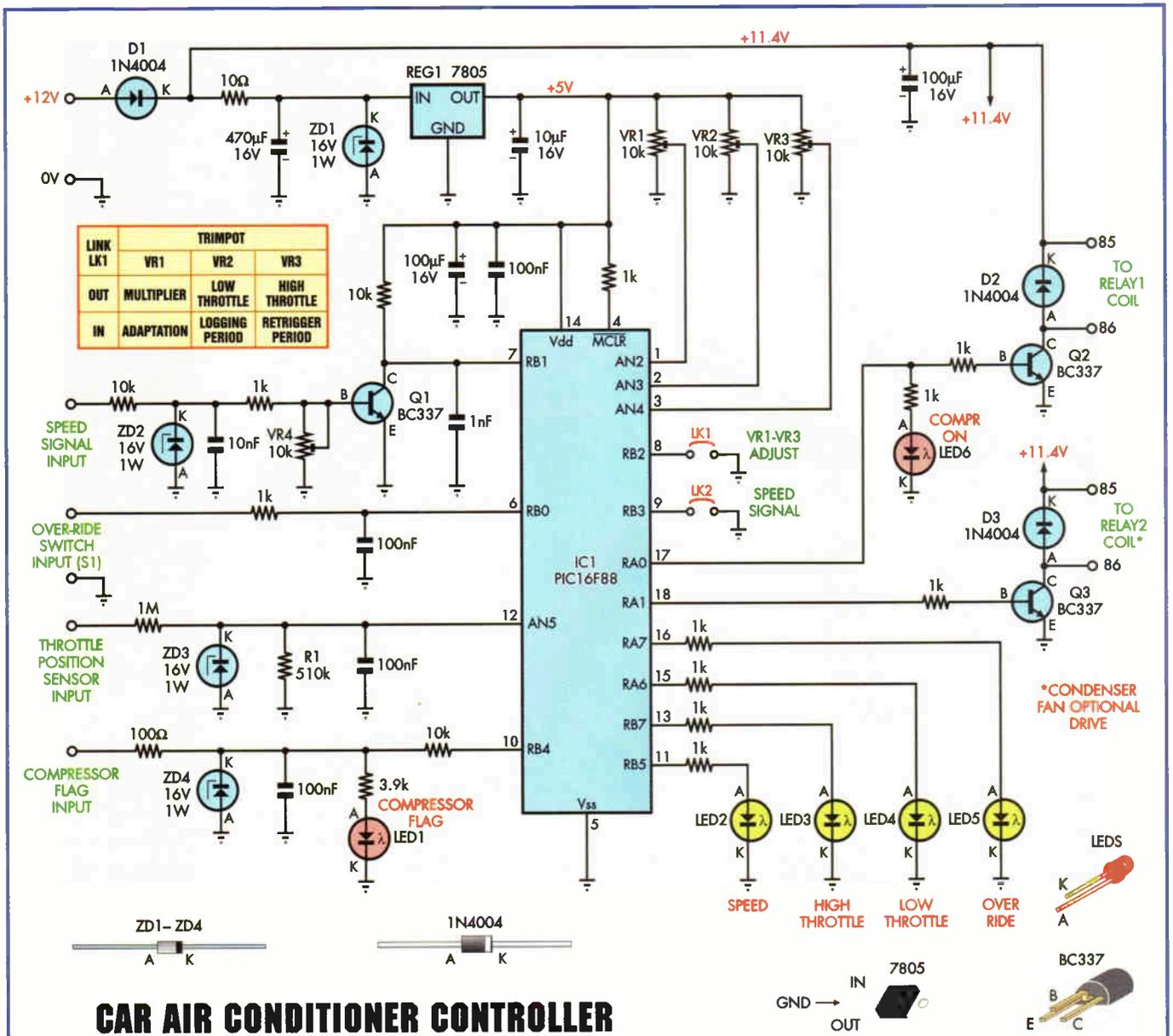
The throttle position is monitored at the AN5 (pin 12) input via a 1M $\Omega$  resistor. This resistor has a high value in order to prevent any loading on the car's throttle position sensor. Zener diode ZD3 clamps any transients that exceed 16V, while the 100nF capacitor filters the signal to remove high-frequency noise.

Resistor R1 (510k $\Omega$ ) is included to attenuate the throttle position sensor output if its voltage range goes up to 14.4V. Alternatively, this resistor is left out for speed sensors with a 0 to 5V range (the more usual case).

IC1 converts the voltage applied to its AN5 input to a digital value. In this case, 0V is converted to '0', while 5V becomes 255. Voltages between these extremes have values between 0 and 255.

Next in line is the compressor flag input, this connects to RB4 (pin 10) via series 100 $\Omega$  and 10k $\Omega$  resistors. Zener diode ZD4 and the 100nF capacitor again act to clamp transients and filter the input signal. A high-level compressor flag signal (up to 14.4V) is indicated via LED1, which is connected via a 3.9k $\Omega$  current-limiting resistor.

Inputs RB2 and RB3 are for links LK1 and LK2. These inputs are normally held high (+5V) via internal pull-up resistors. When a link is installed, its corresponding input is pulled low to 0V. Link LK1 selects the function of



## CAR AIR CONDITIONER CONTROLLER

Fig.4: the circuit is based on PIC microcontroller IC1. This device monitors several input signals and controls the compressor and its condenser fan via external relays. The numbers by the relay coil connecting points refer to numbers on the specified car horn relay contacts – see text and also Fig.3.

trimpots VR1, VR2 and VR3, while LK2 is installed if you want to dispense with the 'compressor off when vehicle is stationary' feature in Medium mode (see Table 3).

Trimpots VR1, VR2 and VR3 each connect across the +5V supply, with their wipers (moving contact) connected to the AN2, AN3 and AN4 inputs respectively. The voltages on their wipers are converted to digital values in a similar manner to the voltage on the AN5 input.

These values set the multiplier value and the low and high-throttle thresholds when link LK1 is out (Table 4). Alternatively, they set the adaptation

value, the logging period and retrigger period when LK1 is installed.

### Indicator LEDs

Indicator LEDs LED2 to LED5 are driven by the RB5, RB7, RA6 and RA7 outputs of IC1. These show the speed signal, high throttle, low throttle and override conditions, respectively.

In operation, the Speed LED (LED2) flashes at a 1Hz rate when a speed signal is detected. By contrast, the High-Throttle LED (LED3) lights continuously when the throttle position sensor voltage goes above a threshold set by VR3. Conversely, the Low-Throttle LED (LED4) lights when the throttle

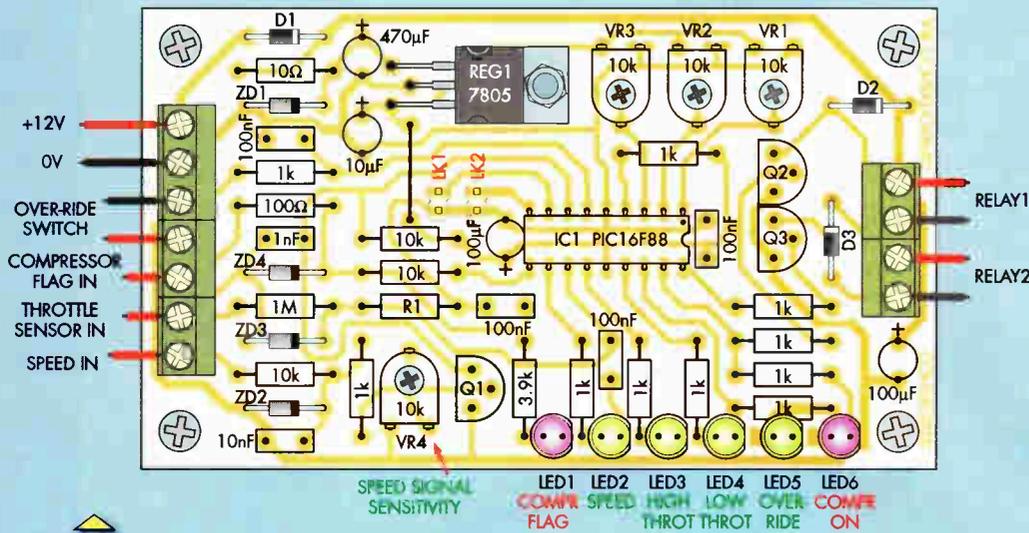
sensor voltage goes below a threshold set by VR2.

LED 5 is the Override indicator. It lights for the duration of the override period when switch S1 is pressed.

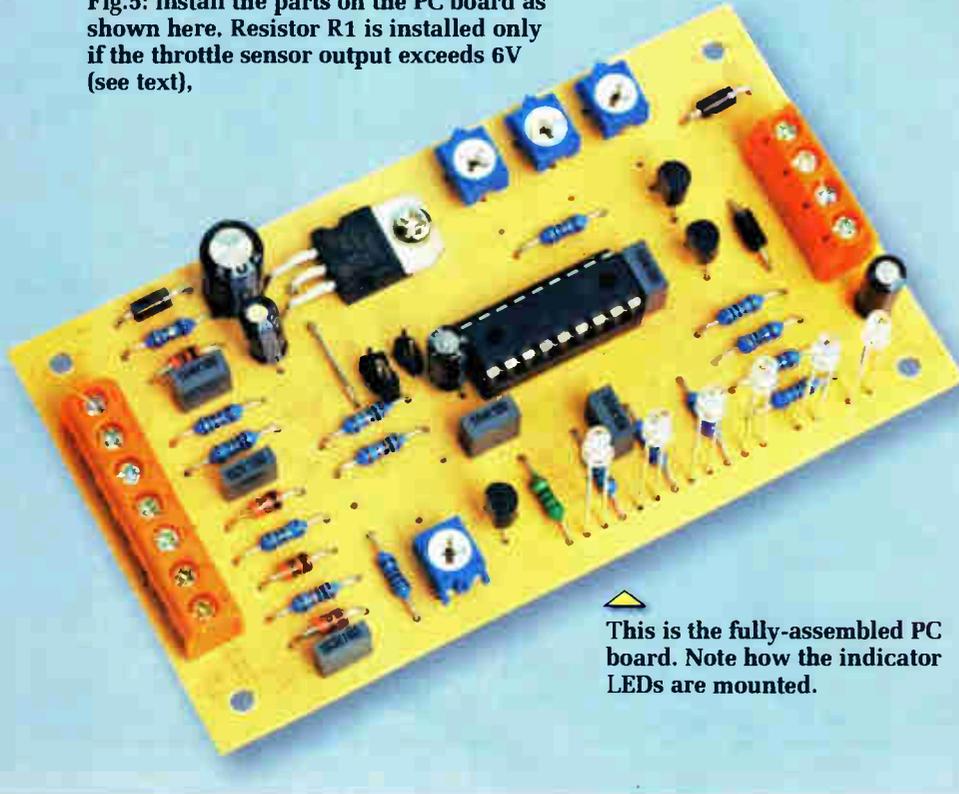
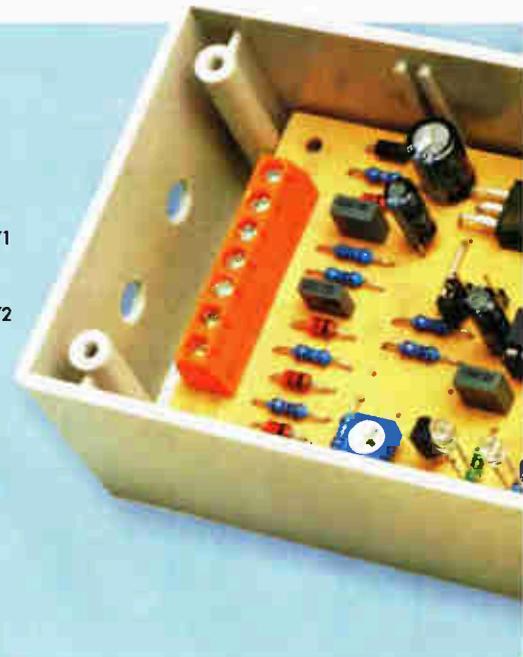
Finally, LED6 indicates when the compressor is on, which is whenever IC1's RA0 output goes high. This output also drives the base of transistor Q2 via a 1kΩ resistor. When RA0 goes high, Q2 turns on and drives Relay1.

Transistor Q3 is driven by output RA1 in a similar manner to Q2. This transistor drives Relay2, which in turn controls the condenser fan in some installations.

# Constructional Project



**Fig.5:** install the parts on the PC board as shown here. Resistor R1 is installed only if the throttle sensor output exceeds 6V (see text),



**This is the fully-assembled PC board. Note how the indicator LEDs are mounted.**

x 44mm. PC-mounting screw terminal blocks at either end of the board take care of the external wiring connections.

Fig.5 shows the component layout and assembly details. As usual, start by carefully checking the PC board for defects (shorted tracks or breaks in the copper pattern). While you're at it, check the hole sizes. In particular, check the holes for the screw terminals and the four corner-mounting holes. Enlarge these holes if necessary.

That done, install all the resistors, but note that R1 should be left out for the time being. Table 1 shows the resistor colour codes, but you should also use a digital multimeter to check the values, as some colours can be difficult to decipher.

The diodes and IC socket can go in next, taking care to ensure that they are all oriented correctly. (Do not install the PIC in its socket at this stage.) Follow these with the capacitors, again taking care to ensure that the electrolytics go in the right way around.

Transistors Q1 to Q3 are next on the list, after which you can install LED1 to 6. The latter should be mounted so that the top of each LED is 28mm above the PC board (pushing the LEDs down onto a cardboard spacer between their leads is the best way to achieve this).

Make sure that each LED goes in with its anode lead towards the left (the anode lead is the longer of the two). Note that LEDs 1 and 6 are red, while the remaining four LEDs are green.

## Power supply

Power for the circuit is derived from the vehicle's ignition supply. This is fed to a 3-terminal voltage regulator (REG1) via diode D1, which provides reverse polarity protection. A 10Ω resistor and a 470μF capacitor decouple the supply following D1, while Zener diode ZD1 (16V) protects REG1 from damage due to voltage transients.

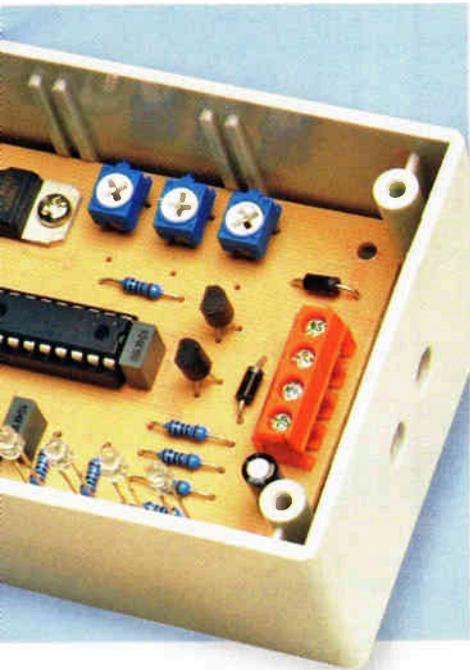
Pin 4 (MCLR) of IC1 is connected to REG1's output via a 1kΩ resistor. This pin resets the microcontroller each time power is applied.

## Software

The software files are available for free download via the *EPE* Downloads site, access via [www.epemag.co.uk](http://www.epemag.co.uk). Pre-programmed PICs are available from **Magenta Electronics** – see their advert in this issue for contact details.

## Construction

All parts (except the relays) are installed on a PC board measuring 107mm x 61mm. This board is available from the *EPE PCB Service*, code 685. The completed board is housed in a plastic box measuring 130 x 68



Voltage regulator REG1 is next on the list. As shown, this device is mounted with its metal tab flat against the PC board. It is installed by first bending its leads down by 90°, then slipping it into position and fastening its tab to the board using an M3 x 6mm screw and nut. That done, its leads can be soldered to the PC board and cut to length.

Don't solder REG1's leads before bolting down its metal tab to the board. If you do, this could impose a strain on the soldered joints and could crack or lift the board tracks.

The board assembly can now be completed by installing trim pots VR1 to VR4, the screw terminal blocks and the link headers for LK1 and LK2. Don't install IC1 in its socket yet – we'll get to that shortly.

## Testing

The test procedure is quite brief and simply consists of checking the supply rails *before* IC1 is plugged into its

socket. To do this, apply power to the +12V and 0V terminals and check that there is 5V between pins 14 and 5 of IC1's socket. If this is correct, switch off and install IC1, taking care to ensure it is oriented correctly – see Fig.5.

## Adjustments

Initially, before switching on the Air Conditioner Controller for the very first time, the programmed settings are: Multiplier – x1.2; Low Throttle Threshold – 1.25V; High Throttle Threshold – 3.75V; Adaptation – minimum; Logging Period – 5 minutes; and Retrigger Period – 5s. However, these settings will be immediately altered by the settings of VR1, VR2 and VR3 when power is applied.

As indicated previously, link LK1 also plays a role here. If LK1 is out, then the Multiplier, Low Throttle and High Throttle settings will be set by VR1 to VR3. Conversely, if LK1 is in place, then the Adaptation, Logging Period and Retrigger Period will, of course, be adjusted by the trim pots – see Table 4.

Once a setting is changed, it is remembered unless changed again via the link and trim pot adjustments. You will need to make a note of the settings for VR1, VR2 and VR3 so that you can return these to their selected settings whenever the link is changed to make the alternative adjustments.

The initial tests can be performed using the test setup shown in Fig.6. You will need a couple of momentary-contact pushbutton switches, a 10kΩ (or any value up to 100kΩ) linear potentiometer (to simulate a throttle position sensor) and some hook-up wire. If you have one, a signal generator (or oscillator) can be used to check the speed signal detection. It's then just a matter of following the procedure set out below.

**Step 1:** install LK1 and adjust VR1, VR2 and VR3 fully anticlockwise. This

will set the Logging Period to 64s, the Retrigger Period to 0s and the Adaptation to its minimum setting.

**Step 2:** remove LK1 and adjust VR1 fully clockwise to set the multiplier to x2.

**Step 3:** set VR2 about 1/4 of a turn clockwise and VR3 about 3/4 of a turn clockwise.

**Step 4:** if you have an oscillator connected, set it at about 100Hz (or anywhere between 2Hz and 1kHz) and adjust trim pot VR4 (sensitivity) so that the Speed LED flashes. If the LED does not flash, check that the oscillator level is sufficient. When the oscillator is disconnected the LED should stop flashing.

**Step 5:** rotate the external potentiometer fully anticlockwise and check that the Low-Throttle LED lights. Conversely, check that the High-Throttle LED lights when the potentiometer is rotated fully clockwise.

**Step 6:** set the potentiometer mid-way so that neither throttle LED is lit. Now press the compressor flag switch. The compressor flag LED (LED1) should immediately light, followed by the compressor LED (LED6) within 0.5s. Release the switch and both LEDs should extinguish.

**Step 7:** press and hold the Compressor Flag switch again and check that the Compressor LED extinguishes as the pot is rotated clockwise to a high setting.

**Step 8:** check that the signal generator is off and press and hold the compressor flag switch. Check that the compressor

**Table 2: Capacitor Codes**

Value	µF Code	IEC Code	EIA Code
100nF	0.1µF	100n	104
10nF	.01µF	10n	103
1nF	.001µF	1nF	102

**Table 1: Resistor Colour Codes**

No.	Value	4-Band Code (1%)	5-Band Code (1%)
1	1MΩ	brown black green brown	brown black black yellow brown
1	510kΩ	green brown yellow brown	green brown black orange brown
3	10kΩ	brown black orange brown	brown black black red brown
1	3.9kΩ	orange white red brown	orange white black brown brown
10	1kΩ	brown black red brown	brown black black brown brown
1	100Ω	brown black brown brown	brown black black black brown
1	10Ω	brown black black brown	brown black black gold brown

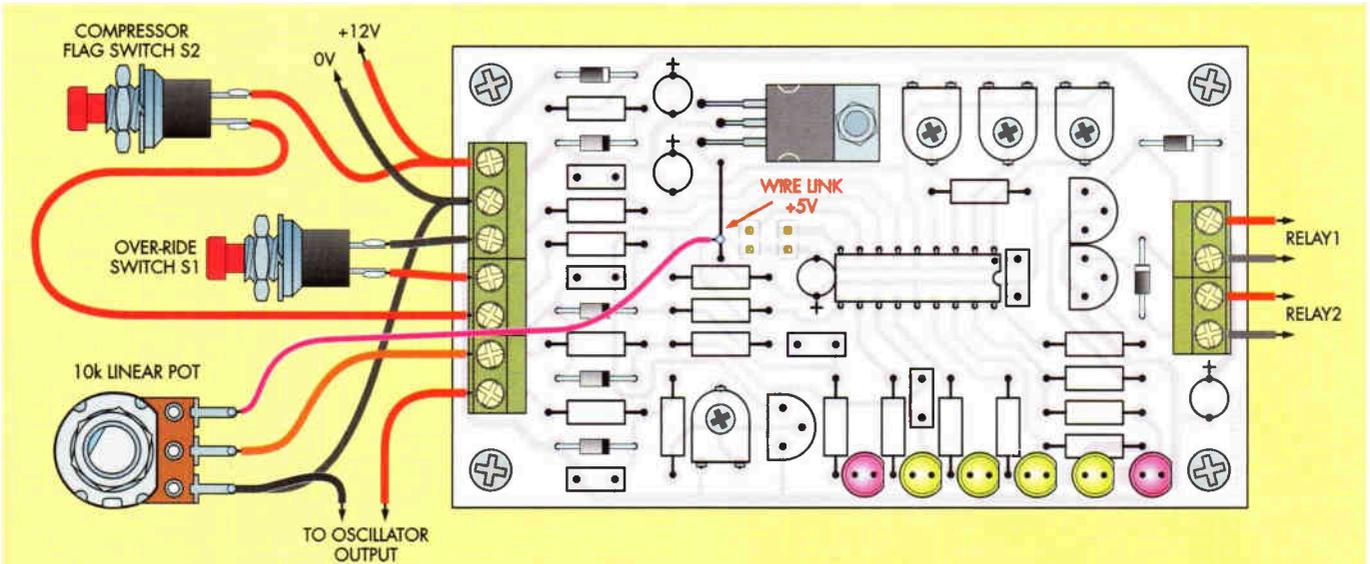


Fig.6: this is the test set-up for the controller board. The 10kΩ potentiometer simulates the throttle sensor, while an external oscillator is used to simulate the speedometer signal input.

