

THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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MULTI THROTTLE CONTROL

A simple controller for PC flight simulators

- ★ **Up to four engines**
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TEACH-IN 2008 – PART 5

Introduction to timers, BCD counting and equality checking

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MARCH 2008 PRINTED IN THE UK





HB7 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 1 kg
 Base plate: beech - Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
 Bearing application: 10 high-class ball-bearings
 Material: screw, side parts all stainless steel
 Cylinder brass, Rest aluminium and stainless steel.
 Available as a kit £80.75 or built £84.99
www.mamodspares.co.uk



HB9 Stirling engine

Base measurements: 156 mm x 108 mm x 130 mm, 0,6 Kg
 Base plate: beech Working rpm: approx. 2,000 min
 Bearing application: 6 high-class ball-bearings
 Material of the engine: brass, aluminium, stainless steel
 running time: 30-45 min.
 Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



HB10 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 0,6 Kg
 Base plate: beech Working rpm: approx. 2,000 rpm
 Bearing application: 6 high-class ball-bearings
 Material of the engine: brass, aluminium, stainless steel
 running time: 30-45 min
 Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



HB11 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 0,7 Kg
 Base plate: beech
 Working rpm: 2000 - 2500 rpm/min.run
 Bearing application: 4 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
 Available as a kit £97.75 or built £101.99
www.mamodspares.co.uk



HB12 Stirling Engine

Base measurements: 156 mm x 108 mm x 130 mm, 1 Kg
 Base plate: beech Working rpm: 2000 - 2500 rpm/min.
 Bearing application: 6 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
 Available as a kit £136 or built £140.25
www.mamodspares.co.uk



HB13 Stirling Engine

Base measurements: 156 mm x 108 mm x 150 mm, 0,75 kg
 Base plate: beech Working rpm: 2000 - 2500 rpm/min.
 Bearing application: 6 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
 Available as a kit £97.75 or built £101.99



STEAM ENGINE KIT

Everything in the kit enables you to build a fully functional model steam engine. The main material is brass and the finished machine demonstrates the principle of oscillation. The boiler, uses solid fuel tablets, and is quite safe. All critical parts (boiler, end caps, safety vent etc.) are ready finished to ensure success. The very detailed instruction booklet (25 pages) makes completion of this project possible in a step by step manner. Among the techniques experienced are silver soldering, folding, drilling, fitting and testing. £29.70 ref STEAMKIT Silver solder/flux pack £3.50 ref SSK

www.mamodspares.co.uk



HB14 Stirling Engine

Base measurements: 156 mm x 108 mm x 150 mm, 1 kg
 Base plate: beech Working rpm: 2000 - 2500 rpm/min.
 Incl. drive-pulley for external drives
 Bearing application: 10 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel
 Available as a kit £140.25 or built £144.50
www.mamodspares.co.uk



HB15 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 0,75 kg
 Base plate: beech Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
 Bearing application: 6 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel
 Available as a kit £97.75 or built £102
www.mamodspares.co.uk



HB16 Stirling Engine

Base measurements: 128 mm x 108 mm x 170 mm, 1 kg
 Base plate: beech Working rpm: 2000 rpm/min. (the engine has a aluminium good cooling Cylinder)
 Bearing application: 10 high-class ball-bearings
 Material: screw, side parts total stainless steel
 Cylinder brass Rest aluminium, stainless steel.
 Available as a kit £140.25 or built £144.50



2kW WIND TURBINE KIT

The 2kW wind turbine is supplied as the following kit turbine generator 48v three taper/ twisted fibreglass blades & hub 8m tower (four x 2m sections) guylines / anchors / tensioners / clamps foundation steel rectifier 2kW inverter heavy-duty pivot tower. £1,499



Solar Panels

We stock a range of solar photovoltaic panels. These are polycrystalline panels made from wafers of silicon laminated between an impact-resistant transparent cover and an EVA rear mounting plate. They are constructed with a lightweight anodised aluminium frame which is predrilled for linking to other frames/roof mounting structure, and contain waterproof electrical terminal box on the rear. 5 watt panel £29 ref 5Wnav 20 watt panel £99 ref 20Wnav 60 watt panel £249 ref 60Wnav. Suitable regulator for up to 60 watt panel £20 ref REGNAV



Solar evacuated tube panels

(20 tube shown) These top-of-the-range solar panel heat collectors are suitable for heating domestic hot water, swimming pools etc - even in the winter! One unit is adequate for an average household (3-4 people), and it is modular, so you can add more if required. A single panel is sufficient for a 200 litre cylinder, but you can fit 2 or more for high water usage, or for heating swimming pools or underfloor heating. Some types of renewable energy are only available in certain locations, however free solar heating is potentially available to almost every house in the UK! Every house should have one - really! And with an overall efficiency of almost 80%, they are much more efficient than electric photovoltaic solar panels (efficiency of 7-15%). Available in 10, 20 and 30 tube versions. 10 tube £199, 20 tube £369, 30 tube £549. Roof mounting kits (10/20 tubes) £12.50, 30 tube mounting kit £15



BENCH PSU 0-15V 0-2a Output
 and voltage are both smooth and can be regulated according to work, Input 230V, 21/2-number LCD display for voltage and current, Robust PC-grey housing Size 13x15x21cm, Weight 3,2kg £48 REF trans2