LED goes off as the potentiometer is rotated fully anticlockwise.

If the signal generator is now connected, then the compressor LED should come on. Note that if link LK2 is installed, the compressor LED should stay lit for low potentiometer settings, even when there is no oscillator signal.

**Step 9:** set the potentiometer mid-way and press the compressor flag switch for about 16s. At the end of 16s, release it for 16s, then press it again

for another 16s and release it for 16s. This will build up an on-off duty cycle log of the compressor flag signal over the 64s logging period.

**Step 10:** release the compressor flag switch during low throttle (ie, Low-Throttle LED lit). Check that the compressor flag LED extinguishes, while the compressor drive LED stays lit for a short period before it too switches off.

This is the cool down period and will not be initiated again until the compressor drive flag goes from low to high again (ie, by releasing and then pressing the compressor flag switch).

**Step 11:** press the override switch (S1) and check that the Override LED lights. The compressor output LED should now light whenever the compressor flag LED lights (ie, when S2 is pressed). This should happen for any

potentiometer setting and regardless of whether or not the oscillator (speed) signal is on off. This override should continue for two minutes.

## Boxing up

Assuming that everything checks out, the finished PC board can be installed in a UB3-type plastic box (103m × 68 × 44mm) by clipping it into the integral side pillars. The indicator LEDs protrude through matching holes in the lid and these can be drilled using the front-panel artwork as a template – see Fig.7. You will also have to drill holes at either end of the box to pass the external wiring to the terminal blocks.

## Installation

Fig.3 shows the installation details. First, you will need to trace some of the connections in your car's wiring. The speedometer signal wire will need to be located, as will the throttle position sensor and compressor drive wiring. That means that a copy of your car's wiring diagram is an absolute necessity.

In addition, you will need to locate a +12V ignition terminal (ie, a wiring point that only goes to +12V when the ignition is on). This can easily be located inside the fuse box. If you don't intend to use the speed signal input in Medium Mode (ie, you don't want the compressor to automatically cut out when the vehicle stops), install link LK2 on the PC board – see Table 3.

Table 3: Modes		
Mode	Link LK2	Speed signal
High	Out	Required
Medium	In	Not required
Low	Out	Not required

Table 4: Setting the trimpots				
Link LK1	VR1	VR2	VR3	VR4
Out	Multiplier (anticlockwise x1, clockwise x2 in 0.8% steps)	Low throttle threshold (anticlockwise 0V, clockwise 5V at pin 12 in 255 steps)	High throttle (anticlockwise 0V, clockwise 5V at pin 12 in 255 steps)	Speed signal sensitivity (anticlockwise low sensitivity, clockwise maximum sensitivity)
In	Adaptation (anticlockwise no adaptation, clockwise maximum in 16 steps)	Logging period (anticlockwise 64 seconds, clockwise 16 minutes in 64 second steps)	Retrigger period (anticlockwise 0 seconds, clockwise 15 seconds in 1 second steps)	Speed signal sensitivity (anticlockwise low sensitivity, clockwise maximum sensitivity)

## What if the compressor runs all the time?

Some car air-conditioners are not thermostatically controlled, which means that the compressor runs continuously whenever the air-conditioner is switched on.

In this case, there's not much point in logging the compressor flag signal since it will be high all the time. As a result, you will not be able to use the controller's extended cool-down feature. However, the controller can still be used to automatically switch off the compressor when the vehicle is accelerating (high throttle) and when the vehicle is stationary.

Once you've located the throttle position sensor lead, use a multimeter to determine its output voltage range. Normally, it covers the range from just above 0V at idle throttle position through to about 5V at full throttle. It's just a matter of turning the ignition on (but *not* starting the engine) and then adjusting the accelerator position while you make the voltage measurements.

If the voltage is above about 6V with high throttle, install resistor R1 on the PC board. If it is around 6V or less, the resistor can be left out.

In addition, the wiring to the condenser fan needs to be checked out. Fig.2 shows the two possible wiring configurations, while Fig.3 shows how each configuration is connected to the controller.

Note that the 85, 86, 30 and 87 numbers in Fig.3 refer to the connections marked on the specified relay for the coil and the relay contacts. Note also that Relay2 is not required if the condenser fan is connected directly across the compressor and its series pressure switch.

Be sure to use 30A automotive horn relays, as specified in the parts list. These can be bolted to the chassis and plugged into the specified bases. The wires from the relay bases are then lengthened and spliced into the car's wiring using insulated automotive crimp connectors.

Similarly, use automotive connectors to make the connections to the sensors, the +12V and 0V (chassis) supply connections and to the override switch. If you have an older car, the latter can be installed on the dashboard. On more modern cars, it can be hidden under the dash but should still be readily accessible.

Note that the ignition-switched +12V supply to the controller should not go to 0V when the starter motor is cranked.

## 24V Operation

Want to operate this unit from a 24V supply? It's just a matter of changing a few component values, as follows: ZD1 to ZD4 should be 33V 1W Zener diodes; the 470 $\mu$ F capacitor at the input to REG1 should be rated at 35V; the 100 $\mu$ F capacitor decoupling the relay supply should be rated at 35V; if R1 is needed it should be 220k $\Omega$ ; and finally, the relays must have 24V coils.

### Pressure switch

Whatever you do, make sure that the pressure switch is included in series with the compressor – see Fig.2 and Fig.3. It's there to independently switch off the compressor to prevent icing when necessary. Note also that you will need to initially wire the Air-Conditioner Controller so that it can be accessed for easy adjustment. After you are satisfied with the adjustments, it can be tucked up out of the way under the dashboard.

### Adjustments

Once the installation is complete, you need to go through the following steps:

**Step 1:** Switch on the ignition so that power is applied to the Air-Conditioner Controller.

**Step 2:** Press the accelerator down very slightly and adjust VR2 (with LK1 out) so that the Low-Throttle LED just lights.

**Step 3:** Press the accelerator down to the position you normally use for brisk acceleration (or for going up hills) and adjust VR3 so the High-Throttle LED just lights.

**Step 4:** Install LK1 and adjust the adaptation control (VR1) to fully anticlock-

## Parts List

- 1 PC board, code 685, available from the *EPE PCB Service*, size 107 x 61mm
- 1 UB3-type plastic box, size 130 x 68 x 44mm
- 1 SPST momentary panel switch (S1)
- 2 30A SPST horn relays (Relay2 optional; see text) (Jaycar SY-4068 or equivalent)
- 2 30A horn relay bases (one optional; see text) (Jaycar SY-4069 or equivalent)
- 1 3-way PC-mount screw terminal block, 5.08mm spacing
- 4 2-way PC-mount screw terminal blocks, 5.08mm spacing
- 1 18-pin DIL IC socket
- 1 M3 x 6mm screw
- 1 M3 nut

### Semiconductors

- 1 PIC16F88 microcontroller, programmed with *aircon.hex* (IC1)
- 3 BC337 NPN transistors (Q1-Q3)
- 1 7805 +5V voltage regulator (REG1)
- 3 1N4004 1A diodes (D1-D3)
- 4 16V 1W Zener diodes (ZD1-ZD4)
- 2 3mm red high-intensity LEDs (LED1, LED6)
- 4 3mm green high-intensity LEDs (LED2 to LED5)

### Capacitors

- 1 470 $\mu$ F 16V PC electrolytic
- 2 100 $\mu$ F 16V PC electrolytic
- 1 10 $\mu$ F 16V PC electrolytic
- 4 100nF MKT polyester
- 1 10nF MKT polyester
- 1 1nF MKT polyester

### Resistors (0.25W, 1%)

- 1 1M $\Omega$                       10 1k $\Omega$
- 1 510k $\Omega$  (R1)        1 100 $\Omega$
- 3 10k $\Omega$                     1 10 $\Omega$
- 1 3.9k $\Omega$
- 4 10k $\Omega$  trimpots, horizontal (VR1 to VR4)

### Miscellaneous

Automotive wire, connectors.

wise, the logging period (VR2) to 5 minutes (about 1/3 of a turn clockwise) and the retrigger (VR3) to mid-way for about 7.5s. For a longer retrigger period, set VR3 fully clockwise. If you are not concerned about the compressor rapidly switching on and off, then set VR3 fully anticlockwise.

## This unit doesn't suit all cars

This Air-Conditioner Controller is designed to work with cars that have a throttle position sensor that delivers a voltage dependent on throttle position. This type of sensor is normally installed in cars that use electronic fuel injection and engine management. Cars with a carburettor fuel system are unlikely to include a throttle position sensor.

Cars with a carburettor could, however, be modified to include a potentiometer that is operated by the throttle. A long-life potentiometer would be required, such as one available from Farnell Cat. 469-9518. ([www.farnell-linone.com](http://www.farnell-linone.com)). This is a Vishay 10kΩ linear conductive plastic potentiometer rated for five million operations and 125°C. A 5V supply for the high throttle end of the potentiometer could be obtained from the 5V output of REG1. The 0V signal could be obtained from the 0V input or the chassis.

The potentiometer's wiper provides the throttle position voltage. Note that a low voltage output should coincide with a low throttle, while a high voltage output should be produced at high throttle positions.

The speed signal must be derived from a signal pulse train that's fed out of the engine management computer (ECU); eg, the speedometer signal – see warning panel. Alternatively, if the ECU doesn't have a speed signal input, a signal can be derived directly from the speedometer sensor. A cable-operated speedometer is usually not suitable unless the speedometer outputs a signal for the engine management computer.

### Test drive

It's now time for a test drive, to see how the controller performs. Here's the procedure:

**Step 1:** Start the car and turn the air-conditioner on, then lift the bonnet and check that the condenser fan runs correctly with its new wiring.

**Step 2:** Drive the car. When the compressor flag LED goes out, the cabin will have cooled to the thermostat setting. When it does, press the override switch to allow the compressor flag signal to be logged without the controller's high

load and low throttle settings affecting the compressor drive.

Note: the override switch is not normally used to allow the logging of the compressor flag signal. It's simply used during this initial adjustment procedure to make setting-up much faster and more predictable.

**Step 3:** During the override period, watch the compressor action. There may be long periods when the compressor is on and long periods when it is off. You need to set the logging period so that it's long enough to

## Warning!

Be sure to derive the speed signal for this unit from your car's speedometer signal – ie, from an output from the engine management computer (ECU). **DO NOT tap into a speed sensor signal that's used as an input to the ECU.**

The reason for this is that many cars now have anti-lock braking (ABS), traction control, electronic stability control and other systems that rely on speed sensor signals to the ECU. Tapping into one of these signals could upset the operation of these important safety-critical systems.

cover at least several compressor flag on and off cycles. This is done using VR2 with link LK1 installed – see Table 4.

**Step 4:** Observe the Low- and High-Throttle LEDs. You may need to re-adjust the settings here to suit your driving style.

For example, the high throttle LED may not light at the required acceleration rate. Alternatively, it may light when simply cruising, in which case VR3 should be adjusted further clockwise (LK1 out).

If the Low-Throttle LED lights under cruise conditions, turn VR2 further anticlockwise to correct this.

**Step 5:** If you needed to alter the logging period in step 3, press the override switch again. When the override period expires, check the cool down operation on low throttle. Adjust VR1 for the required multiplier effect (LK1 out).

Note: setting VR1 fully anticlockwise disables the cool down feature, while fully clockwise gives a long cool down period.

**Step 6:** Set the adaptation level for personal preference using VR1 (LK1 in).

That's it, although you may need to do some further fine-tuning later on based on further driving experience. In the meantime, you can enjoy the performance benefits of your new 'intelligent' air-conditioner. **EPE**

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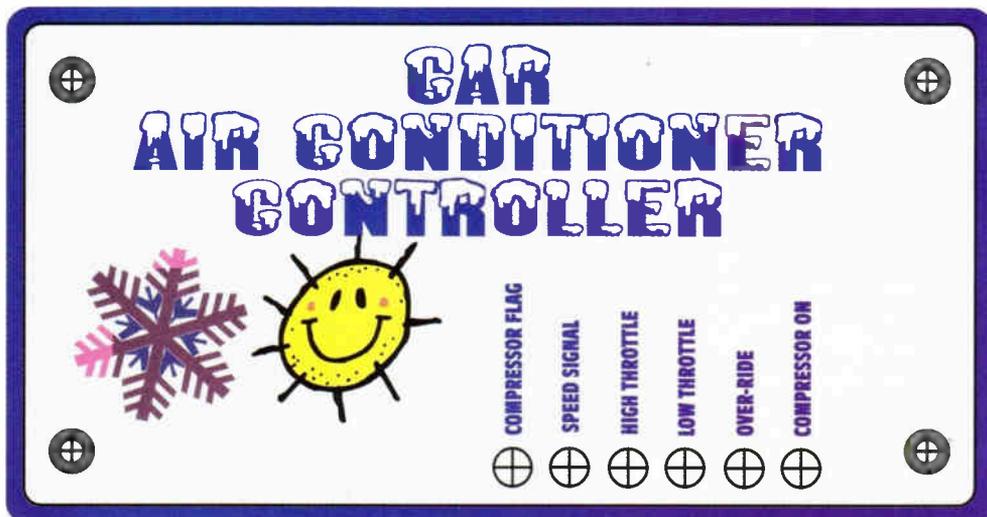


Fig.7: this full-size artwork can be used as a drilling template for the front panel.

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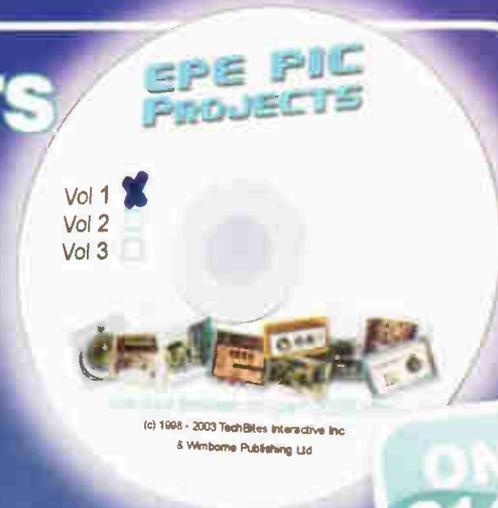
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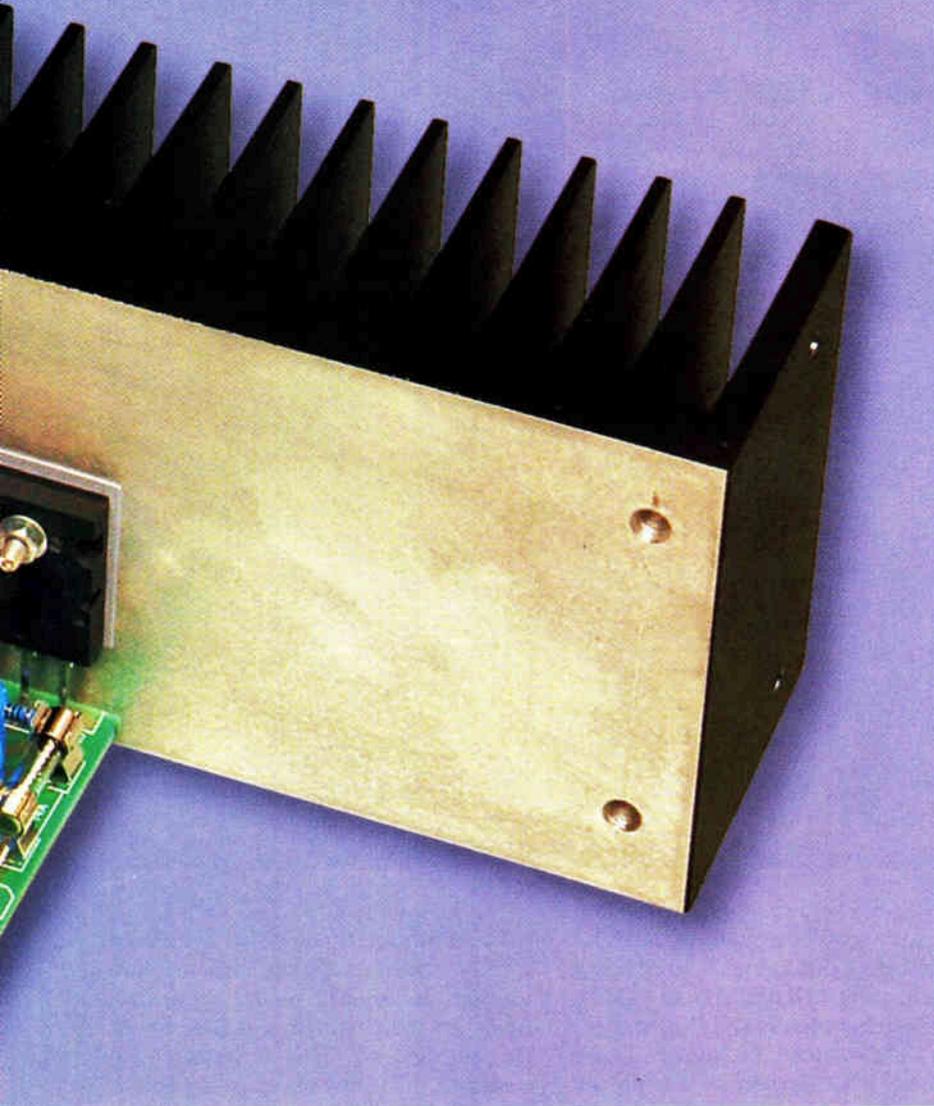
# 20W Class-A Amplifier Module



**PART.1: By LEO SIMPSON & PETER SMITH**

**This new 20W class-A power amplifier module features ultra-low distortion levels, very low noise levels and a greatly simplified power supply, which improves overall efficiency. Since it runs in pure class-A mode, there is no crossover distortion at all.**

The MJL21193 and MJL21194 output transistors are spaced well apart and bolted to a large heatsink. The heatsink may look big, but it has to be that size to safely dissipate around 50W continuously. This view shows the lefthand power amplifier module. The righthand module is laid out almost as a mirror image.



**T**HIS high-performance class-A amplifier has been a long time coming. Readers have been hankering for a more powerful, high-quality class-A amp for sometime now, but until recently, we have resisted because we knew that increasing the power output would bring a proportional increase in overall power consumption.

This is the great drawback of any class-A design. While they are beautifully distortion-free, they dissipate the same high power whether they are delivering a milliwatt, one watt or full power. That's quite a lot of power

dissipation for not very much audio output.

So, how could we increase the power output while staying within certain parameters – ie, large single-sided heatsinks and a 160VA toroidal power transformer? The answer was not simple, but essentially involved analysing the weaknesses of our planned circuit as we progressed to see if we could make worthwhile improvements.

The result is, we made quite a few minor modifications to our original amplifier circuit, which, together, adds

up to an overall improvement in the circuit's performance. It also enabled us to dispense with a regulated power supply. This makes the overall circuit more efficient, and means that the amplifier can now use some of the power that would have been previously wasted in the regulated supply. This also reduces component cost and actually helps reduce distortion in an already exceptional design.

Some of the changes in the design are based on ideas and circuits published by the noted audio designer Douglas Self and outlined in a number of his books.

### Redesigned PC board

We completely re-designed the PC board so that the two power output transistors are spread much further apart. Instead of concentrating the heat in the centre of the heatsink, it spreads the heat over a wider area and makes more efficient use of the available heatsink area. In fact, while the new amplifier module can deliver up to 25W (instead of the original 15W), the heatsink temperature remains about the same – ie, about 30°C above ambient.

We must stipulate that even though the amplifier can deliver up to 25W at the onset of clipping, it only provides pure class-A operation up to 20W. Beyond this, it is operating class AB – still with very low distortion – but not genuine class-A.

We made this compromise to reduce the temperature rise on the heatsinks. With sufficient quiescent current to ensure class-A operation up to 25W, the heatsinks simply became too hot.

In fact, the circuit is actually slightly more 'voltage-efficient' than the old one, so that the available output voltage from the balanced supply rails is greater than before. We will see just how these improvements have come about as we go through the circuit description.

### Performance

We will present the complete circuit description and mention the differences with the older design where appropriate. But first, let's talk about performance.

The distortion of this new design is amazingly low. Fig.1 shows the total harmonic distortion at 1kHz for power levels from 100mW up to clipping, which occurs in excess of 25W. Note



Fig. 1: this graph plots the total harmonic distortion (THD) at 1kHz from 100mW to just over 25W.

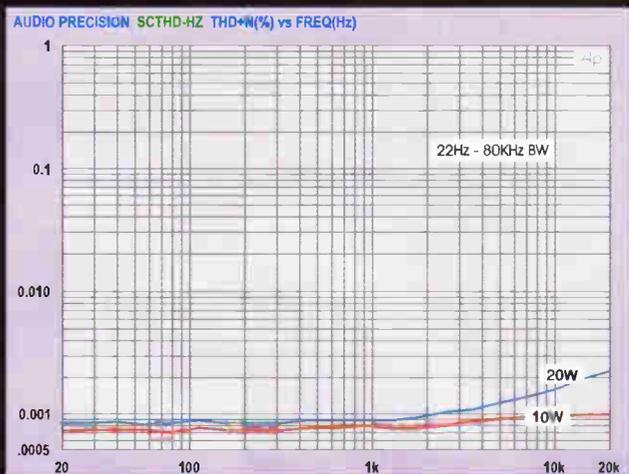


Fig. 2: the distortion versus frequency at 10W and 20W into an 8Ω load (measurement bandwidth 22Hz to 80kHz).

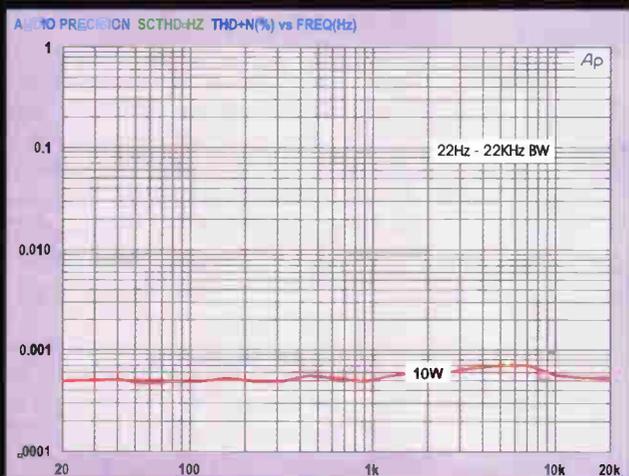


Fig. 3: distortion vs frequency at 10W from 20Hz to 20kHz (measurement bandwidth 22Hz to 22kHz).

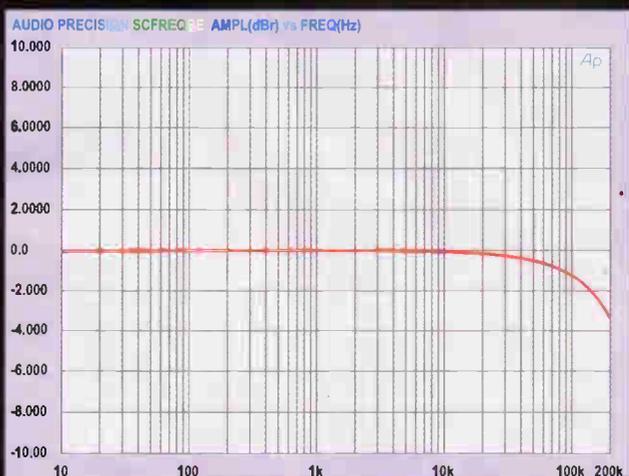


Fig. 4: the frequency response is 'ruler' flat over the audible frequency range, with -3dB points at 1.5Hz and 190kHz.

that the distortion for power levels between say 5W and 20W is far below 0.001% and is typically less than 0.0006% at around 10W.

Similarly, Fig. 2 shows the distortion versus frequency for power levels of 10W and 20W into an 8Ω load, using a measurement bandwidth of 22Hz to 80kHz. This is a far more stringent test, as the distortion for any amplifier, even quite good designs, usually rises quite markedly at high powers for frequencies above 5kHz. But for this design, at 10W, the distortion at 20kHz is only marginally above that at 1kHz. At 20W, the new design has about half the distortion of the original at 15W, and that is right across the spectrum, not just at one frequency!

Fig. 3 is included largely as a matter of academic interest and is

taken for a power output of 10W for frequencies from 20Hz to 20kHz, but with a bandwidth of 22Hz to 22kHz. Note that this means that harmonics above 22kHz will be ignored and therefore the distortion for signal frequencies above 10kHz will be artificially attenuated.

Frequency response is 'ruler' flat, as shown in Fig. 4. It is -1dB at 90Hz and -3dB at 1.5Hz and 190kHz. This is a much wider frequency response than the original circuit and comes about because we have used much gentler filtering at the input of the amplifier. We will describe the reasoning behind this later in the article.

Residual noise measurements have also improved. Unweighted signal-to-noise ratio, with respect to 20W into 8Ω, is -115dB, while the A-weighted figure is -118dB.

Even though those noise figures are highly creditable, they are not low enough to enable us to accurately measure the distortion at low power (ie, below 5W). This is because the residual noise becomes a significant part of the measurement and largely masks the actual distortion. We hope to feature some equivalent scope plots next month.

For the moment, we can unequivocally state that this new class-A amplifier module is one of the lowest distortion designs ever produced, anywhere!

## Circuit concept

The full circuit diagram of the 20W Class-A Amplifier module is shown in Fig. 5. While the general configuration is similar to that used in our first circuit, very few

## Parts List – 20W Class-A Amplifier Module

- 1 PC board, code 687 ('left') or 688 ('right'), available from the *EPE PCB Service*, size 146mm × 80mm
- 2 Micro-U TO-220 finned heatsinks (20° C/W)
- 3 TO-126 heatsink pads
- 2 TO-3P heatsink pads (Farnell 936-753 recommended, see text in Part 2)
- 1 diecast heatsink, 300 × 75 × 49mm (W × H × D) (Altronics H-0545)
- 1 PC-mount phono socket (CON1)
- 2 M3 × 10mm tapped spacers
- 2 M3 × 6mm pan head screws
- 2 M3 × 10mm pan head screw
- 2 M3 × 20mm pan head screws
- 6 M3 flat washers
- 4 M3 nuts
- 5 M4 × 10mm screws
- 5 M4 flat washers
- 5 M4 shakeproof washers
- 5 M4 nuts
- 5 6.3mm single-ended chassis-mount spade lugs
- 4 M205 fuse clips (F1 and F2)
- 2 3A M205 slow-blow fuses
- 1 11.8mm or 13.8mm ID bobbin
- 1 2m length of 1mm-diameter enamelled copper wire
- 0.7mm diameter tinned copper wire for links
- 1 1kΩ 25-turn trimpot VR1

### Semiconductors

- 2 2SA970 low-noise *PNP* transistors (Q1 and Q2) (available from [www.futurlec.com](http://www.futurlec.com))
- 4 BC546 *NPN* transistors (Q3, Q4, Q8 and Q9)
- 3 BC556 *PNP* transistors (Q5 to Q7)
- 2 BD139 *NPN* transistors (Q10 and Q11) (Farnell 955-6052)

- 1 BD140 *PNP* transistor (Q13) (Farnell 955-6060)
- 1 MJL21193 *PNP* transistor (Q12) (Jaycar ZT-2227, Farnell 955-5781)
- 1 MJL21194 *NPN* transistor (Q14) (Jaycar ZT-2228, Farnell 955-5790)
- 2 1N4148 signal diodes (D1, D2)

### Capacitors

- 1 1000μF 35V PC electrolytic
- 2 470μF 35V PC electrolytic
- 4 47μF 25V PC electrolytic
- 1 220μF 25V PC electrolytic
- 1 820pF 50V ceramic disc
- 1 100pF 50V NPO ceramic disc (Jaycar RC-5324)
- 4 100nF metallised polyester (MKT)
- 1 150nF 250V AC metallised polyester or polypropylene (Farnell 121-5452)

### Resistors (0.25W, 1%)

- 1 1MΩ            1 510Ω
- 4 10kΩ          1 270Ω
- 3 2.2kΩ        8 100Ω
- 1 1kΩ            3 68Ω
- 1 680Ω          1 16Ω
- 1 6.8Ω 1W 5%
- 1 10Ω 1W 5%
- 2 0.1Ω 5W 5% wirewound
- R1 See text and Part 2
- 2 1.5Ω 5W 5% wirewound (for testing)

### Power Supply

- 1 PC board, code 689, size 134mm × 63mm
- 1 16V+16V 160VA magnetically shielded toroidal transformer (see text in Pt.2).
- 4 M3 × 10mm tapped spacers
- 4 M3 × 6mm pan head screws
- 6 M4 × 10mm pan head screws

- 6 M4 flat washers
- 6 M4 shakeproof washers
- 6 M4 nuts
- 3 6.3mm single-ended chassis-mount spade lugs
- 3 6.3mm double-ended 45° or 90° chassis-mount spade lugs
- Extra heavy-duty hook-up wire and spade crimp lugs for low-voltage wiring
- Mains connection hardware to suit installation

### Semiconductors

- 1 KBPC3504 400V 35A bridge rectifier (BR1)
- 2 3mm red LEDs

### Capacitors

- 6 10,000μF 35V or 50V snap-in PC-mount electrolytics (max. 30mm diameter) (Farnell 945-2869)
- 2 100nF metallised polyester (MKT)

### Resistors

- 2 2.2kΩ 1W 5%

### Transistor quality

To ensure published performance, the MJL21193 and MJL21194 power transistors must be On Semiconductor branded parts, while the 2SA970 low-noise devices must be from Toshiba. Be particularly wary of counterfeit parts.

We recommend that all other transistors be from reputable manufacturers, such as Philips (NXP Semiconductors), On Semiconductor and ST Microelectronics. This applies particularly to the BD139 and BD140 output drivers.

component values are the same. Some of the transistors have been changed, a cascode stage has been omitted, the biasing arrangements for the constant current sources (Q5, Q6 and Q7) have been significantly changed and the impedance of the input and feedback networks has been substantially reduced.

These changes were made to improve the residual noise, the power supply rejection ratio (PSRR) and the voltage efficiency of the amplifier.

In fact, the only stages which are largely unchanged are the  $V_{be}$  amplifier (Q10) and the complementary-feedback pair (CFP) power output stage. So let's go through the circuit.

### Circuit details

The input signal is coupled via a 47μF 25V electrolytic capacitor and a 100Ω resistor (R2) to the base (B) of transistor Q1, one of an input differential pair (Q1 and Q2) using Toshiba 2SA970 *PNP* low-noise transistors.

The 100Ω input resistor (R2) and the 820pF capacitor (C1) constitute a low-pass filter, with a -6dB/octave roll-off above 190kHz.

This is a much lower impedance network than our previous circuit, in order to provide the lowest impedance for the signal source. In fact, a simple 20kΩ volume control, will also degrade the amplifier's noise performance and, for that reason, we will be presenting an active volume control circuit in a future issue.

## Performance: Class-A Amplifier Module

**Output power:** 20W into 8Ω (pure class-A); see text

**Frequency response:** 0dB down at 20Hz; ~0.2dB down at 20kHz  
-3dB @ 1.5Hz and 190kHz (Fig.4)

**Input sensitivity:** 625mV RMS (for full power into 8Ω)

**Input impedance:** ~10kΩ

**Rated harmonic distortion:** <0.002% from 20Hz to 20kHz, typically  
0.0006% (Fig.2)

**Signal-to-noise ratio:** -115dB unweighted, -118dB A-weighted (with  
respect to 20W into 8Ω, 22Hz to 22kHz  
bandwidth)

**Damping factor:** 180 at 1kHz

**Stability:** unconditional

Both the bias resistor for Q1 and the series feedback resistor to the base of Q2 are set at 10kΩ to minimise source impedance and thereby, Johnson noise.

The gain of the amplifier is set by the ratio of the 10kΩ and 510Ω feedback resistors to a value of 20.6, while the low-frequency roll-off (-3dB) of the gain is set by the 220μF capacitor to 1.4Hz.

### Side-effects

Readers may wonder why we used such large electrolytic capacitors in the input and feedback networks. The answer is that we are acting to eliminate any effects of capacitor distortion in the audio pass-band.

Readers might also wonder why we have not used non-polarised (NP) electrolytics for these functions, since they are normally preferable where the capacitor operating voltage is extremely low. The answer is that NP electrolytics could have been used, but they have much greater bulk and we wanted to minimise any extraneous signal pickup due to physically larger capacitors.

That is one of the unwanted side-effects of a much wider frequency response – the amplifier is more prone to EMI (interference) and, in the extreme case, to supersonic oscillation if the wiring details are not duplicated exactly.

Diodes D1 and D2 are included across the 220μF capacitor as insurance against possible damage if the amplifier suffers a fault which pegs the output to the -22V rail. In this circumstance, the loudspeakers would be protected against damage by a

loudspeaker protection module (to be published in a coming month) but the 220μF capacitor would be left to suffer the reverse current.

We have used two diodes here instead of one, to ensure that there is no distortion due to the non-linear effects of a single diode junction at the maximum feedback signal level of about 1V peak.

### Voltage gain

Most of the voltage gain of the amplifier is provided by transistor Q9, which is fed via emitter follower Q8 from the collector (C) of Q1. The emitter follower is used to buffer the collector of Q1 to minimise non-linearity. Q9 is operated without an emitter resistor to maximise gain and output voltage swing.

The collector loads for Q1 and Q2 are provided by current mirror transistors Q3 and Q4. Similarly, the collector load for Q9 is provided by a constant current load comprising transistors Q6 and Q7. Interestingly, the base bias voltage for constant current source Q5 is also set by Q6. Q5 is the constant current 'tail' for the input differential pair and it sets the collector current through these transistors.

### Power supply rejection ratio

The reason for the rather complicated bias network for Q5, Q6 and Q7 is to produce a major improvement in the power supply rejection ratio (PSRR) of the amplifier. Similarly, the PSRR is improved by the bypass filter network, consisting of the 10Ω 1W

resistor and a 1000μF 35V capacitor in the negative supply rail.

Why is PSRR so important? Because this amplifier runs in class-A, it pulls a constant current in excess of 1A (actually 1.12A) from the positive and negative supply rails. This is a great deal higher than the typical quiescent current of a class-B amplifier, which is typically around 20 to 30mA.

The result of this is that the 100Hz ripple superimposed on the supply lines is about 500mV peak-to-peak, when two modules are connected. Hence, we need a PSRR that is much higher than for a typical class-B amplifier.

### Output drivers

The output signal from voltage amplifier stage Q9 is coupled to driver transistors Q11 and Q13 via 100Ω resistors. These protect Q7 and Q9 in the event of a short circuit to the amplifier output, which could possibly blow these transistors before the fuses blow. The 100Ω resistors also have a secondary function in acting as 'stopper' resistors to help prevent parasitic oscillation in the output stage.

As already mentioned, the output stage actually uses complementary feedback pairs (CFP), based on Q11 and Q12 and Q13 and Q14. These give a more linear performance than the more usual Darlington transistor pairs used in many push-pull amplifiers. In effect, they are connected as feedback pairs with 100% current feedback from the collector of Q12 to the emitter of Q11 by virtue of a 0.1Ω 5Ω 'emitter' resistor.

To make the CFP concept easier to understand, consider transistor Q11 as a standard common emitter amplifier with a 100Ω collector load resistor. Transistor Q12's base emitter junction is connected across this 100Ω resistor, and so it becomes a current amplifier stage and its collector load is the common 0.1Ω resistor, which provides the current feedback to the emitter of Q11. Because there is 100% local feedback, these output pairs have unity gain and a very high degree of linearity.

### Output transistors

We should mention the output transistors specified for this amplifier. They are the MJL21193 and MJL21194 plastic encapsulated transistors. They are rated at 250V, 16A (30A peak) and 200W, and are clearly far more rugged than they need to be for an amplifier of this rating.

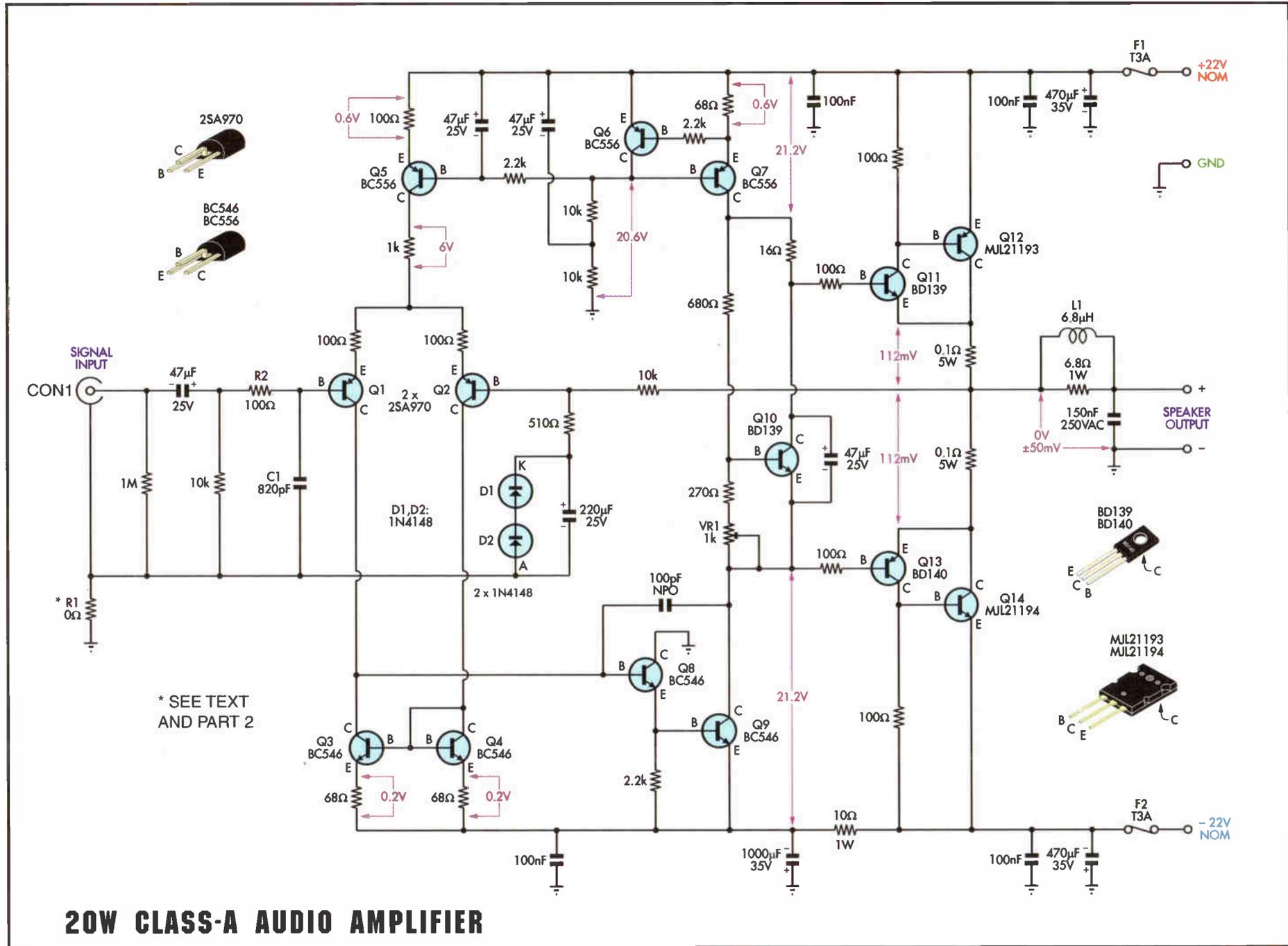
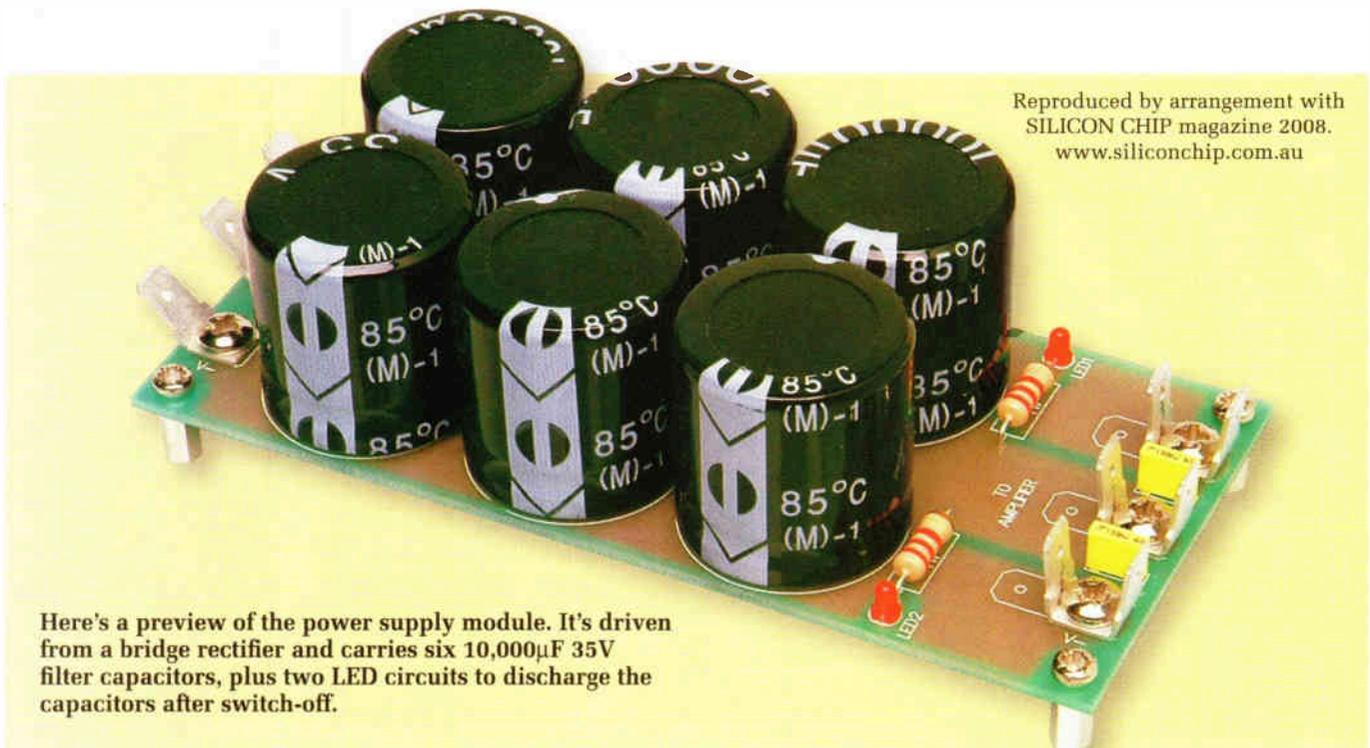


Fig.5: the circuit is a conventional direct-coupled feedback amplifier with complementary feedback pairs (Q11 and Q12, and Q13 and Q14) in the output stage. The  $V_{be}$  multiplier (Q10) is adjusted to give a quiescent current of 1.12A. The power supply details will appear in Part 2, next month.



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Here's a preview of the power supply module. It's driven from a bridge rectifier and carries six 10,000 $\mu$ F 35V filter capacitors, plus two LED circuits to discharge the capacitors after switch-off.

We use them here because they are among the best complementary power transistors for linearity made by any manufacturer in the world (originally made by Motorola and now sourced from On Semiconductor – Google).

Another circuit change is that we have used a BD139 and a BD140 as the driver transistor pairs, instead of using the more usual lower power BC337 and BC327. This was necessary because of the higher power dissipation in the driver transistors.

## Multiplier stage

Transistor Q10 is the  $V_{be}$  multiplier and it has exactly the same arrangement as in any class-B amplifier. A ' $V_{be}$  multiplier' is a temperature-compensated floating voltage source and, in this case, it provides about 1.6V between the bases of Q11 and Q13. Q10 multiplies the voltage between its base and emitter, by the ratio of the total resistance between its collector and emitter to the resistance between its base and emitter.