NEW ELECTRONIC CONSTRUCTION KITS

This 30 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used to make a variety of experiments including Timers and Burglar Alarms. Requires: 3 x AA batteries. £15.00 ref BET1803

AM/FM Radio This kit enables you to learn about electronics and also put this knowledge into practice so you can see and hear the effects. Includes manual with explanations about the components and the electronic principles. Req's: 3 x AA batts. £13 ref BET1801

This 40 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used in making basic digital logic circuits, then progresses to using Integrated circuits to make and test a variety of digital circuits, including Flip Flops and Counters. Req's 4 x AA batteries £17 ref BET1804

The 75 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides components that can be used to make and test a wide variety of experiments including Water Sensors, Logic Circuits and Oscillators. The kit then progresses to the use of an integrated circuit to produce digital voice and sound recording experiments such as Morning Call and Burglar Alarm. Requires: 3 x AA batteries. £20 ref BET1806

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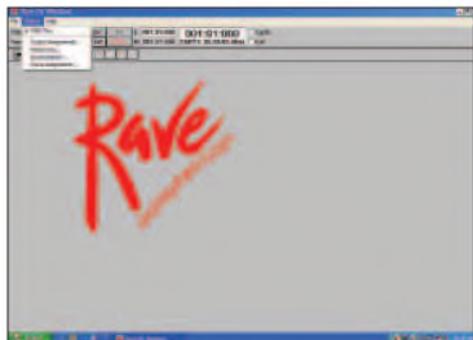
PROJECTS ... THEORY ...
NEWS ... COMMENT ...
POPULAR FEATURES ...

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Our April 2008 issue will be published on Thursday, 13 March 2008, see page 80 for details.

Projects and Circuits

- STUDIO SERIES – STEREO HEADPHONE AMPLIFIER** by Peter Smith 12
A top-class headphone amp that can drive high or low impedance 'phones to full power levels, with very low noise and distortion
- FLUORESCENT TUBE DRIVER** by John Ellis 28
Provides fluorescent lighting from a 6V rechargeable battery. Ideal for emergency, camping and no-mains lighting applications
- MULTI THROTTLE CONTROL FOR PC FLIGHT SIMULATORS** by Robert Gott 42
Build this simple controller and start flying with the big boys
- MIDI DRUM KIT – 4** by John Clarke 62
The software...and driving it!

Series and Features

- TECHNO TALK** by Mark Nelson 10
Strange Bedfellows
- PRACTICALLY SPEAKING** by Robert Penfold 22
Electronic components jargon
- CIRCUIT SURGERY** by Ian Bell 38
Current sources
- TEACH-IN 2008 – USING PIC MICROCONTROLLERS PART 5** by John Becker 52
Introduction to timers, BCD counting and equality checking
- PIC N' MIX** by Mike Hibbett 58
Checksums and CRC checks
- NET WORK** by Alan Winstanley 74
A fine mashup; I'll vouch for that

Regulars and Services

- EDITORIAL** 7
- NEWS** – Barry Fox highlights technology's leading edge Plus everyday news from the world of electronics 8
- BACK ISSUES** Did you miss these? 24
- ELECTRONICS MANUALS** 26
The *Modern Electronics Manual* and *Electronics Service Manual* on CD-ROM
- CD-ROMS FOR ELECTRONICS** 48
A wide range of CD-ROMs for hobbyists, students and engineers
- PIC RESOURCES CD-ROM** 51
EPE PIC Tutorial V2, plus PIC Toolkit Mk3 and a selection of PIC-related articles
- SUBSCRIBE TO *EPE*** and save money 68
- READOUT** John Becker addresses general points arising 70
- PIC PROJECTS** A plethora of PIC projects on CD-ROM 73
- DIRECT BOOK SERVICE** 75
A wide range of technical books available by mail order, plus more CD-ROMs
- EPE PCB SERVICE** 78
PCBs for *EPE* projects
- ADVERTISERS INDEX** 80

Readers' Services • Editorial and Advertisement Departments 7

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 1 rewritable 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**

ABC Maxi AVR Development Board

The ABC Maxi is ideal for developing new designs. Open architecture built around an ATMEL AVR AT90S8535 microcontroller. All circuits are embedded within the package and additional add-on expansion modules are available to assist you with project development.



Features

8 Kb of In-System Programmable Flash (1000 write/erase cycles) • 512 bytes internal SRAM • 512 bytes EEPROM • 8 analogue inputs (range 0-5V) • 4 Opto-isolated Inputs (I/Os are bi-directional with internal pull-up resistors) • Output buffers can sink 20mA current (direct LED drive) • 4 x 12A open drain MOSFET outputs • RS485 network connector • 2-16 LCD Connector • 3.5mm Speaker Phone Jack • Supply: 9-12Vdc

The ABC Maxi STARTER PACK includes one assembled Maxi Board, parallel and serial cables, and Windows software CD-ROM featuring an Assembler, BASIC compiler and in-system programmer.

Order Code ABCMAXISP - **£89.95**

The ABC Maxi boards only can also be purchased separately at **£69.95 each**.

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**

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**



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.

Embedded Engineer's Development Tool (Atmel 89S & AVR)

At last the development tool kit for Atmel 89S & AVR devices that engineers have dreamed of has arrived. The kit includes a Built-in ISP Programmer, Target Section, Interfacing Board, Cables, eBook with codes, e-Learning Software with explanation and CD all in one neat package. Devices covered include 89S51, 89S52, 89S8253, mega8515, mega8535, mega8, mega16 & mega32.

Features

Designed for working professionals, students and product development companies You can connect any device like LCD, 7-Segment, Sensors, Switches to any desired port of the microcontroller No dedicated connections between microcontroller and the interfacing sections. You can connect anything, anywhere e-Learning Tutorial and Book are included Once you start using the kit, you will should never feel the need to attend any trainings because it is simple to use and all concepts are explained in simple language using the tutorial and book Includes 89S51, 89S52, ATmega8, ATmega16, ATmega32 In-circuit Programmer - no need to buy a separate programmer! No ZIF Sockets. No hassle inserting and removing microcontroller to program In-circuit programming reduces development time as you do not need to move microcontroller

Contents

- In circuit programmer for 89S and AVR series (supports up to Atmega128)
- 89S51/52 target section
- ATmega8 Target section
- ATmega16/32 Target section
- Switches
- Relays
- LEDs
- 7 Segment Displays
- 16 X 2 LCD
- ADC
- Motor Driver
- RS232
- EEPROM
- Cables
- Connectors
- Serial Port Lead
- e-Learning Software
- e-Datasheets
- HandyProg Programming software
- IDEs for code writing
- Application source code

Assembled Order Code: EEDT - **£89.95**

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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Order Code EPL500 - **£149.95**
Also available - 30-in-1 £16.95, 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.

Professional Digital Multimeter (9 Function inc Temperature)

High quality DMM offering 31 ranges and 9 functions (see table below for full details) and adjustable LCD screen for easy viewing. Supplied with shrouded test leads, K type temperature probe, shock-proof rubber holster, built-in probe holder & stand.



Large 36mm digit adjustable LCD display • Auto power OFF • Data hold • Automatic polarity indication • Low battery indication • Audible continuity test • Transistor hFE and diode test

Technical Specifications

DC voltage: 200mV-1000V • AC voltage: 2V-750V • DC current: 20mA-10A • AC current: 20mA-10A • Resistance: 200Ω-200MΩ • Capacitance: 2nF-20μF • Temperature: 0 - 1000°C • Max display: 1999

Order Code: DMM225 - Was £31.95

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See website for more super deals!



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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.

Intercooler Water Spray Controller

KC-5422 £3.00 + postage & packing

Intercooler water sprays are a very effective and inexpensive way of upgrading intercooler performance. Using a 'dump' system to trigger the spray often results in the need for frequent water top-ups. Simply add these few components to the Smart Fuel Mixture Display Kit (KC-5374) and reduce water consumption by up to two-thirds with no loss in cooling efficiency.

- As published in this month's EPE Magazine



Voltage Monitor Kit

KC-5424 £6.00 + postage & packing

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

- Requires 12VDC power
- Recommended box: UB5 HB-6015 £0.83
- As published in EPE Magazine November 2007



Lead-Acid Battery Zapper Kit

KC-5414 £11.75 + postage & packing

This simple circuit is designed to produce bursts of high-energy pulses to help reverse the damaging effects of sulphation in wet lead acid cells. This is particularly useful when a battery has been sitting for a period of time without use. The effects are dependant of the battery's condition and type, but the results can be quite good indeed. Kit supplied with case, silk-screened lid, leads, inductors, and all electronic components, with clear English instructions.

- As published in EPE Magazine July 2007



AVR Adaptor Board Kit

KC-5421 £10.25 + postage & packing

This kit is designed in conjunction with KC-5340 AVR ISP Serial Programmer Kit. A low cost method of stand-alone programming for when the application board is unavailable or doesn't include an ISP (or JTAG) header. Programme, erase and rewrite program and data memory in an AVR microprocessor with this socket board. Kit includes support for in-system programming, PCB with overlay, clock source and microcontroller IC socket. This kit is designed in conjunction with KC-5340 AVR ISP Serial Programmer.

- As published in EPE Magazine December 2007



Luxeon Star LED Driver Kit

KC-5389 £9.25 + postage & packing

Luxeon high power LEDs are some of the brightest LEDs available in the world. They offer up to 120 lumens per unit, and will last up to 100,000 hours! This kit allows you to power the fantastic 1W, 3W, and 5W Luxeon Star LEDs from 12VDC. Now you can take advantage of these fantastic LEDs in your car, boat, or caravan.

- Kit supplied with PCB, and all electronic components.
- As published in EPE Magazine April 2007



3V to 9V DC to DC Converter Kit

KC-5391 £4.95 + postage & packing

Allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, this kit will pay for itself in no time. You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell.

- Kit supplied with PCB & all electronic components.
- As published in EPE Magazine June 2007



SMS Controller Module

KC-5400 £15.95 + postage & packing

Control appliances or receive alert notification from anywhere. By sending plain text messages this kit will allow you to control up to eight devices. At the same time, it can also monitor four digital inputs. It works with old Nokia handsets such as the 5110, 6110, 3210, and 3310, which can be bought inexpensively if you do not already own one. Kit supplied with PCB, pre-programmed microcontroller and all electronics components with clear English instructions.