In practice, trimpot VR1 is not adjusted to produce a particular voltage across Q10, but to produce the specified quiescent current of 1.12A in the output stage. This requires a voltage of 112mV across each 0.1 $\Omega$  emitter resistor. In practice, the emitter resistors have a 5% tolerance, so we average the voltage across each of these resistors at 112mV.

Note that you will need a digital multimeter for this adjustment (more on this next month).

An interesting point about Q10 is that we have specified a BD139 for this task instead of a much lower-rated BC547 or similar transistor, which would certainly be adequate from the point of power dissipation. The reason for using the BD139 is that its package and junction does a much better job of tracking the junction temperature of the driver and output transistors and thereby gives much better bias stability. In fact, Q10 is bolted to the same heatsink as driver transistor Q11 to improve tracking.

Also included to improve temperature compensation is the 16 $\Omega$  resistor in the collector circuit of Q10; a small point, but still worthwhile.

## Output RLC filter

The remaining circuit feature to be discussed is the output RLC filter, comprising a 6.8 $\mu$ H air-cored choke, a 6.8 $\Omega$  resistor and a 150nF 250V AC capacitor. This output filter was originally produced by Neville Thiele and is still the

most effective output filter for isolating the amplifier from any large capacitive reactances in the load, thereby ensuring unconditional stability. It also helps attenuate any RF signals picked up by the loudspeaker leads and stops them being fed back to the early stages of the amplifier, where they could cause RF breakthrough.

Finally, as with any high-quality amplifier design, the PC board itself is a very critical part of the circuit and is a major factor in the overall performance. Even small deviations in PC layout can have major deleterious effects on the distortion performance.

That's all for now. In Part 2, we'll show you how to build the matching left and right amplifier modules and describe the power supply assembly. **EPE**

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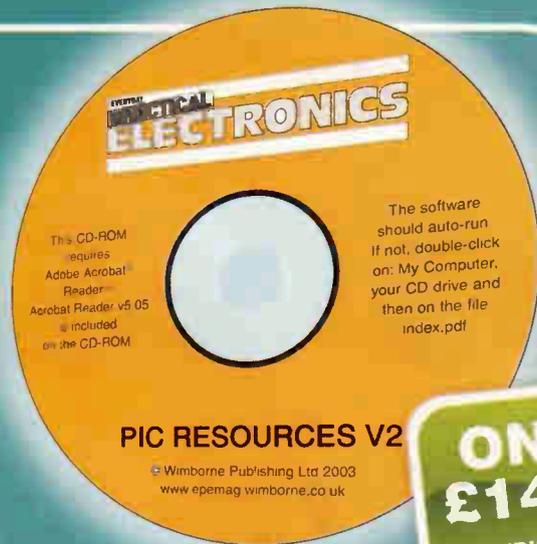
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# Recycle It!



BY JULIAN EDGAR

## Build a £2 battery charger

**Battery chargers needn't cost a fortune. Here's one you can build for a couple of pounds – or even less if you're a good scrounger!**

**R**ECENTLY, we described a sophisticated lead-acid battery charger in *EPE* – in fact, perhaps one of the most sophisticated DIY designs in the world. But hey, it might be good, but it also costs a lot more than a few pounds.

This design? Well, it's right at the other end of the scale – the £2 trickle battery charger! Sure, it takes a bit of fiddling to initially set up, but after that you're laughing.

### The components

This battery charger comprises just a plugpack, a resistor and a fuse.

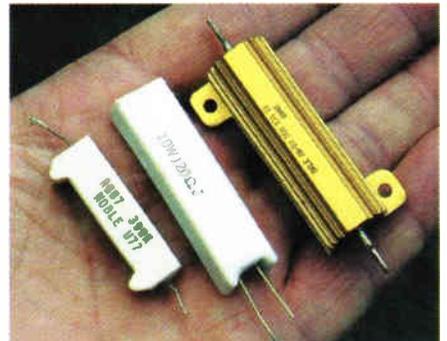
For charging a 12V lead-acid battery, a plugpack with a nominal rating of around 13V to 14V and a current capacity of about one amp (1A) is fine. Low-cost plugpacks matching these specs can be found wherever consumer goods are being thrown away or sold cheaply secondhand.

Those with the required ratings were often used to power printers and older scanners.

Make sure when selecting the plugpack it has a DC (direct current) output. Some higher-powered plugpacks have an AC (alternating current) output because they're designed for garden lights and so don't need to rectify the AC to DC.

The resistor needs to be a high power design (eg, 5W) with a resistance around five ohms (5Ω). Lots of junked goods use high power resistors, so always keep an eye out for these components – they're among the few individual electronic components always worth collecting.

Chassis-mount fuseholders can be found in amplifiers and in-line fuseholders in the supply wiring to car radios and amplifiers. The fuses themselves? Well, they're in nearly all goods – and like



**A high-power resistor limits the charging current flow, especially when the battery is well down in voltage. Always be on the lookout for high power resistors – they're among the few individual electronic components always worth salvaging.**

high-power resistors, fuses are *always* worth salvaging, sorting and storing.

### Building it

The low-budget trickle charger circuit is shown in Fig.1. It's really very simple.

An unregulated 13V to 14V DC plugpack has a no-load output of up to 18V. Connect that straight to a flat battery and more current will flow than is healthy for the plugpack – hence the need for the resistor. To set up the system (a once-only event), you'll need your multimeter, a fairly flat 12V battery, the plugpack and a resistor with a rating of around 5Ω, 5W.

Cut off the original low-voltage plug from the plugpack and use the multimeter to work out the polarity of the output – mark the positive lead. Now wire the plugpack to the battery as shown in Fig.2 – don't forget to include the resistor! Switch on and use the multimeter to check the current flow.

If, for example, the plugpack is rated at 1A (the rating will be written on it) and in this test condition



**A 1A 13.5V plugpack makes an ideal foundation for a trickle battery charger. Plugpacks like this can be picked up for nearly nothing at the tip and where secondhand electrical goods are sold.**

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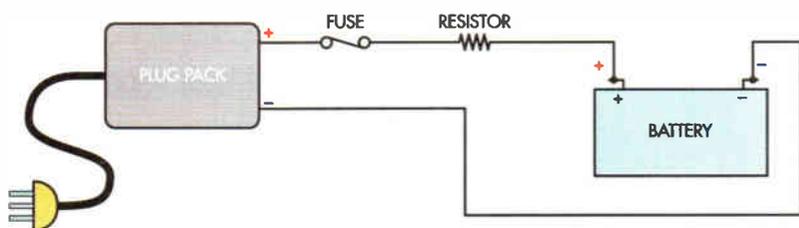


Fig.1: the charger circuit is simplicity itself. The plugpack charges the battery through a high-power resistor, with a fuse providing additional protection.

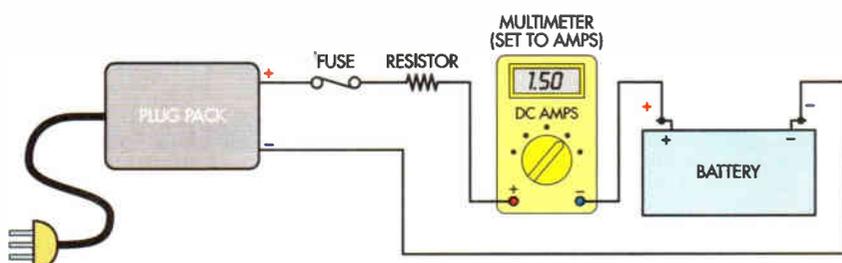


Fig.2: the required value of the resistor is found by measuring the current flow when charging a fairly flat battery. The measured current in this situation should be less than the rating of the plugpack.

the flat battery is drawing more than 1A, increase the value of the resistor. If the current is a lot less than the maximum the plugpack is capable of, reduce the value of the resistor. If you find that there's no current flow, even with the resistor completely removed, you need a better plugpack.

Once an appropriate amount of current is flowing, leave the system charging for a few minutes and then feel the temperature of the resistor. *Careful: it may be very hot!* If it is too hot to touch, increase the resistor's power dissipation. For example, if you are using a 5Ω, 5W resistor, you could try two 10Ω, 5W resistors in parallel (resulting in a 5Ω, 10W combination).

Size the value of the fuse to match the peak current flow that you've measured – eg, a 1A fuse if you've measured a maximum of 1A. If you don't have any fuses of that value, go smaller rather than larger.

### Using it

In practice, the trickle charger works very well. Feeling the temperature of the resistor gives an immediate indication of battery voltage – if the resistor is warm, the battery's voltage is still low and so charging can continue. If it is cold, measure the voltage of the battery to see how high it is. After a few charging events it's easy to get a good feel (groan) for what's happening in the system. *EPE*

## Rat it before you chuck it!



Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you always think that surely there must be some good salvageable components inside? Well, this column is for you! (And it's also for people without a lot of dough.) Each month, we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

And you can contribute as well. If you have a use for specific parts

which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you salvage the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up, but you get the idea . . .)

If you have some practical ideas, write in and tell us!

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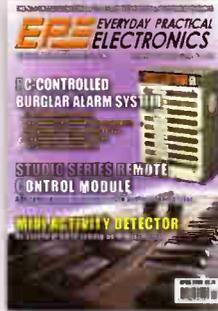
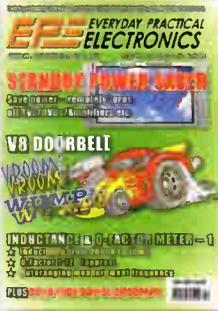


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# INTERFACE

## DIGITAL-TO-ANALOGUE CONVERSION

Recent *Interface* articles have covered the use of USB to serial port adapters with home constructed PC add-ons. The topic of writing to serial ports using Visual BASIC will be concluded in the next *Interface* article. In this month's column we will take a break from serial/USB interfacing and consider the subject of digital-to-analogue conversion.

The simplest approach to precision digital-to-analogue conversion is to use one of the 8-bit parallel converter chips. These mostly require a basic 8-bit output port with no handshake lines. It is just a matter of outputting the appropriate values to the port, and the converter responds with the corresponding output voltages.

A practical converter will not respond instantly to new values, and the maximum time it can take to shift from one output level to another is called the 'settling time'. This is generally the time taken for the output to go from maximum to minimum output voltage, or vice versa.

Feeding values to a digital-to-analogue converter at an excessive rate gives unpredictable results and should be avoided. This is usually achieved in the software rather than using some form of handshaking.

### Bit topsy-turvy

Many of the 'old favourite' converter chips seem to have disappeared in recent years, but there are still plenty of digital-to-analogue converter chips available. The AD557 is one that has featured in previous *Interface* articles, and it remains a good choice for applications where 8-bit resolution will suffice. The circuit diagram of Fig.1 shows the basic way in which the AD557JN converter chip is used. The AD557JN version of the chip has a 16-pin DIL encapsulation, with the eight data inputs conveniently grouped together on one side of the device (pins 1 to 8), and in the right order.

The manufacturer's labelling for the data inputs and outputs of converter chips tends to be a bit confusing. Instead of the usual D0 to D7 the data terminals are often marked Bit 1 to Bit 8, as in this example. The labelling can seem a bit topsy-turvy as it is bit 1 that is the most significant bit (D7) and Bit 8 that is the least significant bit (D0). This is the opposite of what one would probably expect.

The AD557JN requires a normal 5V logic supply and consumes no more than 25mA (15mA typical). It has Chip Enable (CE) and Chip Select (CS) inputs at pins 9 and 10

respectively, and these facilitate interfacing direct to the busses of a microprocessor. Neither is of any use when the chip is driven from a latching 8-bit output port, and they are simply connected to ground (0V) so that the chip is permanently enabled and selected.

The output section of the AD557JN is comprised of an operational amplifier and three feedback resistors. It is normally used with pins 14 to 16 connected together so that all three resistors are used in the negative feedback loop. The output voltage range is then 0V to 2.55V, which works out at 10mV per least significant bit. In other words, the output potential in millivolts is equal to ten times the value written to the converter. Alternatively, dividing the value written to the converter gives the output potential in volts.

It is possible to trim the output voltage using variable resistors in series with the Sense A and Sense B pins, but this is usually unnecessary. External amplification and processing is used to give the required output voltage range.

The AD557JN has a built-in precision band-gap reference source that produces a highly stable 1.2V output. The full scale accuracy of the chip is plus or minus 2.5 LSB at 25°C, but can be as large as plus or minus 4.5 LSB at extreme temperatures. Of greater importance in most practical applications, the relative accuracy is typically plus or minus 0.5 LSB, with a maximum error of plus or

minus 1 LSB. This will more than suffice in most real-world applications. The settling time is typically 0.8µs, but the maximum figure is 1.5µs.

### Bit-by-bit

Using an 8-bit parallel interface is a very straightforward way of handling things, but there will not always be adequate output lines to support this approach. The situation is more difficult with higher resolution converters, where a single 8-bit port is inadequate to drive them in simple parallel fashion. The most common solution is to use a serial interface, but here we are not talking in terms of an RS232C serial interface.

The data is sent to the chip using two ordinary digital output lines that provide a form of synchronous serial interfacing. One of these acts as the data line and the other provides a form of clock signal. The first bit of data is placed on the data line, and then the clock line is pulsed in order to latch this bit into the converter. This process is then repeated for the other bits, in the right order, latching them into the converter one-by-one. This method is clearly much slower than writing the data in parallel form, but the data can still be shifted into the converter at a rate that is more than adequate for many practical applications.

### Resolution

Many real-world applications do not require high resolutions, and using a 12-bit converter, or even an 8-bit type, can involve a degree of 'overkill'. Bear in mind that it can be very difficult to realise the full theoretical performance with converters that have resolutions of 12-bits and beyond. Preventing so-called 'digital noise' from entering the analogue part of the circuit can be problematic, and with a resolution that could well be under a millivolt per least significant bit this can greatly reduce the effective accuracy of the circuit.

Those readers who can remember the BBC Model B computer will probably recollect the noise problems with its 12-bit analogue to-digital converters. Without the use of averaging techniques the true resolution was more like 7 or 8 bits.

If an application requires high resolution, the layout and earthing must be designed very carefully in order to obtain a level of performance that approaches the theoretical limits of the converter. Manufacturers' data sheets often

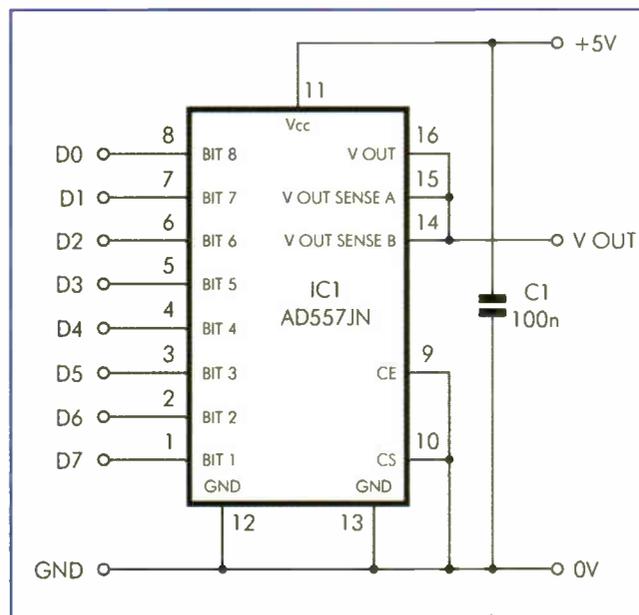


Fig.1. The AD557JN is an 8-bit converter that provides an output voltage range of 0V to 2.55V. This gives a resolution of 10mV (0.01 volts), which is adequate for most purposes

give advice on the optimum earthing arrangements for high-resolution converter chips.

In some applications it is not even necessary to have 8-bit resolution. All that is needed in some cases is a limited range of output levels rather than something that approximates to a continuously variable output level. There are usually simpler and cheaper ways of obtaining a few preset output potentials, but using a 'proper' converter is still worthy of consideration if high accuracy and stability are required.

If (say) six output levels are required, these can be obtained with a high degree of accuracy by outputting the appropriate values to an 8- or 12-bit digital-to-analogue converter. The accuracy and stability of the converter will ensure that the output voltages will have good accuracy, and will maintain that accuracy over a period of time.

Relatively cheap and low-tech methods of obtaining a few different output levels are unlikely to obtain the same degree of accuracy, even if the voltages can be adjusted to precisely the required levels. The voltages will be highly accurate initially, but are likely to drift slightly over a period of time. Of course, stability is not important in some applications, and a more 'rough and ready' approach is then perfectly acceptable.

### Preset voltages

There are numerous ways of using a few digital outputs to produce a selection of output voltages. The circuit of Fig.2 demonstrates a very simple method of obtaining four preset voltages from a simple circuit that can be built at very low cost. In the left-hand section of the circuit there are four digital inputs that each control a CMOS analogue switch (IC1a to IC1d).

An analogue switch provides an action that is similar to a mechanical switch, with an extremely high resistance being provided between the input and output when it is in the 'off' state. The resistance is much lower when the switch is turned on, but at a few hundred ohms it is not as low as that provided by a mechanical switch.

This factor is usually of little practical importance, since this type of switch is only used in applications where minute currents are involved. A switch is turned on by taking the control input to a high (logic 1) level, and switched off by taking the control input to a low (logic 0) state.

The inputs of the analogue switches are fed from separate preset potentiometers that are in turn fed from the +5V supply. Each switch can therefore be supplied with any desired input potential from 0V to +5V.

The outputs of the switches are connected together and the combined output signal is fed to a simple voltage follower buffer stage based on operational amplifier (op amp) IC2. The ultra-high input resistance of IC1 ensures that there is no significant voltage drop through the electronic switches.

For the circuit to operate correctly it is important that only one of the control inputs (D0

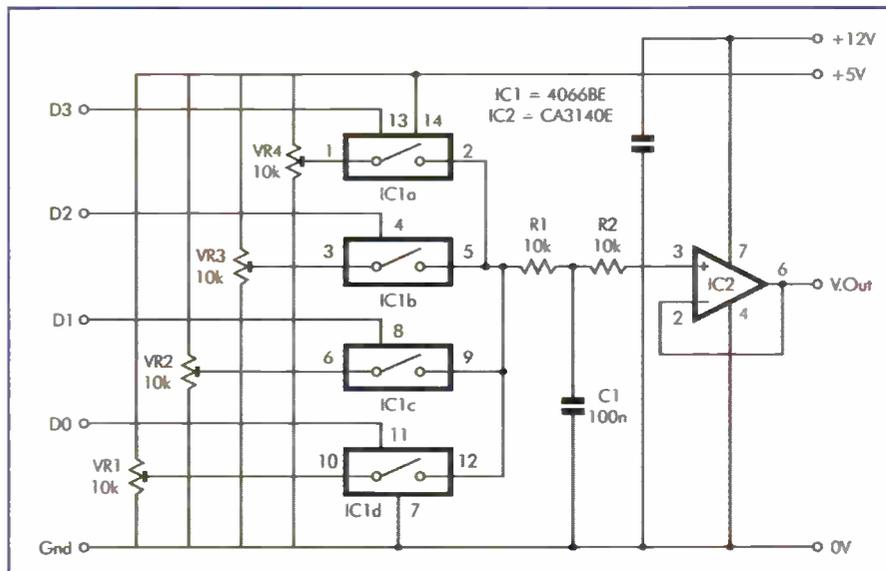


Fig.2. This simple circuit provides any four desired output potentials from 0V to +5V. It is not possible to obtain intermediate levels by taking more than one of the digital inputs to logic 1

to D3) is taken high at any one time. The voltage from one potentiometer is then fed through to the buffer amplifier, and that voltage appears at the output of the circuit.

An advantage of this method is that any four desired voltages can be produced with good accuracy, but a significant drawback is that other output levels cannot be obtained by switching on more than one switch. Bear in mind that the voltages produced by the circuit are derived from the main logic supply, and that any drift in this supply will cause a proportionate change in the output potential.

### Basic D/A converter

The circuit of Fig.3 is for an extremely simple digital-to-analogue converter that provides a range of sixteen output potentials. It is basically just a simple potential divider circuit that has resistor R5 as the lower arm, and any combination of R1 to R4 as the upper arm.

IC1 acts as a buffer amplifier at the output of the circuit. The four diodes (D1 to D4) ensure that R1 to R4 can only add to the input voltage and cannot reduce it by shunting R5 when one of the digital inputs is at logic 0.

Setting input D0 at logic 1 results in about half the drive voltage being produced at the output of the potential divider. The corresponding figures for inputs D1 to D3 are one quarter, one eighth, and one sixteenth respectively. In other words, the circuit provides a set of four voltages that correspond to those from a conventional digital-to-analogue converter.

Unlike the circuit of Fig.2, with this one it is acceptable to have more than one of the digital inputs at logic 1. This results in two or more resistors in the upper section of the potential divider effectively being connected in parallel, enabling a range of additional output voltages to be obtained.

A simple circuit of this type is never going to replace a 'proper' digital-to-analogue converter in an application that requires accurate output potentials, but it does provide an extremely inexpensive means of providing a range of output voltages for something like simple electric motor speed or lighting control.

The circuit works best if the digital inputs operate at CMOS levels, where the logic 0 and logic 1 levels are virtually equal to zero volts and the full logic supply level respectively. The maximum logic 0 drive voltage must be no more than about 0.6V. If necessary, the digital inputs can be driven via CMOS buffer stages.