- Requires a Nokia data cable which can be readily found in mobile phone accessory stores.
- As published in EPE Magazine March 2007

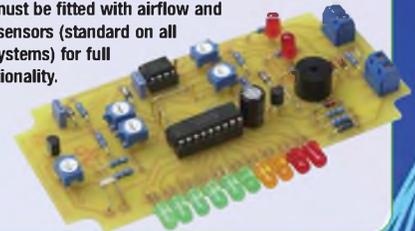


Smart Fuel Mixture Display for Fuel Injected Car

KC-5374 £8.95 + postage & packing

This kit features auto dimming for night driving, emergency lean-out alarm, and better circuit protection. Another great feature is the 'dancing' display, which operates when the ECU is operating in closed loop. Kit supplied with PCB and all electronic components.

- * Car must be fitted with airflow and EGO sensors (standard on all EFI systems) for full functionality.



AVR ISP Serial Programmer Kit

KC-5340 £14.75 + postage & packing

Program, erase and rewrite the program and data memory in your AVR microprocessor without removing it from the application circuit. This kit connects to the computer serial port, uses royalty-free software available on the Internet and allows you to program a multitude of micros in the AVR 8-bit RISC family (see website for full listing). Kit supplied with PCB, Jiffy box with silk-screened lid and all electronic components.



Resistor Substitution Wheel

RR-0700 £5.75 + postage & packing

Convenient resistance selection. Select from 36 values from 5 ohms to 1M ohms. Great for creating new circuits by selecting the best resistance Removes some of the calculations associated with resistance usage

- Comes complete with leads and insulated crocodile clips.
- Uses 0.25W resistors with 5% tolerance



CAT III Autoranging Pocket DMM

QM-1542 £14.00 + postage & packing

An advanced pocket sized DMM that is suitable for serious work. It features detachable leads, capacitance and frequency ranges as well as a CATIII rating and non-contact voltage detection.

- AC & DC voltage: 600V
- AC & DC current: 200mA
- Resistance: 40 MOhms
- Capacitance: 100µF
- Frequency: 100KHz
- Diode test
- Dimensions: 120(L) x 55(W) x 40(D)mm

NEW



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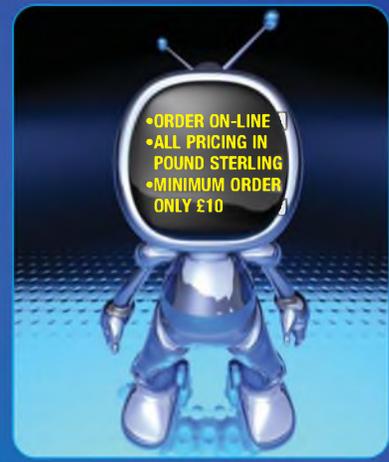
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0-1A	60mΩ
0-3A	20mΩ
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Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL
Wimborne Publishing Ltd., Sequoia House, 398a Ringwood
Road, Ferndown, Dorset BH22 9AU
Phone: (01202) 873872. Fax: (01202) 874562.
Email: enquiries@epemag.wimborne.co.uk
Web Site: www.epemag.co.uk
EPE Online (downloadable version of *EPE*): www.epemag.com
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Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU
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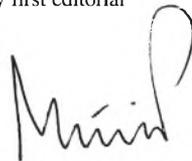
Last month, Mike Kenward was kind enough to announce me as the new 'safe pair of hands' at the editorial wheel. Mike has edited *EPE* for many years, and along with the talented team he has assembled has made it the thriving success we all enjoy – no mean feat when you consider the sad fate of many other electronics magazines. Naturally, I have plans about how to take *EPE* forward, but change will be evolutionary rather than revolutionary, and always in tandem with Mike, who remains the magazine's publisher. I am delighted to say *EPE* stalwarts David Barrington and John Becker remain as consulting editors – my job would be nigh on impossible without their vast experience. Last, but not least, I would like to thank you the readers for your constant support through letters, project and article suggestions, and lively feedback through *EPE's Chatzone* – please do keep sending us your ideas, likes and dislikes.

The future

It doesn't happen often, but every now and again I meet an electronics product that really makes me sit up and take notice. I well remember switching from a DOS-based, command line PC to my first Windows (3.0) computer, and thinking 'there's no going back, from now on this is the way all computers will work'. Of course, it was hardly an original thought – millions of other PC users had exactly the same reaction. I only mention it because I had a similar experience last November, when I bought an Apple iPhone. It's one of those rare engineering products that really seems to have an element of magic in it.

True, it doesn't do much more than many other phones and MP3 players, but like the move to graphical user interfaces in operating systems, it's not so much what it does, but how it does it. The iPhone uses an astonishingly accurate touch screen for all control and data entry operations – the only mouse you need is a finger. Interestingly, I find that it's those with an informed interest in technology who most appreciate the original thinking behind the iPhone's interface. Trust me, there will be many products that follow iPhone's trailblazing example.

I thought long and hard about how to introduce myself in this, my first editorial for *EPE*. Eventually, I opted for two little words: 'Hello world'. They seem appropriate as they are the phrase most often used to test a communications link when learning programming. So, from me to you, the *EPE* worldwide readership – 'hello'.



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Editor: MATT PULZER

Consulting Editors: DAVID BARRINGTON
JOHN BECKER

Subscriptions: MARILYN GOLDBERG

General Manager: FAY KEARN

Editorial/Admin: (01202) 873872

Advertising and Business Manager:

STEWART KEARN (01202) 873872

On-line Editor: ALAN WINSTANLEY

EPE Online (Internet version) **Editors:**

CLIVE (MAX) MAXFIELD and ALVIN BROWN

Publisher: MIKE KENWARD

READERS' TECHNICAL ENQUIRIES

Email: techdept@epemag.wimborne.co.uk

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Las Vegas CES Show

Barry Fox looks at some of the new products at this year's CES Show

THE annual *Consumer Electronics Show (CES)* in Las Vegas is by far the largest consumer electronics show in the world – with 2,700 exhibitors packing the equivalent of 35 football pitches. No members of the public are allowed in, just 140,000 trade visitors which just happens to be the number of slot machines in the county. Someone in the organiser's office with nothing better to do has also just worked out it would take each visitor 2.5 years to meet each exhibitor personally.

Navigating the show is a nightmare, mainly because the aisle and booth numbering defies all human logic. When we asked for it to be explained, the assistant floor manager looked blank and admitted she "didn't go by the signs".

HD DVD Shock

This year's show got off to a shock start with the news that movie giant Warner Bros would no longer support Toshiba's HD DVD high definition disc format, and would instead throw all its weight behind the rival Blu-ray system developed by Sony, Pioneer, Panasonic and Philips. For the past year Warner has released titles in both formats, with Sony's Columbia, Disney and Fox backing only Blu-ray, while Universal, Paramount and DreamWorks have exclusively supported

HD DVD. The eve of show decision "was based purely on consumer preference for Blu-ray," says Warner.

The announcement forced Toshiba and its partners to cancel their grand slam HD DVD party on the show's opening night and scrap private briefings scheduled throughout the show. "We are currently discussing the potential impact of this announcement with the other HD DVD partner companies and evaluating next steps" was all the HD DVD Promotion Group would say. Industry insiders now expect legal actions, both between the companies involved and consumers who have bought players for which there will now be a much narrower selection of discs.

The bombshell announcement was deeply embarrassing for Toshiba. Delegates to CES are traditionally given an expensive rucksack to carry round the show. This year's bag was sponsored by Toshiba and emblazoned 'Toshiba – leading innovation – HD DVD'. To add to their misery the company had scheduled a press conference for early on the first day of the show, to announce three new 'third generation' HD DVD players. Although the press conference went ahead there was no mention or demonstration of the players – just written details left in the paper press pack.

Toshiba's digital consumer chief Yoshihide Fujii, the normally gung-ho 'father of HD DVD' was missing and it was left to Akio Osaka, President of Toshiba USA and Marketing VP Jodi Sally to put on a brave face. "We were surprised by Warner's announcement," admitted Ozaka. "We firmly believe HD DVD offers the best solution for the consumer's wants and needs."

"This is a tough day for me" admitted Jodi Sally. "We have delivered on every promise we have made on features and affordability. Over a million players are in the US market. It's difficult for me to read people writing that HD DVD is dead. We have been declared dead before".

Challenging popular myths that are untrue, Scott Ramirez, Head of Toshiba's TV Marketing, could not resist citing the saying that humans only use 10% of their brain. "It's false," he said, "although after what's been going on over the last few days in this industry, it may very well be true".

The Korean giants, Samsung and LG, were both left in the embarrassing position of launching complex and expensive 'Duo' players that can play either Blu-ray or HD DVD discs. "They will be useful for people who want to watch Paramount and Universal movies" said LG.

How green is Standby?

'Want to go green and digital? Fancy a new digital TV or digital box and want to make sure it's easy to use and energy efficient?', asks Ricability, the Research Institute for Consumer Affairs, founded by Which? magazine around 40 years ago.

Ricability has measured the power consumption of set top boxes, digital TV recorders and iTVs, both in standby mode and in use. "We have just tested another 27 digital TVs and nine set top boxes, to add to the 85 test reports already on our site," says Lindsey Etchell, Principal Researcher. Standby power usage varies hugely between different models – from 0.2W to 3.86W on iTVs and between 1.53W and 15.2W on set top boxes. "All you need do," says Ricability, is "check out the latest digital TV reports at: www.ricability-digitalTV.org.uk".

Unfortunately, and although Ricability issued a press release, 'to raise consumer awareness of the issue', the website provides no easy search option. "The search facility on our site is currently

limited to whether or not a product has the ESR, Energy Saving Trust logo", admits Caroline Jacobs, Ricability's Development Manager. "To compare specific data on power usage in use/on standby/in eco mode, users need to look at the individual reports of the products they are interested in. However, this may be changed in the future. We hope to review and further develop the search criteria."

GPS SATNAVS

The makers of GPS Satnavs are now facing the same problem as the makers of cell-phones; they must find new ways of getting us to junk perfectly good equipment and buy a newer model that does much the same things plus a little of something slightly different. Mio Technology has been developing SiRFInstantFixII. This decidedly uncatchy name has a welcome purpose, to reduce the time a satnav takes to find the orbiting satellites overhead that tell the device where it is. The new system continually uses the position of satellites it has found to predict the choreographed position of other satellites up to three days

in the future. This lets the satnav start giving reliable directions only five seconds after it is switched on (browse www.mio.com and www.sirf.com).