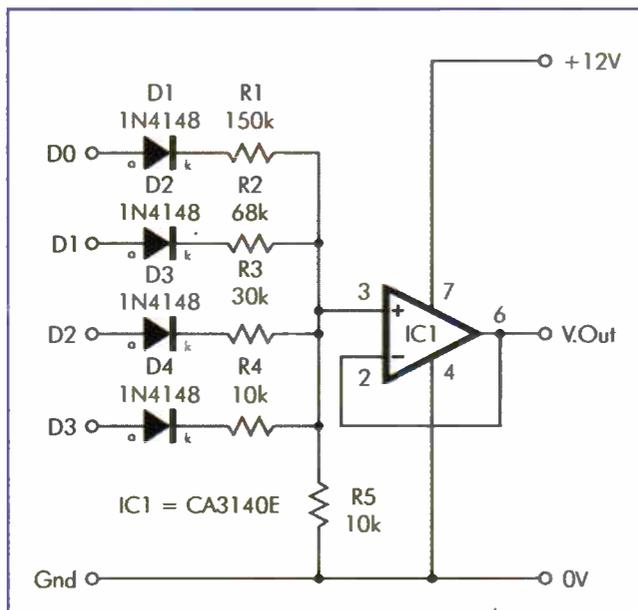
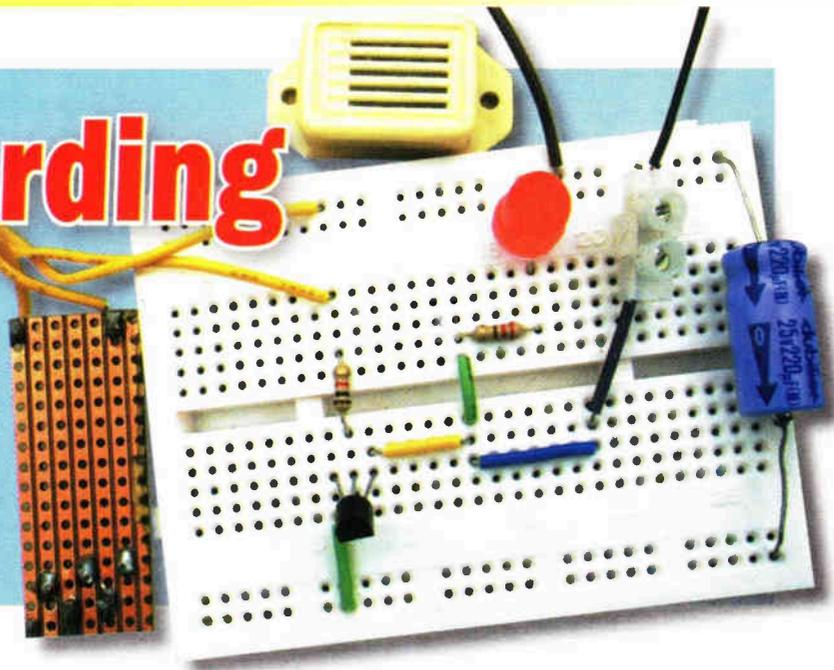


Fig.3. This basic 4-bit digital-to-analogue converter circuit provides a range of sixteen output voltages, but it is only suitable for undemanding applications. The output voltage range is typically 0V to about 2.7V



## Breadboarding Projects

by Dr Malcolm Plant



### A beginner's guide to simple, solder-free circuit prototyping Part 1: Introduction – Circuit Tester – Rain Check

THE projects presented in this series are assembled on 'breadboard'. No, not a breadboard used for cutting bread or even one made of wood, but one made of plastic pierced by numerous small holes. The particular breadboard used for all the projects is called 'Protobloc', meaning a 'block' or board for prototyping circuits. As shown in Fig. 1.1, it enables you to assemble a working circuit without needing to solder components together.

A circuit assembled on Protobloc lets you add and replace components and to change connections as necessary. It also means that the components can be reused in other projects. Professional circuit designers often use breadboard like Protobloc to evaluate their circuit designs having first sketched them on paper or via a computer drafting program.

Apart from the first project, *Circuit Tester*, all the other projects are assembled using Protobloc. The *Circuit Tester* is really a 'cheap and cheerful' instrument for measuring resistance, as reflected by the relative brightness of a light emitting diode (LED). In no way is it a replacement for a multimeter, which is far more accurate and versatile. Nevertheless, you will find it useful for checking the polarity of some components.

#### Protobloc

The Protobloc used here has 400 small holes, each one allowing a component lead to be inserted and to be gripped by double-leaf spring contacts underneath each hole. Link wires are used to bridge across these 'sockets' enabling components to be interconnected.

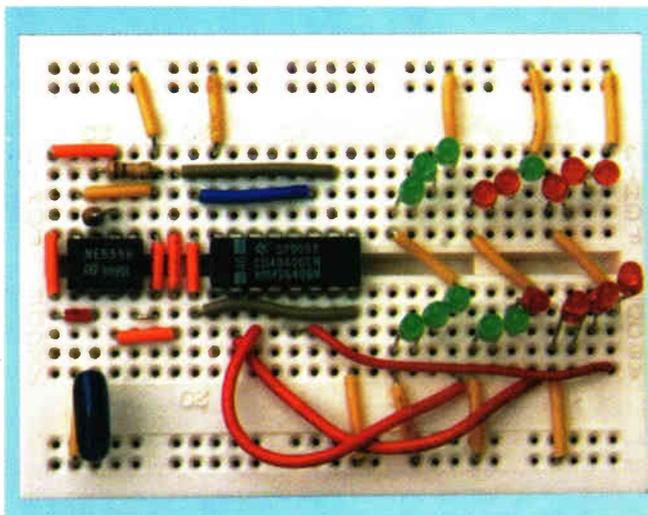


Fig.1.1: An example of circuit assembly using a Protobloc

These sockets are arranged in a grid pattern which are precisely 0.1 inch (2.54mm) apart. This separation is to accommodate integrated circuits (ICs) which have terminal pins spaced apart by the same amount.

The holes of each line of the two lines of holes at the 'top' are all joined together, as are the ones at the 'bottom' of the Protobloc. It is normal practice to connect the positive and negative of a power supply to these rows. In the projects described we use the topmost line for the positive supply and the bottommost line for the negative supply. A 9V battery, eg a PP3 or PP6, is used for all the projects. None of the projects requires you to use the mains supply; indeed you are advised not to make any use of mains power unless you are qualified, or supervised by someone who is qualified in this area.

The vertical lines of holes are linked together in groups of five and there is no link across the central channel of the breadboard. This enables each pin of the IC to be accessed by connections made to the remaining four sockets in the vertical groups of socket on each side of the IC.

When using Protobloc, you should not try to mimic the layout of components in the circuit diagram. Instead, you should concentrate on the connections between the components in achieving the neatest possible arrangement of components. In the projects this has been done to enable you to follow the interconnections easily. In some cases this has meant using more links than is necessary, and you may

well find a more efficient use of link wires. However, you are advised not to modify the layouts as shown until you become more experienced with using Protobloc to evaluate your own circuit designs.

## Assembly rules

To ensure trouble-free assembly and a successful working project when using Protobloc, you should try and follow these six important rules:

1. Always use single-core plastic-coated wire of 0.6mm diameter for wire links, not thicker. The ends of the wire should be stripped of plastic for about 8mm. The use of thicker wire can permanently damage the springy sockets underneath each hole. Wire links already cut to length with bare ends and bent at right angles are available from suppliers.

2. Never use stranded wire, as it can fray and catch in the sockets, or a strand can break off and cause unwanted connections below the surface of the breadboard.

3. It is very important to make sure that the bared ends of link wires and component leads are straight before inserting them into the breadboard. Kinks in the wire will catch in the springy clip below the socket and damage it if you have to tug to release the wire from the holes. You should use snipe nose pliers (see below) to straighten leads that are kinked.

4. Make sure that the arrangement of components and wire links are tidy, with components fitting snugly close to the surface of the Protobloc. This usually means providing more link wires than is perhaps necessary so as to avoid having wires going every-which-way across the board. Your finished assembly should be a tidy work of art!

5. Never connect the battery leads to the top and bottom rails of the breadboard until you have carefully checked that all the connections correspond to those on the circuit diagram.

6. Some components, such as switches and relays, do not have appropriate wire leads for insertion into the Protobloc. If you have access to a soldering iron, solder short lengths of single-core 0.6mm diameter plastic-sleeved wire to the terminals of these components.

If you don't have access to a soldering iron, then resort to the less satisfactory solution of using leads with crocodile clips on the ends. Some leads, such as the battery connectors, can be prepared by connecting them to a single section of terminal block and anchoring short lengths of 0.6mm diameter wire to the other side of the block, as shown in Fig.1.2.

## Tools

Only three basic tools are needed for the successful assembly of circuits on Protobloc. These are a small screwdriver, snipe-nose pliers and wire cutters/strippers. These three tools are shown in Fig.1.3. The screwdriver should be a 2mm flat blade type that will be useful for adjusting preset variable resistors, for example. (Components such as these will be introduced when they are being used in a project).

The snipe-nose pliers are essential for straightening wires and making right-angled bends at the ends of the wire links. You will also find them invaluable for picking up small components and wire links and inserting them in the holes on the breadboard. A pair of wire cutters/strippers is

## 18 EASY-BUILD PROJECTS

Circuit Tester  
Rain Check  
Dark Switch  
Moisture Monitor Mk 1  
Thermostat  
Games Timer  
Clap Switch  
Intercom  
Frost Alert

Simple Die  
Festive Lights  
Bat Detector  
Ultrasonic Remote Control  
Motion Detector  
Lightning Detector  
AM Radio  
Sound Meter  
Moisture Monitor Mk 2

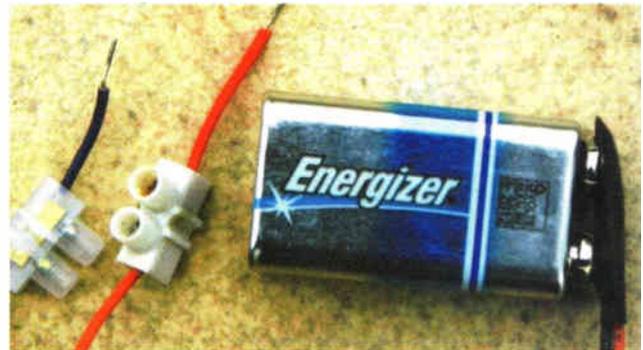


Fig.1.2: How to provide battery leads with single strand wire for Protobloc assembly

essential not just for trimming wires to length but also for stripping the plastic covering from wire ends.

## Sources of components

In designing the circuits and considering the arrangement of components, an attempt has been made to limit the range of components needed so that some of those used in one project can be used in another. This applies mainly to resistors, capacitors and ICs.

## Aim of the projects

The projects are not intended to teach concepts as such; rather the intention is to motivate your interest in electronics through practical applications and to help you to understand how the principal building blocks of circuit design are combined to produce these applications.

## You will need...



Fig.1.3: Three basic tools for assembling Protobloc projects: screwdriver, snipe-nose pliers and wire cutter/strippers

## Project 1: Circuit Tester



**Y**OU will find this simple project a handy way of checking the electrical properties of some components and circuits that you will be using when assembling projects on Protobloc. However, instead of using a Protobloc for this project, it has been assembled on a 6-way length of screw-terminal block, as shown in Fig.1.4. Its circuit diagram is shown in Fig.1.5.

The circuit can be housed in a small project box, as shown in the photos, to become a permanent, though simple, instrument that can be put to use at a moment's notice.

The components required for the Circuit Tester are shown in the opposite panel.

### How it works

To use the Circuit Tester you connect the crocodile clips to the ends of a component and keep an eye on the brightness of the LED (LED1), which indicates the electrical resistance between the clips. It works by trying to pass a small current through the component being tested, LED1 shining brightly, dimly or not at all according to the resistance of the component which is in series with it.

Materials having a high resistance, such as plastics and paper, will not allow much current, if any, to flow through them, so LED1 will not light. Whereas, materials with a low resistance, such as metals, will allow current to flow easily through them, as shown by LED1 shining brightly.

Note that the current flowing between the crocodile clips is direct current (DC) provided by a 9V battery. This DC current enables you to test the polarity of a number of components.

Note that the current flowing between the crocodile clips is direct current (DC) provided by a 9V battery. This DC current enables you to test the polarity of a number of components.

### Assembly

Follow the wiring of the terminal block as shown in Fig.1.4, making sure that LED1 is connected so that its anode (A) lead is in the position shown on the terminal block. The other lead is known as the cathode (K). Usually, the anode is the slightly longer lead.

The resistor, R1, is connected in series with LED1 and is required to ensure that too much current does not flow through the LED when the crocodile clips are connected together.

### Component Info

Fixed value resistor, R1: value 220Ω, 1/4W carbon film. Its value is colour coded, the bands are red, red, brown, and the fourth silver band indicates the 10% tolerance of the resistor.



Two 10mm red light-emitting diodes, one used as LED1 and the other spare for testing purposes. These large LEDs are easily seen. The anode lead is the longer lead.



9V PP3 battery and battery clip.



Test leads terminated at one end with a crocodile clip: one red and one black. Remove clip from one end of a black and red lead.



Two 6-way lengths of terminal block, one for the project and the other spare. Or one 12-way block cut in two.



Short lengths of 0.6 mm diameter insulated wire for making links on the terminal block. I suggest you buy a jump wire kit that contains a variety of lengths of plastic-covered wire of the right diameter for use in terminal blocks and with breadboards.



One small project box, eg 59 × 87 × 31mm. See photo of project.

You will also need a small screwdriver, a wire stripper and cutter, a set of small drills and a hand drill or electric drill.

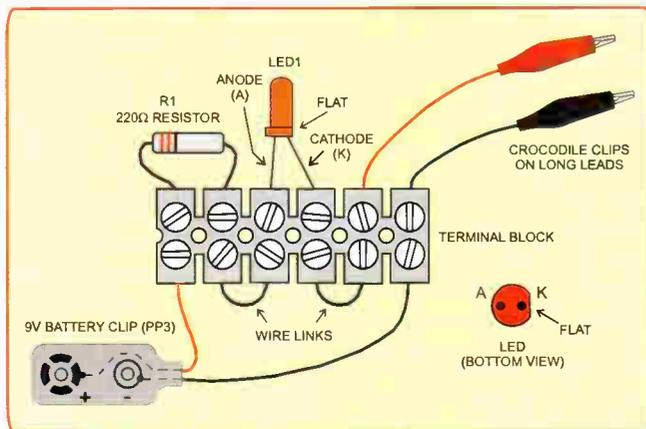


Fig.1.4: Assembly of the Circuit Tester

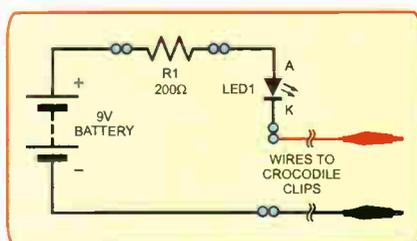
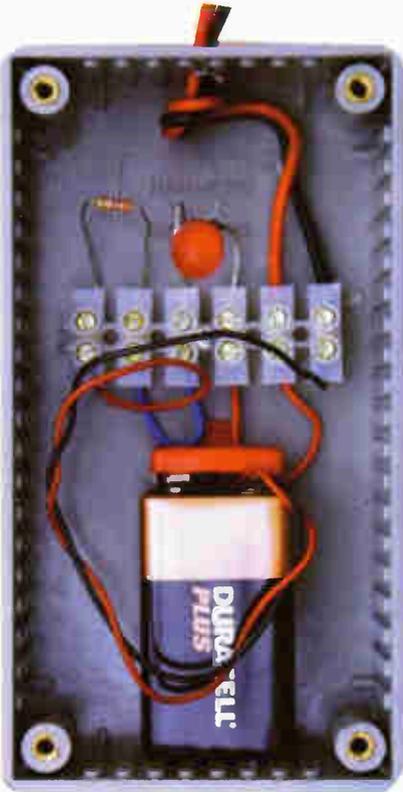


Fig.1.5: Circuit diagram for the simple Circuit Tester



Positioning of components inside the small plastic box.

## Boxing up

The Circuit Tester can be fitted into the box using a screw to hold the terminal block, or glue it to the base of the box. Drill a hole to allow LED1 to poke through the lid when it is closed. Make a knot, or use a strain-relief gromet, in the crocodile lead cables inside the box to stop them pulling on the terminal block.

Once the project is assembled, clip the two crocodile clips together and LED1 should light brightly, showing negligible electrical resistance between the leads.

## Take care

Follow the simple activities described in the panel opposite to find out how to use the Circuit Tester, but first note the following precautions.

When the Circuit Tester is not in use, clip the leads to a piece of rigid insulating material, such as cardboard or plastic, to avoid the clips accidentally touching and draining the battery. This avoids having an on-off switch.

**Never use the Circuit Tester to test mains operated equipment, whether that equipment is switched on or switched off.**

## Using the Circuit Tester

The following activities will give you a feel for ways of using this simple tester

### Activity 1 – Fuse Tester

You now have a ready-made fuse tester, but remember never to test any fuse or device that is connected to the mains electricity supply. Press the crocodile clips across the metal ends of the fuse – if the LED shines brightly, the fuse is good.

### Activity 2 – Random Resistance Tester

Test different materials and objects for their ability to conduct electricity by clipping the crocodile clips across two points on them. For example: the lead of a pencil; brass and silver objects around your room; the resistance of your upper body between your hands (moisten your fingers with saliva before gripping the clips – the LED should just glimmer); a pendant, the stem of a plant, etc.

Remember that low electrical resistance between the clips causes the LED to glow more brightly than higher resistance. Draw up a list recording high, medium and low resistance of these items.

### Activity 3 – Salty Water

Fill a cup with tap water and then dip the metal ends of the crocodile clips just under the surface, separated by a couple of centimetres. The LED should barely glow, indicating that tap water does not have a particularly low or high resistance.

Now add a sprinkling of ordinary table salt to the water and stir it in. What effect does this have on the brightness of the LED? How has the salt changed the resistance of the water?

Next, moisten a dish cloth with the salty tap water. Clip one crocodile clip to the edge of the dish cloth and touch the other crocodile clip to different parts of the cloth. Watch the LED fade and brighten while you do this as the resistance between the clips varies depending on how much moisture exists between the clips and their distance apart. How might you use the Circuit Tester to find out whether a plant pot needs watering? Try it!

### Activity 4 – Light Sensor

You need a light dependent resistor (LDR) for this activity; an LDR is a widely used semiconductor that changes its electrical resistance with the amount of light falling on it – you will be using an LDR in some breadboard projects later. Its appearance is shown in the photo below. It should be a type generally known as an ORP12.



Clip the crocodile clips to the two leads. It doesn't matter which crocodile clip goes to which lead. Allow more or less light to reach the sensitive face of the LDR and at the same time watch the brightness of the LED on the Circuit Tester. What can you say about the resistance of the LDR when it is brightly illuminated compared with when it is in shadow?

Change over the connections of the crocodile clips and you'll notice no difference in the way light changes the electrical resistance of the LDR – it is said to be non-polarised.

### Activity 5 – Temperature Sensor

You need a thermistor for this activity. Like, the LDR, the thermistor is a widely used semiconductor that changes its electrical resistance as it warms up and cools down – you will be using a thermistor in a breadboard project later. Its appearance is shown in the photo below. It should be a negative temperature coefficient (NTC) type and have a nominal value of about 5kΩ at 25°C.



Clip the crocodile clips to the two leads. It doesn't matter which crocodile clip goes to which lead. Put some warm water in a cup and

dip the thermistor just under the surface, at the same time watch the brightness of the LED on the Circuit Tester.

Next dip the thermistor into cold water. What can you say about the resistance of the thermistor when it is warm compared with when it is cool? Change over the connections of the crocodile clips and you'll notice no difference in the way temperature changes the electrical resistance of the thermistor – it is also said to be non-polarised.

### Activity 6 – One-way Traffic

Some electronic components have the ability to stop electricity (current) from flowing through them in one direction but allowing it to flow in the opposite direction. They are generally known as *diodes*.

Let's examine an LED, such as the one you used for making the Circuit Tester. First connect the crocodile leads across the LED leads any way round. Does the LED on the tester glow? If it doesn't, change over the connections and the LED should light. The red crocodile clip identifies the anode terminal of the LED. The LED is said to be *forward biased* by the positive voltage on the red croc clip, enabling current to flow through the LED being tested.

If the LED on the Circuit Tester does not glow, it is because the red croc clip is connected to the cathode terminal of the test LED, which is said to be *reverse-biased* and no current can flow through it.

Note that if the LED in the Circuit Tester does not light for both positions of the crocodile clips,

the LED under test is probably damaged. The test that you have just done works equally well for finding the anode terminal of a rectifying diode.

### Activity 7 – Transistor Tester

Transistors of the *NPN* and *PNP* variety are used in the projects that follow. They are called *bipolar* transistors, since they are made from *N*-type and *P*-type semiconductors, through which electricity flows mostly by negatively charged electrons, or mostly by positively charged holes, respectively.

The circuit symbols for these two transistors are shown in Fig.1.6 and identify the emitter (E), base (B) and collector (C) terminals. Thus, *NPN* and *PNP* transistors can be considered as comprising two diodes connected as shown. Once you have this structure in mind, you can identify whether a transistor is *NPN* or *PNP* by using the Circuit Tester, as you did for the LED above.

All you need to do is to find the colour of the crocodile clip that, when attached to one of the transistor terminals, causes the LED on the Circuit Tester to light up when the black clip is attached to the remaining two terminals in turn. This would then be an *NPN* transistor and the red lead identifies the base terminal. If it is a *PNP* transistor, the black lead identifies the base connection if the red lead causes the LED to light up when it is attached to the remaining two terminals.

This simple test does not identify which of the remaining transistor terminals are the collector or the emitter.

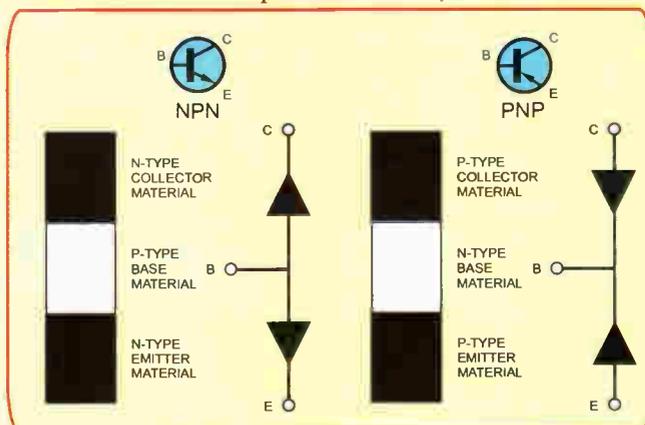


Fig.1.6: Symbols for bipolar transistors, and their representation as two coupled diodes

## Project 2: Rain Check Circuit

**T**HIS project requires only a handful of components and is an ideal introduction to the use of a Protobloc for assembling a working circuit. The circuit is shown in Fig.1.7. It acts as an electronic switch turning on a buzzer, WD1, when water wets a simple sensing device, X1.