Tele Atlas provides the software maps used by Mio, Tom Tom and Pioneer. The company is currently ploughing its profits back into a mammoth project, which will let next generation satnavs display three dimensional images of landmarks that drivers see as they drive down mapped roads. A truck has eight cameras round the sides and four more on the roof in bug-eye configuration to capture 360 degree images four times a second.

The first 3D maps are for New York, Los Angeles and Toronto, with more coming for Rome, Paris and Berlin. The satnav screen shows the road ahead and complete, textured 3D pictures of landmarks like the Empire State Building, United Nations Headquarters, Hollywood Sign and Eiffel Tower. The helpful advice 'you can't miss it' could finally come true when the satnav manufacturers start building 3D into their devices sometime later this year. A lot of perfectly good satnavs will then become eminently junkable.

PICOSCOPE 'SCOPES EVEN MORE POWERFUL

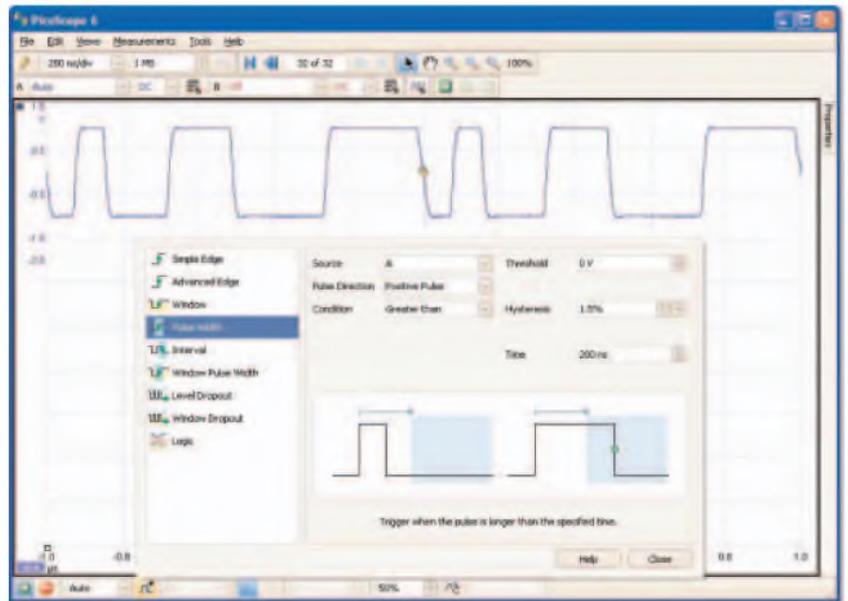
You have no doubt seen publicity about PicoScope's high-performance 5000 Series PC Oscilloscopes. These scopes already have the highest real-time sampling rate of any USB PC Oscilloscope, at one gigasample per second. Their specifications are improving all the time, and the latest feature to be added is a new set of advanced triggering functions.

Pico Technology, worldwide leader in the design and manufacture of PC Oscilloscopes, has released the latest version of PicoScope 6. This version is the first to support Pico's entire range of USB PC oscilloscopes, and has a number of new features.

Owners of the high-performance 5000 Series 'scopes are already familiar with the improved layout and advanced triggering options of PicoScope 6. It now supports all Pico oscilloscopes from the entry-level 2000 Series, through the general-purpose and high-precision 'scopes of the 3000 Series, up to the high-performance 5000 Series with 1GS/s real-time sampling rate.

The most exciting new feature in PicoScope 6 is resolution enhancement. This filtering algorithm adds up to four bits to the effective resolution of a scope. For example, it can boost the effective resolution of a PicoScope 5203 or 5204 from 8 bits to 12 bits, and the 12-bit PicoScope 3224 and 3424 high-resolution scopes can now deliver up to 16 effective bits. The resolution enhancement is selectable in increments of 0.5 bit.

PicoScope 6 now has independent horizontal zoom, using a new control that is



easily accessed from the toolbar to give precise control over timebase magnification. The familiar windowed zoom tool is still there to allow quick inspection of waveform details. The text file export feature has been improved so that text-format data files up to one million samples long can now be exported.

According to Alan Tong, Managing Director of Pico Technology, "This release will allow more of our customers

to try out the PicoScope 6 software. It shows that we are committed to continually improving our products and adding new features. Like all our software upgrades, this release is free of charge and comes with full technical support."

PicoScope 6.0.12 is available for download now, free of charge, from the Pico Technology website at www.pico-tech.com. Call Pico on +44 (0) 1480 396 395 for more details.

Microchip's PIC18 LCD Microcontrollers

Microchip has announced six new members of its 8-bit PIC family featuring an integrated LCD module. The PIC18F85J90 family doubles the amount of Flash and RAM memory available in 64- and 80-pin PIC18 LCD devices. This increased memory enables users to add more complex functions, such as speech playback.

Example applications for the new family include dashboard displays; handheld terminals; appliance display/control units; utility meters; home security systems and exercise equipment.

Additional features include: up to 32 Kbytes of self-programming Flash program

memory; up to 2 Kbytes of SRAM; enhanced LCD module supporting up to 192 pixels (4 commons x 48 segments); software controllable internal oscillator (32kHz to 8MHz); 12 Channel, 100k samples-per-second 10-bit A-to-D converter; two analogue comparators, with internal voltage reference.

All six members of the family are supported by Microchip's high-performance

development systems, including the MPLAB Integrated Development Environment, MPLAB C18 C Compiler, MPLAB ICD 2 In-Circuit Debugger, the PICDEM HPC Explorer Board and the forthcoming PICDEM LCD 2 demo board.

For additional information, visit www.microchip.com/lcd.

Brunning's PIC Training

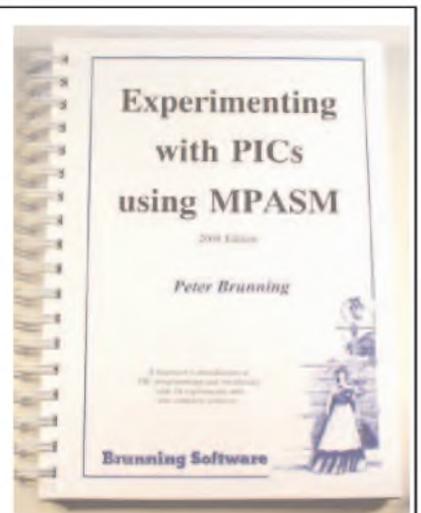
Brunning Software have just released the professional beginners' versions of their PIC training courses. Peter Brunning has rewritten *Experimenting with PIC Microcontrollers* so that the instructions relate to the Microchip assembler. This makes the professional version a little more difficult for beginners, but it is ideal for newcomers to PICs who have a professional reason for wanting to learn.

At the same time, the programmer/experimental module, which is common to all courses, has also been expanded. It now has two RS232 ports, one for control and one for experimental use, and a USB port for experimental use.

A USB adaptor with USB lead is now included as standard.

The PIC training course is £164 plus carriage. The PIC and Visual C# training course is £189 plus carriage.

For more information, contact Brunning Software, 138 The Street, Little



Clacton, Clacton-on-Sea, Essex CO16 9LS. Tel: 01255 862308. Web: www.brunningsoftware.co.uk

LED 'FLUORESCENTS'

The Ronfell Group tell us that they have introduced LED 'fluorescents' and quote the following key facts:

Power saving 85%; glass or IK7 food safe shatterproof; no mercury; no WEEE directive costs; warm white to white; low wattage and 70,000 hours lifetime; no ballast, starter or capacitor; same end caps and fitting; replace T8 and T12 2, 3, 4 and 5ft tubes; T5 replacements due soon.

For more details, contact Ronfell Group, Challenge House, Pagefield Industrial Estate, Miry Lane, Wigan, Lancs WN6 7LA. Tel: +44 (0) 1942 492200. Fax: +44 (0) 1942 492233. Email: ronfell@ronfell.com. Web: www.lightingequipmentnews.com or www.ronfell.com.

Strange Bedfellows

Mark Nelson takes another look at some of the iconic brand names of the electronics industry, how they came into being and how fortune treated them

Do you remember the time not so long ago when almost every shopping centre had a Tandy shop? Maybe you scorned the tiny packs of penny resistors and capacitors that they sold for rather more than penny prices, but you must admit that Tandy was a handy shop to have on your doorstep when you needed a 22k resistor or some 1A glass fuses at 5.15pm on a Saturday afternoon. A changing economic environment meant that Tandy shops are now a thing of the past, but the memory lingers on.

Tandy UK was a subsidiary of Radio Shack (USA), a store name that would not have struck a chord with most British people and, in any case, there was already an established amateur radio shop of the same name in West Hampstead, London. So the British (French and Belgian) businesses traded under the Tandy name, which was not named after two owners with the initials T and Y (as some people thought). In fact, the electronics business was a relatively minor division of the Tandy Leather Company, that at one time was represented in the UK by Pearce Tandy Leathercraft of Northampton.

Friends disunited

The Hinckley-Tandy Leather Company was founded in 1919 in Fort Worth, Texas by two friends, who decided to go into business together selling leather soles, heels and shoelaces to shoe repair shops in the Fort Worth area. Following a disagreement in 1950, the business was divided into a Hinckley division, concentrating on show supplies, and the Tandy Leather Company that focussed on selling a broad range of leather goods through a chain of shops and by mail order.

Radio Shack was an entirely independent business, formed in Boston, Massachusetts back in 1921. It grew slowly at first, but was quick to cash in on the post-war hi-fi boom. By the early 1960s, Radio Shack had expanded to nine retail stores (plus a mail-order business) and was now a leading distributor of electronic parts and products. Charles Tandy, boss of Tandy Leather, was intrigued with consumer electronics and saw the small Radio Shack chain as an excellent opportunity for rapid growth. He bought the under-funded company in 1963 and it soon grew to a business with outlets all over the USA, doing particularly well from the CB radio and home computer booms.