Thyristor CSR1 is the main semiconductor in the circuit. This has three leads, cathode (K), gate (G) and anode (A). These leads must be connected to the buzzer, the battery and the rain sensor as shown.

The 'component info' panel shows how to identify the anode and cathode terminals of the LED (LED1), and also the connections to the thyristor. If it is

### Component Info

This is a TO92 package. Viewed as shown with the flat side facing and the pins pointing down, the terminals are from left to right: cathode, gate, and anode.



CSR1, thyristor type 2N5060

The longer lead is the anode, the shorter lead is the cathode. The anode lead is connected to the positive power supply line, as shown in the circuit diagram.



LED1, red light-emitting diode

It does not matter which way round these resistors are connected. Their values are colour-coded.



Resistor R1 and R2.  
R1 1kΩ brown, black, red, silver  
R2 220Ω red, red, brown, silver

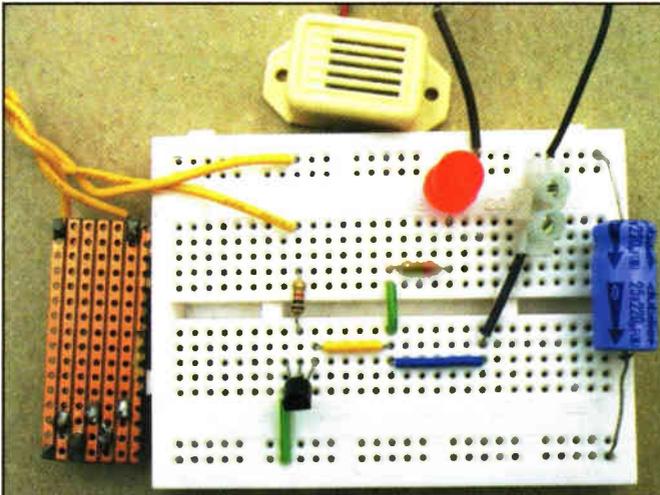
Use the centre pole and either of the other two connections to make an on/off switch.



Switch S1

## Components needed...

- Thyristor, CSR1:** type 2N5060 in a TO92 style package
  - Resistors, R1 and R2:** values 1k $\Omega$  and 220 $\Omega$ , respectively both 1/4W, carbon film
  - Buzzer, WD1:** operating voltage 6V
  - Relay, RLA:** low voltage 5V or 6V type, single-pole changeover
  - Capacitor, C1:** axial electrolytic, 220 $\mu$ F, 25V
  - Switch, S1:** single-pole single-throw (SPST) (optional)
  - Sensor, X1:** stripboard, approx 16 holes  $\times$  7 holes.
- Also, see Notes
- Battery, B1:** 9V and connecting leads
  - Protobloc and wire links**



**Layout of components for the Rain Check breadboard. The rain sensor is made from a piece of stripboard**

not clear from the relative lengths of these leads which are the anode and cathode terminals, use the Circuit Tester as described earlier to identify them.

The 'component info' panel shows the TO92 package thyristor. Viewed as shown, with the flat side facing and the

pins pointing down, the terminals are from left to right: cathode, gate, anode – see Fig.1.8.

The longer LED lead is the anode, the shorter lead is the cathode. The anode lead is connected to the positive supply line, as shown in Fig.1.8

The circuit can be regarded as made up of three interlinked building blocks. Building block one is the sensor, X1; building block two is the switch, based on CSR1; and building block three is the output, which is the visual signal provided by LED1 and the audible signal provided by WD1.

Sensor X1 is made as described in the Notes. When the gaps between the conducting strips become wet, the

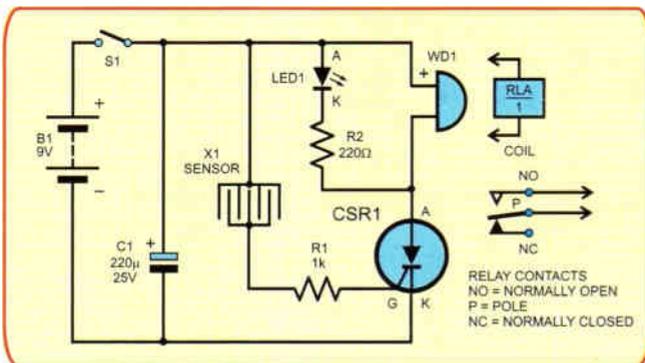
electrical resistance between the conducting and non-conducting parts of the sensor falls. This causes the voltage to rise on the gate terminal, switching on the thyristor. Current then flows through the buzzer, which continues to sound until opening and closing switch S1 resets the latch.

First you will need to dry the sensor, of course! Switch S1 can be any single-pole single-throw (SPST) type. For the Protobloc assembly, S1 is not essential because the circuit can be reset by unplugging and reinserting one of the battery leads.

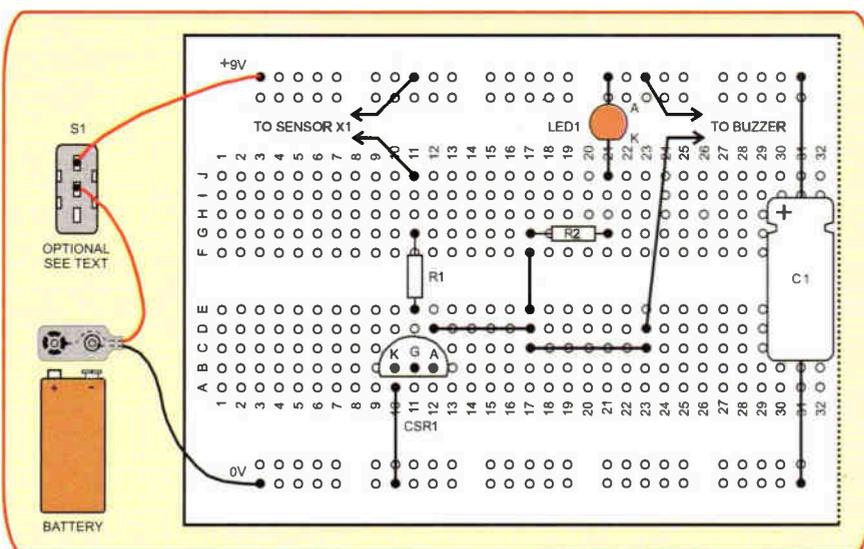
### Notes

- Make the sensor from a small piece of stripboard, linking alternate copper tracks using short lengths of wire to provide an interleaved set of tracks – see photo.
- You will find that bridging the strips with your lightly moistened finger tip will switch on the buzzer – and there you have a Touch Switch!
- A low voltage relay connected in place of the buzzer is optional, but allows you to control more current than the thyristor is capable of providing
- **Do not use the relay to switch mains-operated devices**
- Capacitor C1 connected across the supply lines ensures that the thyristor switches on and off cleanly by stabilising the supply voltage
- Use the Circuit Tester to show the fall in resistance of the sensor when it becomes wet. Remove the sensor from the circuit. Attach the crocodile clips to the sensor leads when the sensor is dry, then moisten the sensor and watch the LED on the Circuit Tester brighten, indicating a gradual lowering of resistance between the tracks of the sensor.

**Next Month:** A simple Dark Switch and Moisture Monitor Mk.1



**Fig.1.7: Circuit diagram of the Rain Check**



**Fig.1.8: Breadboard layout for the Rain Check**

# Ingenuity Unlimited

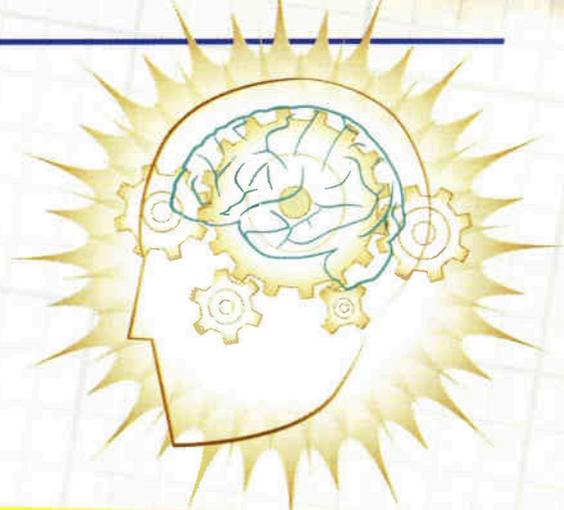
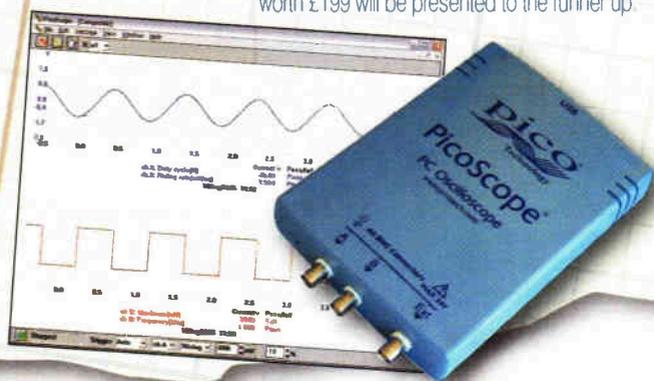
Our regular round-up of readers' own circuits

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The circuits shown have NOT been proven by us. Ingenuity Unlimited is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. Please draw all circuit schematics as clearly as possible. Send your circuit ideas to: Ingenuity Unlimited, Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. Email: [editorial@epemag.wimborne.co.uk](mailto:editorial@epemag.wimborne.co.uk). Your ideas could earn you some cash and a prize!

## Super Simple Counter – Neat Motoring

THE 'simple' counter must be one of the more sought-after electronic circuits. Yet even the simplest such circuit tends to have a daunting level of complexity.

With this in mind, the circuit in Fig.1 provides an unusually simple solution. This uses a cheap analogue quartz clock as a display, and an exceptionally simple driver to provide the required pulses for the quartz clock's tiny stepper motor.

### How it works

IC1, a dual D-type flip-flop, wires two simple divide-by-two circuits in parallel, so that the Q and Q-complement outputs reverse each time a binary input at pins 3 and 11 goes both high and low. This parallel arrangement is necessary to provide the necessary current for motor M1.

The critical aspect of this circuit lies in the driver for stepper motor M1 when the voltage reverses across Q and Q-complement. Motor M1 is effectively powered by the charge on capacitors C2 and C3, through current limiting resistor R1.

It is hard to depict the waveform that is needed to drive motor M1. This requires that the motor should ordinarily be 'neutral', with positive-negative/negative-positive pulses activating M1 alternately. Resistor R1 and capacitors C2/C3 see to it that pulses of a tenth of a second ( $t = CR$ ) are applied to motor M1. If the stepper motor fails to advance decisively, the values of C2 and

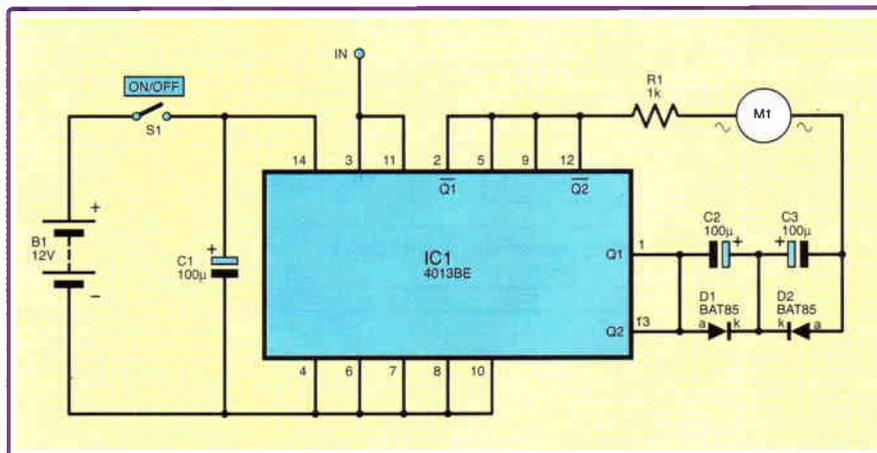


Fig.1. Circuit diagram for the Super Simple Counter

C3 may be increased, or (less advisedly) the value of R1 decreased.

When the output voltage from IC1 pins 1 and 13 goes negative, capacitor C2 charges while C3 is by-passed through diode D2. Thus, when the output flips to positive, C2 is by-passed through D1, and C3 charges.

To be more precise, when the negative potential on pins 1 and 13 is applied to C2, it charges the electrolytic by sinking current through M1, while simultaneously pins 2 and 12 positive output fully charges C2 through R1, M1, and D2. The resulting current pulse energises the motor and advances its movement.

Once IC1 'flops', output pin 1 reverses to positive polarity, setting off a sequence of events. Capacitor C2, already charged from the previous pulse cycle, momentarily adds its charge to C3, just before diode D1 conducts to shunt by-pass capacitor C2, doubling the drive voltage to M1, and advancing the motor once more. This sequence of events continues between C2 and C3, interacting with D1 and D2 whenever the output reverses polarity.

As simple as it is, this circuit should effortlessly count the attendance at a major soccer match, or the number of people attending a major convention centre over



## Regulator overload protection

Recently *Neroku* posted the following question about overload protection of linear voltage regulators on the *EPE Chat Zone* forum (access via [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk)):

We all know 78XX series regulators are virtually indestructible due to the following features:

- 1) Thermal shutdown
- 2) Current limiting
- 3) Short circuit protection

Well, my question is – if the current limiting circuitry is the same as the short circuit protection (ie, when the output of such a regulator is shorted, the current is limited by the device) then has this something to do with foldback current?

This month, we will look at the topic of regulator overload protection, looking at some of the concepts mentioned or implied by *Neroku's* question: namely, current limiting, safe operating area and foldback.

### 78XX series regulators

The 78XX series regulators have been around for many years. These are generic devices available from a number of semiconductor manufacturers, who still have them in full production at the time of writing (eg Fairchild ([www.fairchildsemi.com](http://www.fairchildsemi.com)) and ST microelectronics ([www.st.com](http://www.st.com))). However, National Semiconductor ([www.national.com](http://www.national.com)) describes the LM78XX series as discontinued, having been replaced with the LM340 series; although they still mention the LM78XX devices in the LM340 datasheet.

The XX in the name indicates the regulated output voltage. Values of 5, 6, 8, 9, 12, 15, 18 and 24V are available. The typical circuit for these devices is shown in Fig.1 and a typical package and pinout are shown in Fig.2. Note that 78XX series regulators are available in a variety of packages, so you should always check the pinout for the package you have on the manufacturer's datasheet before using it.

In Fig.1, capacitor  $C_1$  is required if the regulator is located a significant distance from the power supply filter capacitors or if the output load capacitance is large. A tantalum, mylar or other capacitor types with low impedance at high frequencies should be used. It should have short leads and be located as close to the regulator as possible. Capacitor  $C_0$  is not usually

essential, but improves stability and transient response.

The 78XX series of regulators are generally stable and do not have such critical capacitance requirements as the more modern low dropout (LDO) devices. However, in comparison with LDO devices,

they require a larger input-to-output voltage difference and hence are less efficient.

A simplified version of the internal circuitry of a basic linear regulator is shown in Fig.3. The regulator controls the current supplied to the load in such a way as to keep the supplied voltage (regulator output

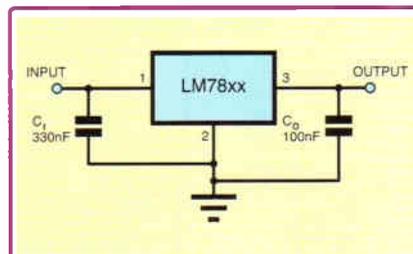


Fig.1. Standard circuit diagram for LM78XX series regulators

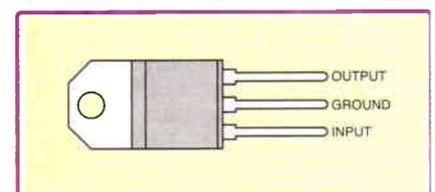


Fig.2. The LM78XX pinout connections for a common TO-220 package

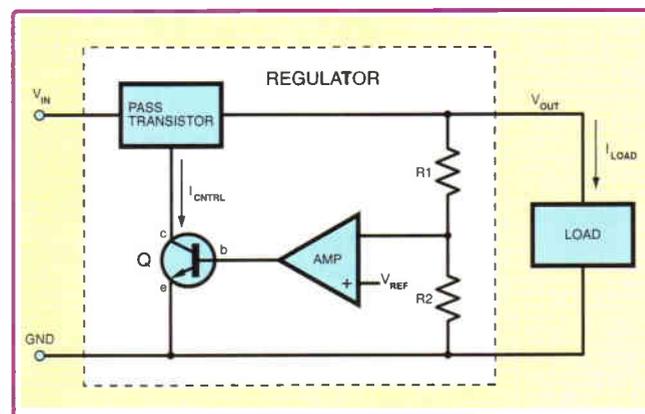


Fig.3. Typical circuit schematic for a linear regulator

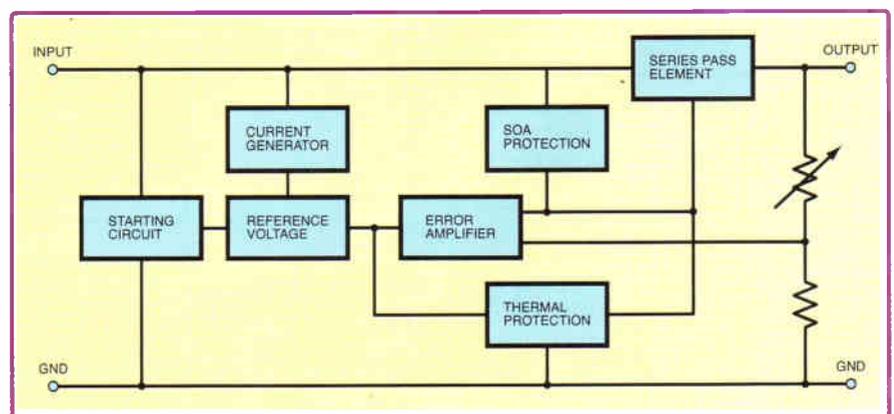


Fig.4. Block schematic diagram for the LM78XX series regulators. Based on Fairchild Semiconductor datasheet ([www.fairchildsemi.com](http://www.fairchildsemi.com))

voltage,  $V_{OUT}$ ) constant. The regulator contains a potential divider which produces a fixed fraction of the regulated supply voltage. This is compared to the fixed reference voltage. If the output voltage decreases, the amplifier output will increase because the potential divider is connected to the inverting input.

The increased output voltage will increase the control current to the pass transistor and hence the current to the load, which will tend to increase the output voltage and offset the initial decrease. This negative feedback loop will keep the potential divider voltage equal to the reference voltage and hence keep the output voltage fixed as the load varies. Fig.3 does not include any overload protection circuitry.

## Safe operating area

In Fig.4 is shown a block diagram for the LM78XX series regulators. Notice that it contains both safe operating area (SOA) and thermal protection blocks.

If the regulator is overloaded or its output is shorted, the safe operating area (SOA) circuit will take it into constant-current mode (in which the output voltage is reduced to maintain a constant load current, hence limiting dissipation). Even with this protection the regulator may overheat; what happens will depend on the ambient temperature and the size and quality of regulator's heatsink (if there is one).

If the regulator reaches its maximum temperature, the thermal protection will then operate, reducing the load current. Reducing the load current will reduce the heat dissipated by the regulator, so that the circuit will reach a point of balance between the dissipation tending to heat it up and the protection circuit winding down the supplied current to reduce the power passed.

The safe operating area, or more specifically, Forward Biased safe operating area (FBSOA) curves for power transistors are used to show the maximum safe voltage and current combinations for both continuous and pulsed operation. An example is shown in Fig.5, which is based on the SOA curves for a TIP41C NPN epitaxial silicon general purpose power transistor from a Fairchild Semiconductor datasheet ([www.fairchildsemi.com](http://www.fairchildsemi.com)).

In Fig.5 the green shading indicates the safe continuous operation at the specified

temperature. The red area is the unsafe area, where device degradation or destruction will occur.

The amber area is safe only for short periods of time, as specified on the curve; for example, although the maximum continuous collector current at  $V_{CE} = 5V$  is 6A. The device can handle collector currents of 10A for periods under 5ms.

For a linear regulator, it is the SOA of the main pass transistor within the series pass element (see Fig.3 and Fig.4) which is of primary concern. The protection circuitry attempts to keep this transistor within the safe operating area.

## Power dissipation

The SOA curve alone is not sufficient for a designer to determine safe device operation. The curve is specified at a particular operating temperature, usually 25°C. At higher temperatures, the power handling of power transistors decreases. This is described on the datasheet using a derating curve. The device operating temperature can be estimated from the power dissipation and thermal properties of any heatsink structures, or other cooling, employed to remove heat from the device.

The power dissipated under worst-case conditions, such as output short circuit conditions, can be relatively large compared to normal operation. This means that despite the regulator's current limiting circuitry it may overheat.

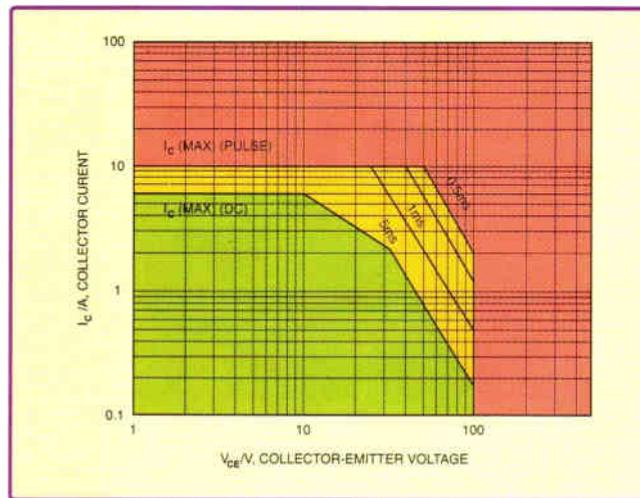


Fig.5. Typical bipolar power transistor safe operating area (SOA) curve. (TIP41C, from Fairchild Semiconductor datasheet – [www.fairchildsemi.com](http://www.fairchildsemi.com))

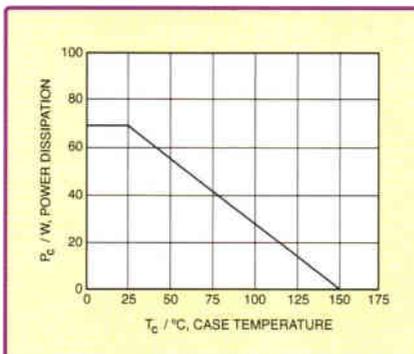


Fig.6. Typical bipolar power transistor (TIP41C, see Fig.5) power derating curve

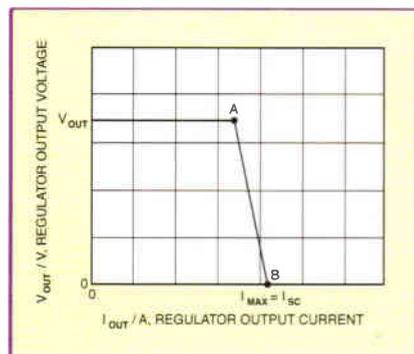


Fig.7. Regulator output voltage against load current, with basic current limiting

One solution is to make the heatsink much larger (possibly by a factor of three or more), but this is often not very practical or economical. Another approach is to use 'foldback' current limiting, which pulls down the output voltage under overload conditions to reduce the short circuit output current to a fraction of the full load current.

## Current limiting

We will now move on to look at current limiting, in both basic and foldback form. We will discuss the basic principles rather than looking at what is implemented in any particular regulator. For that information, consult manufacturers' datasheets and application notes.

The graph in Fig.7 shows the output voltage against output current for a regulator with basic current limiting. If the load resistance is steadily decreased, the voltages remain constant as the current increases due to the regulator's action.

Once the current limit is reached (point A on the graph) further decreases in load resistance will result in reduced output voltage. The current remains almost constant even as the load resistance is reduced to zero (regulator output short circuit). This is point B on the graph, which corresponds to both the maximum output current and the short circuit current.

When  $V_{out}$  is zero the voltage drop across the regulator is equal to the input voltage  $V_{in}$ . Thus the power dissipation at point B is much larger than at A where the current is similar, but the voltage drop is only  $V_{out} - V_{in}$ . Thus the short circuit power is much larger than normal operating power.

If foldback is used, the output current is reduced in overload conditions. This is illustrated in Fig.8 and results in a short circuit current (point B on the graph) which is much lower than the maximum operating current (point A on the graph). The reduced short circuit current results in a lower dissipation under overload conditions even though the full input voltage is across the regulator.

## Current limiting

Fig.9 shows a basic current limiter circuit for a linear regulator. The schematic shows the regulator's series pass circuit (which contains the power transistor Q1), but does not include the rest of the control and regulation circuitry as shown in

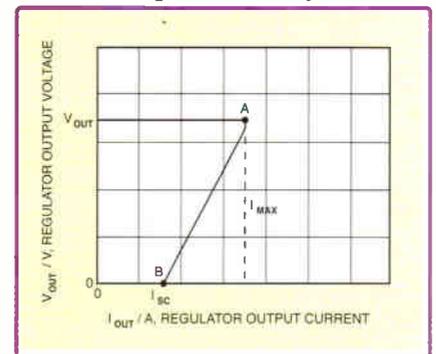


Fig.8. Regulator output voltage against load current, with 'foldback' current limiting

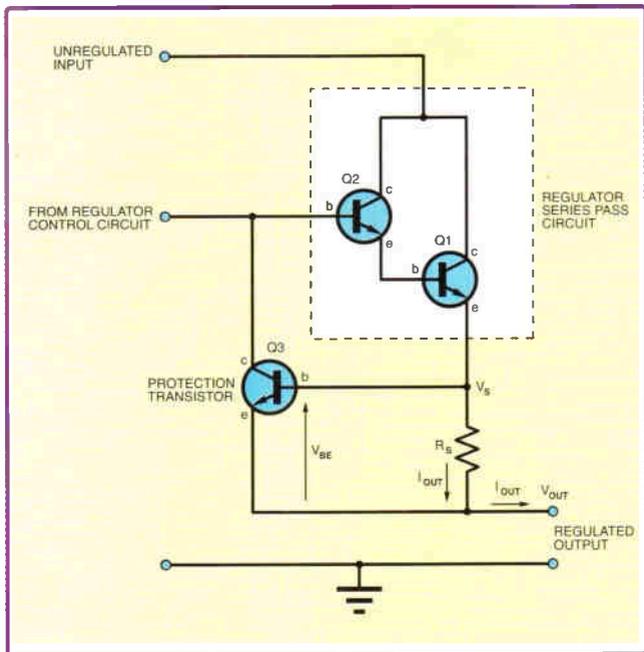


Fig.9. Circuit diagram to illustrate the basic current limiting protection

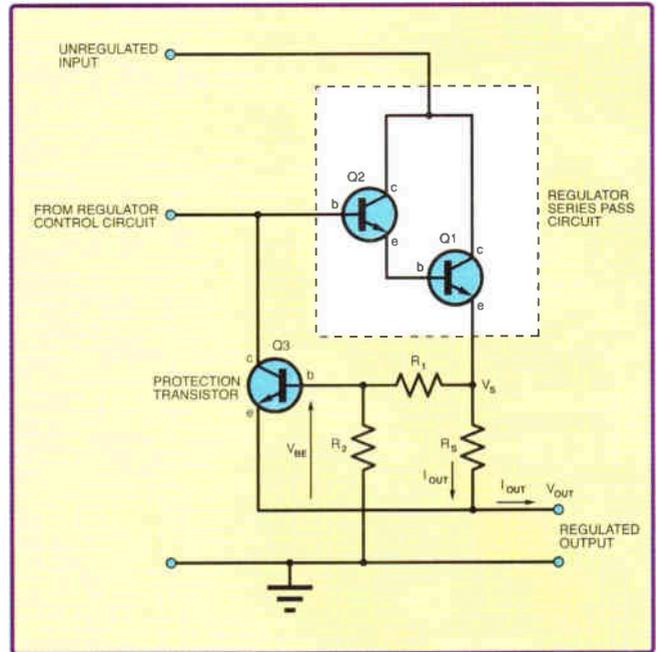


Fig.10. Circuit diagram to illustrate the concept of 'foldback' current limiting

Fig.3. The protection circuitry comprises a (low value) sense resistor,  $R_S$ , and transistor Q3.

The output current from the regulator flows through the sense resistor, creating a voltage drop, which is applied to the base-emitter junction of Q3. If the output current,  $I_{OUT}$ , is large enough, the voltage dropped across  $R_S$  will be sufficient to turn on Q3, which will 'steal' base current from Q2, resulting in reduced output current. Any tendency to further increase  $I_{OUT}$  will turn Q3 on further, which in turn will tend to reduce  $I_{OUT}$ .

Once Q3 is on, the output current will remain approximately constant. Any decrease in load resistance under these conditions will therefore reduce the output voltage rather than it being held at the regulated value. Therefore, the behaviour of this circuit corresponds with the graph in Fig.7.

The current limit,  $I_{OUT,MAX}$ , and output short circuit current,  $I_{OUT,SC}$ , are found by applying Ohm's law to  $R_S$ :

$$I_{OUT,SC} = I_{OUT,MAX} = \frac{V_{BE}}{R_S}$$

### Foldback current limiting

The circuit in Fig.10 can be used to illustrate the fundamentals of foldback current limiting. The circuit is similar to the basic current limiter, but with the addition of a potential divider linking the sensing resistor  $R_S$  to the protection transistor Q3.

For the circuit in Fig.10, the voltage at the base of the protection transistor is equal to  $V_{OUT}$  plus the protection transistor's  $V_{BE}$  drop. It is also equal to the potential divider output voltage from the potential divider formed by resistors  $R_1$  and  $R_2$  supplied by the voltage at the sense resistor,  $V_S$ . So we can write:

$$V_{OUT} + V_{BE} = \left( \frac{R_2}{R_1 + R_2} \right) V_S$$

Now  $V_S$  is equal to  $V_{OUT}$  plus the voltage dropped by the output current flowing through the sense resistor, that is  $V_S = V_{OUT} + I_{OUT}R_S$ . Substituting this in the above we get:

$$V_{OUT} + V_{BE} = \left( \frac{R_2}{R_1 + R_2} \right) (V_{OUT} + I_{OUT}R_S)$$

We can rearrange the above equation to make  $I_{OUT}$  the subject. First multiply through by  $(R_1 + R_2)$

$$\begin{aligned} (R_1 + R_2)V_{OUT} + (R_1 + R_2)V_{BE} \\ = R_2V_{OUT} + R_2R_S I_{OUT} \end{aligned}$$

The  $R_2V_{OUT}$  terms cancel:

$$R_1V_{OUT} + (R_1 + R_2)V_{BE} = R_2R_S I_{OUT}$$

Swap sides and divide through by  $R_2$

$$R_S I_{OUT} = \left( \frac{R_1}{R_2} \right) V_{OUT} + \left( 1 + \frac{R_1}{R_2} \right) V_{BE}$$

Divide through by  $R_S$

$$I_{OUT} = \frac{1}{R_S} \left[ \frac{R_1}{R_2} V_{OUT} + \left( 1 + \frac{R_1}{R_2} \right) V_{BE} \right]$$

In this equation,  $V_{BE}$  is the voltage at which the protection transistor Q3 starts to turn on; the corresponding value of  $I_{OUT}$  is the maximum output current minus the current at which the protection circuit starts to take control of the output. Under these conditions  $V_{OUT}$  is at the regulated output voltage,  $V_{REG}$ , at point A on Fig.8, where we get the maximum output current:

$$\begin{aligned} I_{OUT,MAX} \\ = \frac{1}{R_S} \left[ \frac{R_1}{R_2} V_{REG} + \left( 1 + \frac{R_1}{R_2} \right) V_{BE} \right] \end{aligned}$$

When  $V_{OUT}$  is zero we get the short circuit current, at point B on Fig.8:

$$I_{OUT,SC} = \frac{1}{R_S} \left( 1 + \frac{R_1}{R_2} \right) V_{BE}$$

The ratio of  $I_{OUT,MAX}$  to  $I_{OUT,SC}$  sets the amount of foldback, typically  $I_{OUT,SC}$  is around one third of  $I_{OUT,MAX}$ .

Thus, in answer to Neroku's question, current limiting is closely related to short circuit current and foldback does indeed control the short circuit current, but not all regulators necessarily use foldback. As always, you need to check the datasheet for details of device operation. Current limiting circuits very similar in principle to those described here are also used to protect the output stages of power amplifiers.

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## Interfacing PICs to the Internet via Ethernet – Part 2

Last month, we gave a whistle-stop introduction to Ethernet and TCP/IP (transport control protocol/internet protocol), and why it might be of interest to the hobbyist. In later articles we will go into the nuts and bolts of these protocols, but for now we will concentrate on the IC that provides the capability to connect our microcontroller designs to the Internet – namely, the ENC28J60.

### ENC28J60

The ENC28J60 was the first – and possibly still the only – easy to use Ethernet interface IC. There are plenty of Ethernet controller ICs on the market, and many have found their way into small embedded designs. Devices such as the Realtek RTL8039 and the Cirrus Logic CS8900 have been available for many years.

These devices, while requiring only a few additional passive components to create a fully functioning interface, provide a complex connection to a microcontroller – or were only available in difficult to solder fine pitched flat packages. Microchip presumably realised that there was a market for an even simpler part that could be used by the rest of us, and the ENC28J60 was born.

Like the devices from Realtek and Cirrus Logic, the ENC28J60 requires only a few additional low-cost passive components to create the full Ethernet Interface. Unlike those other parts, however, it uses a simple four-wire SPI interface to the microcontroller. That's an interface which is easy-to-use, supported by many processors directly or can be easily 'bit-bashed' in software. And the final major plus point: it is supplied in a simple SO28 surface mount package, and even the venerable dual-in-line package. It operates at 3.3V, but can interface to a 5V microprocessor using a cheap logic level converting IC.

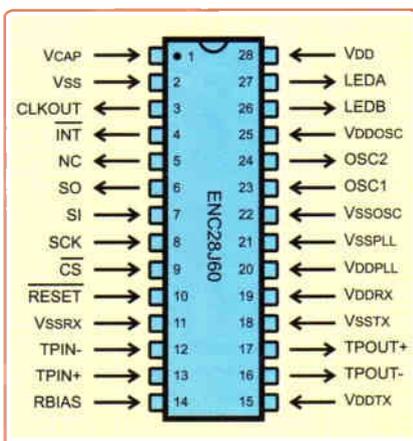


Fig.1. Microchip's ENC28J60 pinout details

Fig.1 shows the pinout of the device. While many of these pins may appear unfamiliar, most of them are related to the analogue interface, which we can ignore for now. There are only five pins required to be connected to the processor:

- SO SPI data out
- SI SPI data in
- SCK SPI clock in
- /CS Chip select in
- INT Interrupt out

Plus the power supply pins, of course.

The INT signal is an optional interrupt to the processor, which can be ignored if you 'poll' the status of the device to find out if received data packets are present. The Microchip Stack software ignores this pin, so we can ignore it too.

There is also a RESET input signal which will reset the chip, but this can be wired to the positive supply with a resistor in most cases. Once again, the Microchip Stack software assumes this pin is hard-wired, so we can do the same. If you want more fault tolerant control of your interface (ie, to be able to reset the device should you lose communications with it) then simply connect it to an output pin on your processor.

So what about the other pins? These connect to the analogue interface components. Microchip provides an example circuit in the datasheet, but our circuit, shown in Fig.2, is slightly different. One of the key components required on an Ethernet interface is a pulse transformer, which isolates the circuit from the Ethernet wiring. This provides a level of noise immunity and also isolates your electronics from the signals on the wires.

While you can purchase a basic transformer for this purpose, many suppliers provide a connector with the transformer and some key components already fitted – including two LEDs that provide status information about the Ethernet link. These connectors are not expensive, relatively easy to obtain and reduce the component count even further. With one of these 'integrated magnetics' connectors, the circuit design becomes one of the simplest you are likely to ever build!

### Ethernet interface circuit

The circuit in Fig.2 implements everything you need to connect a microprocessor to an Ethernet interface, and therefore onto the Internet, directly through a broadband modem or router. There are three aspects of the circuit that need careful attention, however.

First, you should try to obtain fairly accurate resistors for those 49.9Ω parts,

50Ω will do, but they must be 1% tolerance devices. These resistors can affect the DC balance of the Ethernet wires, which might upset other devices on the network if they are not accurate. If in doubt, use a multimeter to select appropriate values.

Second, the inductor in the circuit is there for reducing noise within the circuit. The output signals generated by the ENC28J60 are quite 'hard' and can create a lot of high frequency noise, but for a hobbyist circuit you can simply replace the inductor with a wire link.

Finally, be careful when purchasing the 'integrated magnetics' connector. There are many variants, and not all are suitable for this device. We used the MagJack SI-50001 by Bel Stewart, which worked well. Look at the datasheet of other parts carefully before selecting an alternative.

### Features

The ENC28J60 provides a number of features in a single package. It provides the physical interface (PHY in interface terminology) which translates the digital signals to the required electrical signals. In addition, the media access controller (MAC) which translates our data that we want to send into an appropriate Ethernet data structure, and performs address recognition and error detection. It also provides an 8KB SRAM buffer that will hold our transmit and receive data.

That final point is important. The Ethernet interface operates at 10M bits per second, which can be a little too fast for our processor to cope with. If we had to process each byte as it came in, our software would simply run out of time processing the information and critical data bytes would get lost or overwritten.

The 8KB buffer on the chip itself allows the chip to receive several data packets, store them in RAM and simply make us aware that the data is available for reading at our leisure. The buffer can also store transmission data that we write into it, and send the packet in its entirety when we send a final 'transmit' message to the chip.

The way the chip manages the 8KB buffer is through *Buffer Descriptors*. This is just a fancy pair of words for a data structure; the RAM is organised into blocks of data with a number of bytes at the front which contains information about the size and status of the block. When packets are received, the header of the buffer descriptor is updated to indicate that the buffer contains unread received data.

Our microcontroller can 'poll' these fields, find buffers with data in them and read the

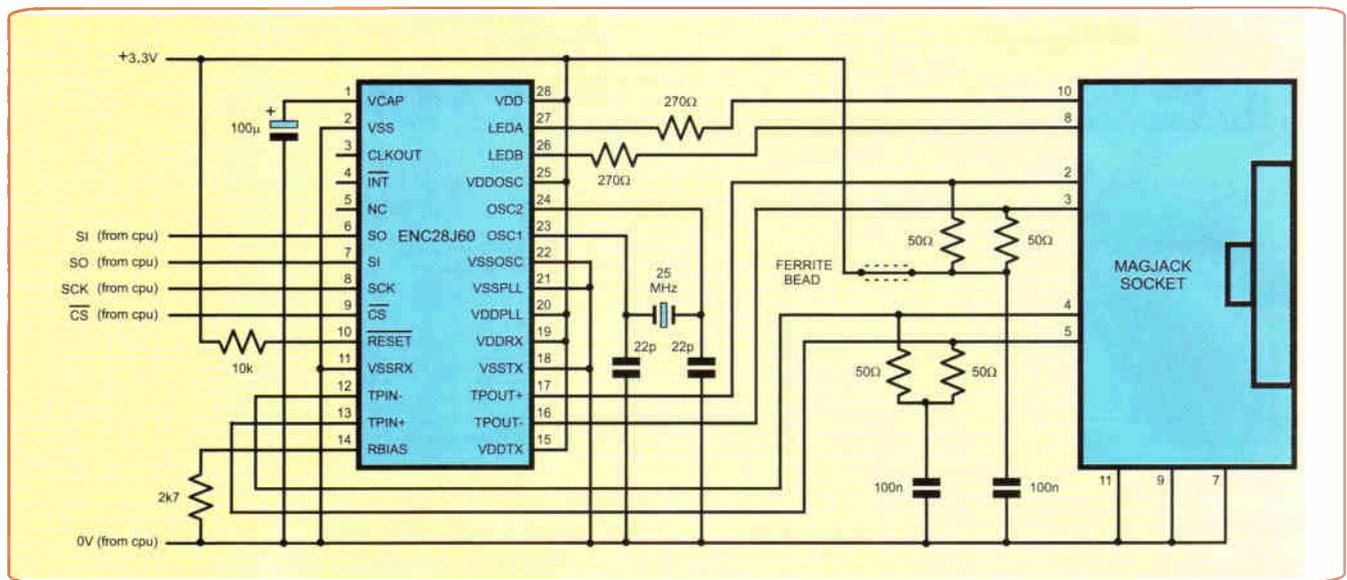


Fig.2. Ethernet interface circuit diagram

data out at our leisure. When we have done so, we set a bit in the header to indicate that the buffer is now free, and the buffer becomes available for the chip to again store incoming messages. We don't need to worry about the detail of this; the Microchip Stack software takes care of it for us.

It is, however, important to read incoming data as quickly as possible – otherwise, other incoming packets (perhaps a simultaneous request for a web page from another user) might be discarded. The TCP/IP protocol will cope with this situation though, as the remote user's web browser will automatically resend the request.

If several requests get lost due to the slow speed with which you read data out of the chip's memory, then it is possible that the user's web browser will report an error with the connection. The moral of the story is: if you are expecting a lot of simultaneous access to your device, then use a fast processor. Just how fast is a difficult question to answer. We will be using a PIC18F2620 running at 40MHz, and only time will tell how that will perform. And that will be something you can judge for yourself – more about *that* next month.

## Stack software

As we mentioned last month, the software required to implement the TCP/IP interface is quite complex, but fortunately for us Microchip have written the software already and provide it to us free of charge. You can download it from the Microchip website – see the link at the end of the article.

The stack software is supplied as a simple installation program. Once you have downloaded it, run it, and the source code is installed by default to C:\Microchip Solutions. The installation consists of a help file and a number of source files, plus several MPLAB workspace project files, which enable you (if you have already installed the latest MPLAB and C18 C compiler) to build example source code immediately. These files are rather general purpose and support a number of different processors and hardware setups, which can be quite confusing. We will demystify this next month.

The software provides a number of additional protocols and Internet applications

that allow you to concentrate on the *content* of your web server or application, without having to delve too deeply into the protocols themselves. The software includes:

**Web Server:** The application that will 'serve' your web pages from your hardware to other users on the Internet

**Email Client:** Provides the ability for your device to send email messages to anyone on the Internet, all under program control

**TFTP Client:** Similar to the file transfer program FTP, enables your device to receive binary or text files, and store them

**DHCP Client:** Enables your device to be automatically configured with an IP address, from an Internet service provider or your home router device

**MPFS File System:** A set of software routines that provide a simple file system, which allows you to store individual files in external Flash or EEPROM memory; very useful for a Web server application that holds its web pages as a series of standard files. This means that you can create your web pages on a standard PC and easily download them into your device's Flash or EEPROM memory.

There are many other useful functions which may be enabled or disabled. Some of these will only be applicable if you have the appropriate hardware on your board (no point enabling UART functions if you don't have a serial port for example). Also, every feature or application included in your design will use up valuable program memory – so depending on the size of the processor you intend to use, you may have to cut down on the features you enable.

In the design we present next month we have used the PIC18F2620, a 28-pin PIC with 64KB of memory. This provides enough space for a web server and still leaving space for experimentation.

A software 'wizard' program is included to simplify selecting applications and features – in many cases you won't even need to edit the code itself.

## Other options

The ENC28J60 isn't the only Ethernet device manufactured by Microchip; they

now produce a number of microcontrollers with an Ethernet interface similar to the ENC28J60 built in. This can reduce the chip count from just two to the minimal one.

You might be wondering why we haven't used one of those in this design. The reason is simple – the ENC28J60 is an interface IC that can be connected to any processor, with whatever additional features that you want. It's still worth considering the combined PIC plus integrated Ethernet interface to see if it suits your needs, but the ENC28J60 provides a great deal of flexibility and is a relatively simple introduction to Ethernet interfacing.

Of course, you are not limited to Ethernet for connecting to the Internet; serial interface protocols such as SLIP and PPP can also be used, which require nothing more than a MAX232 voltage level converter. Unfortunately, you will have to connect it to a PC already connected to the Internet, or hook it up to a dial-up modem.

The ENC28J60 is available from several hobbyist-friendly suppliers, including Digikey and Farnell. The 'integrated magnetics' connector that we used in this example is the MagJack SI-50001, available from Farnell. Don't forget, you will require an Ethernet cable, an RJ45 to RJ45 lead. These are often supplied with broadband routers, but can also be purchased from most high street computer retailers. If you intend to connect the ENC28J60 to your PC directly, you will need a 'crossed over' cable, just like with RS232 leads. For connecting to a router a standard 'straight through' cable is required.

Next month, we will describe the processor side of the equation, explain how to adapt the Microchip Stack software to our needs and present a live, working example.

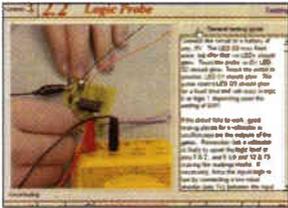
## References

Microchip Stack software: [http://ww1.microchip.com/downloads/en/DeviceDoc/Microchip\\_TCIPIP\\_Stack\\_v4.51\\_Installer.zip](http://ww1.microchip.com/downloads/en/DeviceDoc/Microchip_TCIPIP_Stack_v4.51_Installer.zip)

ENC28J60 datasheet: <http://ww1.microchip.com/downloads/en/DeviceDoc/39662c.pdf>

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## ELECTRONICS PROJECTS



Logic Probe testing

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The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

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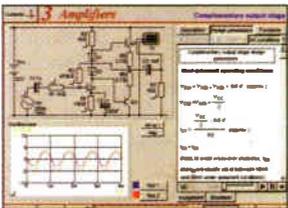


Circuit simulation screen

*Electronics Circuits & Components V2.0* provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: **Fundamentals:** units and multiples, electricity, electric circuits, alternating circuits. **Passive Components:** resistors, capacitors, inductors, transformers. **Semiconductors:** diodes, transistors, op amps, logic gates. **Passive Circuits. Active Circuits. The Parts Gallery** will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.

Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

## ANALOGUE ELECTRONICS

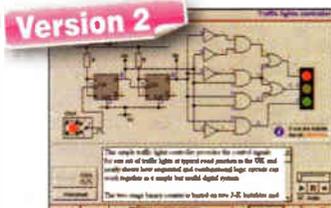


Complimentary output stage

*Analogue Electronics* is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

Sections on the CD-ROM include: **Fundamentals** - Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections), **Op Amps** - 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** - Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** - Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** - 6 sections from Positive Feedback to Crystal Oscillators. **Systems** - 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

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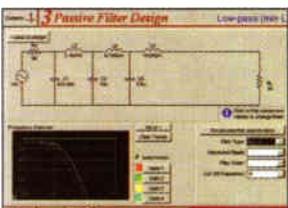


Virtual laboratory - Traffic Lights

*Digital Electronics* builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

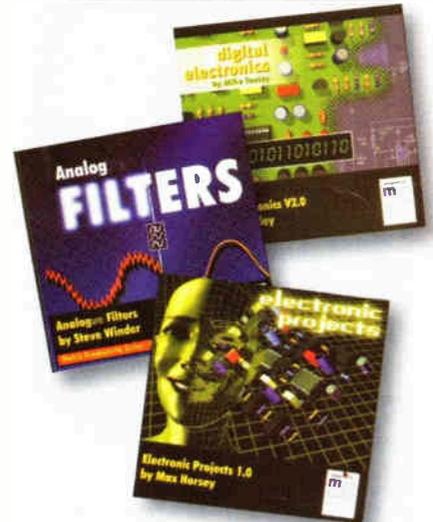
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables - including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors - architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

## ANALOGUE FILTERS



Filter synthesis

*Analogue Filters* is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.



## ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

*Robotics and Mechatronics* is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
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- Clear circuit simulations

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# PICmicro TUTORIALS AND PROGRAMMING

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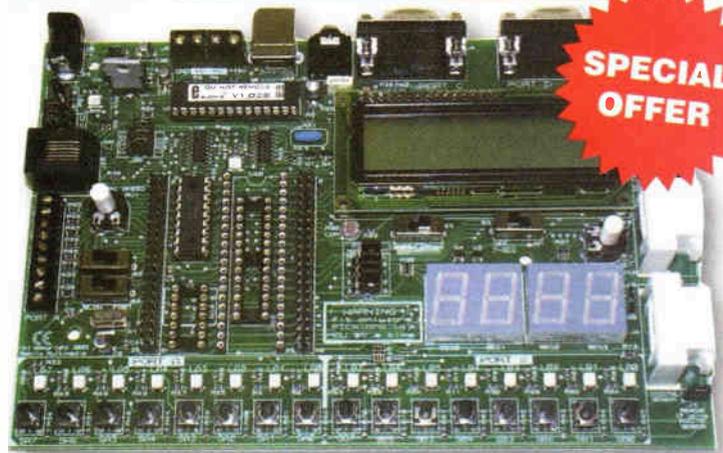
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- Supports low cost Flash-programmable PICmicro devices
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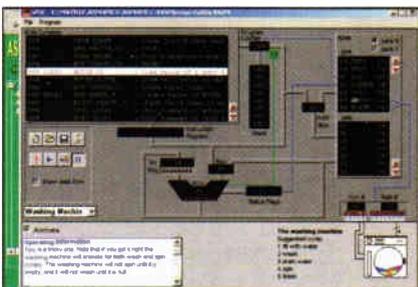
### ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

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

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

- Comprehensive instruction through 45 tutorial sections
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- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture and functions
- Expert system for code entry helps first time users
- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
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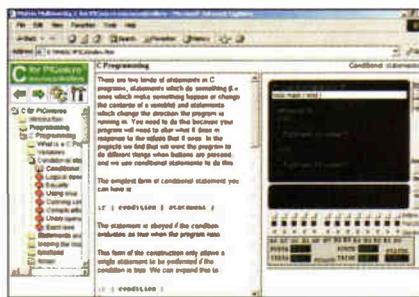


### 'C' FOR 16 Series PICmicro Version 4

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

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- Virtual C PICmicro improves understanding
- Includes a C compiler for a wide range of PICmicro devices
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Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.

- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- New features in Version 3 include 16-bit arithmetic, strings and string manipulation, improved graphical user interface and printing, support for 18 series devices, pulse width modulation, I2C, new ADC component etc. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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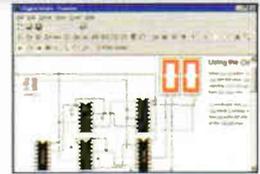
Flowcode V3 (Hobbyist/Student) – For details on Flowcode, see the previous page.

This offer gives you two separate CD-ROMs in DVD style cases – the software will need registering (FREE) with Designsoft (TINA) and Matrix Multimedia (Flowcode), details are given within the packages.

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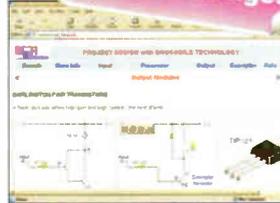
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# READOUT

Email: [editorial@wimborne.co.uk](mailto:editorial@wimborne.co.uk)

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



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All letters quoted here have previously been replied to directly

## ★ LETTER OF THE MONTH ★

### Linux and Ubuntu

Dear EPE

I have read Alan's *Net Work* column following the failure of two of my hard drives after installing Ubuntu. Graham Harby's letter in *Readout* (June'08) persuaded me to give Linux a go on my workshop computer, but I need Windows for my other software I chose to install Linux alongside Windows as a dual boot system.

Unfortunately, within an hour of running Ubuntu my hard drive failed. On inspection, I found that the chips on the underside of the drive had melted and the pins were no longer in physical contact with the chips.

Suspecting the fault was due to over heating, as well as installing a new hard drive I also fitted an additional system

fan. This seemed to fix the problem for a couple of days, until the DVD rewriter failed, followed shortly afterwards by the PSU. A new PSU and DVD drive were installed and the computer sprung back to life, but only for around fifteen to twenty minutes. The computer then abruptly shut down, no lights on the case and no fans running, just a message on screen saying 'NO SIGNAL'.

I've tested the PSU and it still works, so I guess that probably spells the end for that motherboard, although I haven't had time to check it over yet. Although probably not the only factor, given that my PC and Alan's were getting on a bit, overheating certainly seems to have played its part.

I had already installed it on my sister's computer and she hasn't had a single problem, the internet is much faster and with

all the bundled software there's everything for the kids doing their homework as well. To any other reader considering Ubuntu, I would make sure the data cables are tucked neatly aside so as not to prevent the air flow, not an easy task on my workshop PC due to the very compact case. If your case does not already have a system fan installed I'd recommend doing so.

All that said, once you have used Ubuntu on the net you'll probably not log on under Windows again. The difference in speed is quite astonishing.

Craig Patterson, via email

*Thanks Craig. Alan comments that it seems we have hit onto something with the Linux thing (he thought we might), and that it's hard not to let it take over!*

### DC Relay Switch

Dear EPE,

I was interested to see your project *DC Relay Switch* in August's *EPE*. May I suggest the following modifications:

1. Change the layout and the relay so that it can safely switch mains supplies.
2. Build in a supply of 12 volts powered from the mains voltage being switched. (You plainly have a plugpack fetishist on your staff).

With these changes it would be a useful piece of kit. In its present form it is a solution looking for a problem.

Sebastian Linfoot, via email

*Thank you Sebastian. The use of a plugpack means the unit is safe for the inexperienced to build and a note about switching mains is given in the box on page 24.*

### Tinplate

Dear EPE,

My memory might be playing tricks, but I seem to remember a request in *EPE* a while ago for a source of tinplate to make screening enclosures. Traditionally, a 'tin' food can is cut open to yield a piece of flat material that accepts solder. Recently, manufacturers have tended to add reinforcing pleats to the can, reducing the flat area to a useless proportion.

My old dad is still doing his own shopping despite being 86 (don't tell him I told you that!) and just came home with two varieties of canned fruit of the 'Del Monte' brand, the cans are completely smooth and presumably suitable for the purpose.

Godfrey Manning G4GLM, via email

*Thanks Godfrey – a useful tip it would seem (but we don't normally advertise food products in *EPE*!)*

### Free electricity?

Dear EPE,

If you wave a magnet over a coil of wire, electricity is generated. I wonder what would be the effect of laying cables in a road surface? Cars are magnetic, so they could produce an AC electric current of unknown frequency which could be rectified and stored in a capacitor for use to drive a 230V inverter.

If there is insufficient car magnetism to operate the system, perhaps people could be persuaded to have their car wheels magnetised, which should not affect the performance of the car.

The cables in the road would have to be laid at a slant so that all four wheels would not operate at the same time, since one may cancel out another, depending on the polarity of each magnet. Some roads have very high

traffic density so a lot of electricity would be generated.

As an alternative, what about the idea of having powerful magnets embedded in the road to allow electric vehicles with a pickup coil to recharge their batteries as they go along?

John K. Eley, Leicester

*Thank you John, unfortunately electricity generated in this way would not be free – the extra drag generated would use extra car fuel and the eventual cost would be quite high, but it might work on downhill sections where the increased drag would assist braking. However, you should read this month's Techno-Talk.*

### PIC and LCD Graphics

Dear EPE,

I really enjoyed the Dominoes section in *Teach-In 2008*, especially how to create your own LCD graphics using the CG RAM. I have always wanted to show a low battery graphic in my current project as I use low voltage detection on PortD.

Peter Barrett MIEAust, via email.

*Hi again Peter, I'm really pleased that you found the TI part so useful, and have done something worthwhile with it. It's good to know that I've helped people.*

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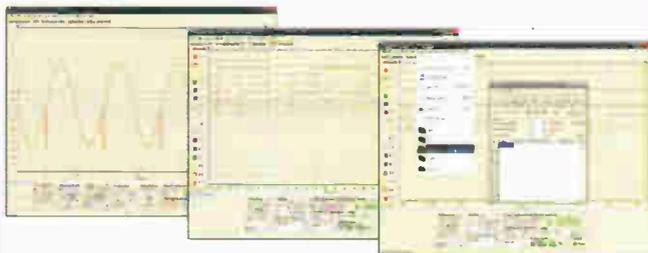
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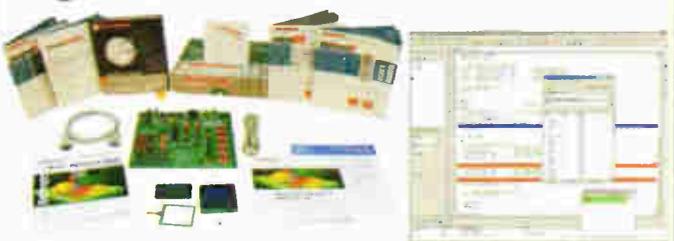
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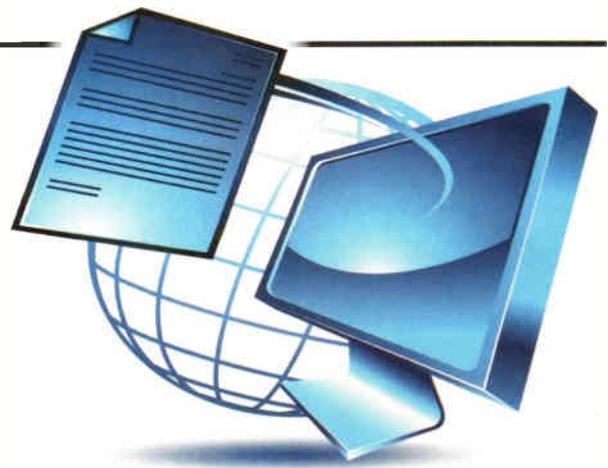
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# Net Work

Alan Winstanley



Last month, we introduced the Tracert command, a test that shows the route from your local system through to a chosen IP address. If your PC is connected to the Internet then Tracert is accessible via the command prompt in Windows XP (go Start/ Run/ cmd to launch a DOS prompt).

It is also a rapid way of checking whether a web server or mail server is currently available: for example, when a particular website was unavailable, typing `tracert www.[website address]` produced an error message:

```
C:\Documents and Settings\ARW>tracert www.[website].co.uk
Unable to resolve target system name www.[website].co.uk.
```

The same command helps to troubleshoot certain email problems: if, for some reason, it is not possible to fetch email in the normal way, then `tracert [mailserver address]` will at least determine if the server is available, and the tracert session will start by translating the server's address into its IP address. A typical POP3 mailserver has an address of `mail.mydomain.co.uk` or similar.

Don't be surprised, however, if 'timed out' errors are displayed after a short period. It is not uncommon for networks to return such an error and it does not necessarily mean that there is a network outage.

When several PCs are connected to a local area network behind a router, then the router adopts a unique IP address that is visible to the outside world. Fortunately, the router masks the IP addresses of the individual network PCs, and their IP addresses can be seen using the `ipconfig /all` command. A local IP address will appear as 192.168.2.1 or similar; also, the system's ethernet adaptor type will be shown. The screenshot shows that both an Intel ethernet card and a Bluetooth network adaptor are installed on the writer's PC.

There are many more arcane TCP/IP commands available that are of interest to network specialists, but some very useful web-based tools can be had for free or for a modest subscription. Sites including `www.dnsstuff.com` and `www.iptools.com` offer a variety of utilities

that Internet enthusiasts might explore, and `www.domaintools.com` is another versatile site to check over.

## WHOIS that?

So far we have discussed IP addresses and how nodes connected to the network each have a unique IP. The DNS (domain name server/system) translates a human-recognisable address into the corresponding IP address. However, if only the IP address is known, then a reverse DNS lookup can be used to find the 'English' name for that resource. DNS Tools offers such a service. Try using `www.ipchicken.com` to find your own IP address, and then paste that IP into the DNS Tools website, checking for the reverse lookup. The 'plain English' name for your Internet connection will be shown. It works for web or mail server IP addresses as well.

The web page will in fact display a single line '[IP address] resolves to [human readable address].' Clicking the IP address shown on DNS Tools launches another useful service: WHOIS.

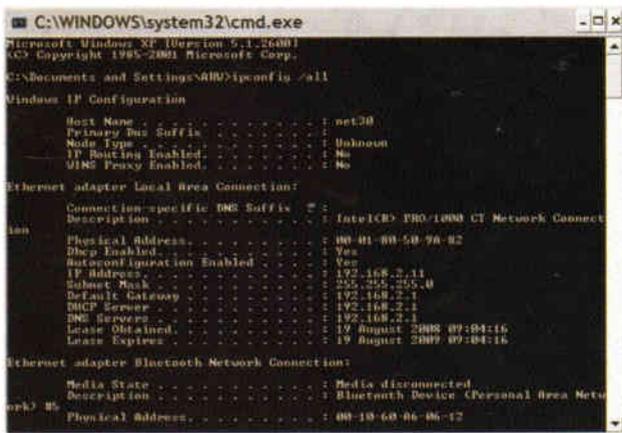
A WHOIS query reveals more details behind the ownership and configuration of a domain name. In the UK, domain names ending with `co.uk`, `org.uk` and others are ultimately managed by Nominet, so the obvious place to browse is the website `www.nominet.org.uk`. This web site is the sole UK authority for the registration of UK domain names. (Note, however, that it makes no sense to purchase a domain direct from Nominet: it is considerably cheaper to use a domain name seller such as `Easily.co.uk`).

To demonstrate WHOIS in action, type a complete domain name into the WHOIS search box on Nominet's website, excluding any 'www' prefix. The basic domain registration details will be given, including the ISP that is allocated to manage the domain (the IPS or internet provider security tag) and the 'nameservers', which is that part of the configuration that points the domain name to the providers of the mail and web services. Hence, it is possible to purchase a domain from one supplier, and point it to a second to handle web and mail services.

By simply typing this link `http://whois.domaintools.com/ebay.com` into your browser, a total WHOIS lookup and much more besides will be displayed for the eBay domain name.

Having introduced the principles of IP addresses and domain names, in next month's column we will offer a practical way of diagnosing some strange behaviour displayed by a router.

You can email Alan at: `alan@epemag.demon.co.uk`



The IPconfig command highlights more information on the available network hardware and local IP address used by the host.

Domaintools.com (right) provides a wealth of data related to domain name configuration and ownership. Simply type a domain name into the WHOIS field



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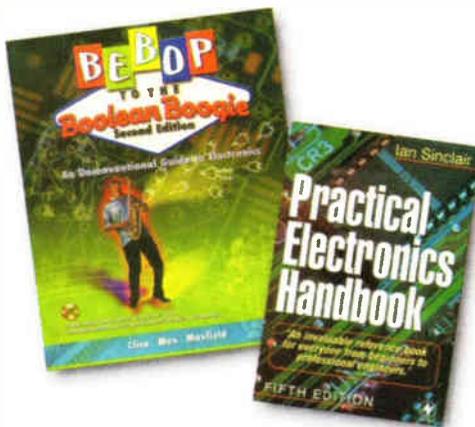
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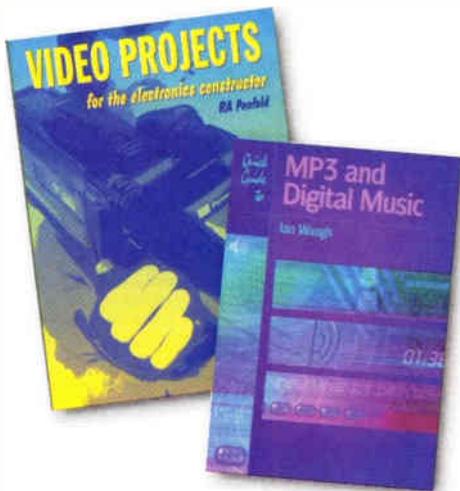
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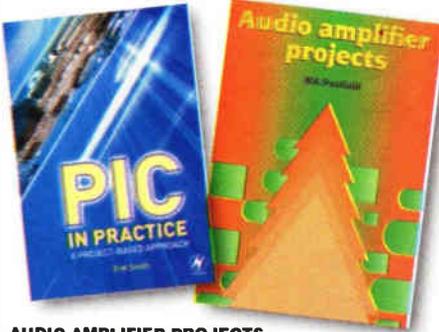
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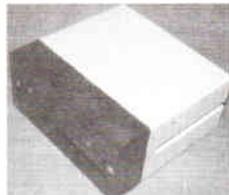
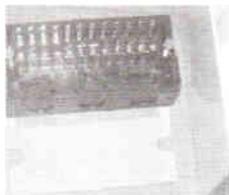
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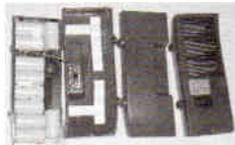
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### BREADBOARD PART 2

Following on from last month's launch of our new practical learning series, this article looks at Darlington transistors, relay switching, a light switch and a moisture meter for your pot plants.

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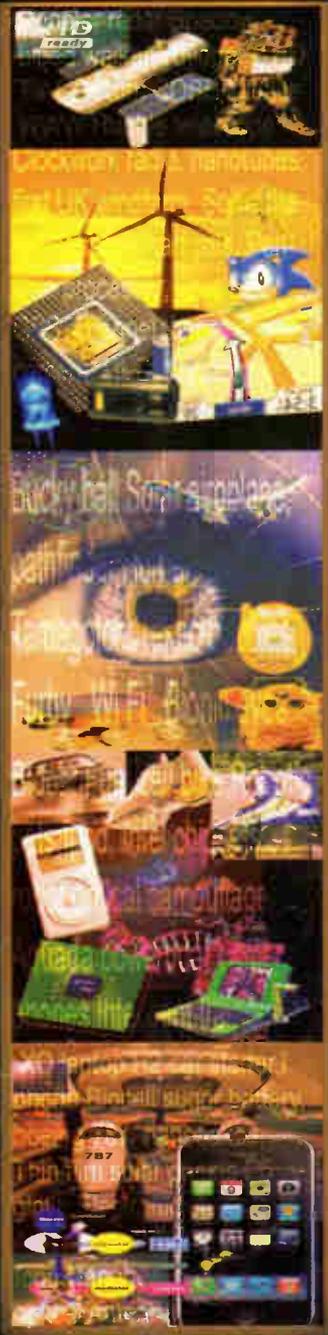
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