Tandy's expansion was, however, not so successful outside the USA, where the very US-centric product range did not go down so well. The Canadian operation has closed

down and the stores in Britain ended up being sold to Carphone Warehouse in 1999. Tandy's French operations fell into bankruptcy, but apparently one store survives in Belgium. Tandy entered the Australian market in 1973 and operated in competition with Dick Smith Electronics. In 2001 Woolworths Limited, which owns DSE, acquired Australian Tandy and merged the two operations.

Sounds familiar

Leather and electronic pastimes may sound like a strange connection but they shouldn't! Back in those heady days of early home computers, when Tandy had a huge share of the US market and we were enjoying the Sinclair Spectrum, BBC Micro, Dragon 32 and the Tangerine, another leather company was eyeing Tandy's success.

The Connecticut Leather Company had been founded in 1932, again to wholesale leather supplies to shoemakers. Spin-off operations included leather craft kits in the 1950s and plastic wading pools in the 1960s. The leather part of the business was sold off and the company renamed Coleco. It became a highly successful toy company in the 1980s on the back of its Cabbage Patch Kid dolls and to a lesser extent for some TV game consoles.

When this business had peaked, the firm looked to home computers for a new sales opportunity and in 1983 bought out the Coleco Adam, which you may remember. Unfortunately, the product stood little chance against the more established brands of computer and disappeared off the market two years later. The assets of Coleco were purchased in 1989 by Hasbro, but the Coleco brand was revived in 2006 to sell handheld consoles containing Master and Game Gear titles made by Sega.

More outlandish marriages

What's the connection between electronic connectors, fruit bottling, model railways and fireworks? You guessed? – a very bizarre one!

For 50 years, one of the most enduring (and robust) pattern of multiway connector in electronics has been the McMurdo red series, made of solid dark red plastic with chunky contacts. If the name is unfamiliar a quick glance at: www.in2connect.uk.com/c2/uploads/red_range1.pdf will remind you. It turns out that the McMurdo Instrument Company was originally the British McMurdo Silver Company Ltd, founded in 1937 by Mr McMurdo Silver as a UK base for the manufacture of valve radios, using designs from US company McMurdo Silver Inc.

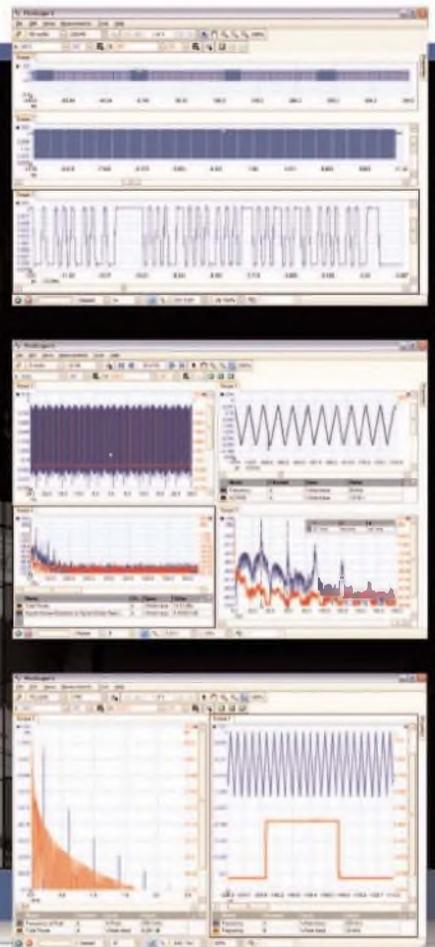
After the war, McMurdo's main line of business was making moulded components for the electronic industry and they are still in business today. McMurdo entered the marine safety electronics market with the introduction of an emergency position indicating radio beacon conforming with international Safety of Life at Sea regulations. Since then McMurdo has developed its own search and rescue transponder as well as its own product range of GMDSS VHF radios.

The connection with fireworks made sense. James Pain & Sons, a company tracing its origins back to 1670, was officially formed in Brixton, south London around 1850 to manufacture fireworks and is still one of the top brands in retail rockets and roman candles. You can't rely on 5th November for all-year-round sales, however, and increasingly the firm expanded into commercial pyrotechnics. It merged in 1965 with Wessex Aircraft Engineering Company, which made smoke generators to indicate wind direction for the War Office. The resulting Pains Wessex company by then belonged to the match people Bryant and May. The combination of Pains Wessex Safety Systems and McMurdo marine security electronics made a very good 'match'.

Things are never static, however, and nine years after the acquisition of Pains Wessex Ltd in 1986 by the Chemring Group PLC, the new owner decided to divest itself of the McMurdo Electronics business and to retain its core pyrotechnic competencies. The connectors are now marketed by In2Connect of Alresford, Hants. and are still recommended for equipment such as ATM and vending machines, gaming equipment and industrial control applications where larger gauge wires of up to 16awg are required.

So what's the model railway connection? By way of diversification, McMurdo also made plastic wagon kits for 00 scale model trains, sold under the Rex name by distributor ERG of Bournemouth. These were made not of polystyrene but from polymethyl methacrylate, an acrylic material known by the trade names of Perspex, Lucite and Diakon. Users were instructed to join the parts with liquid chloroform, which may or may not have affected their success. In this respect, McMurdo followed the same path as Graham Farish, who, after the last war, diversified from making radio components (and snap closures for home bottling) into model railways. But whereas Graham Farish dropped its other lines, McMurdo remained in electronics.

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.

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.

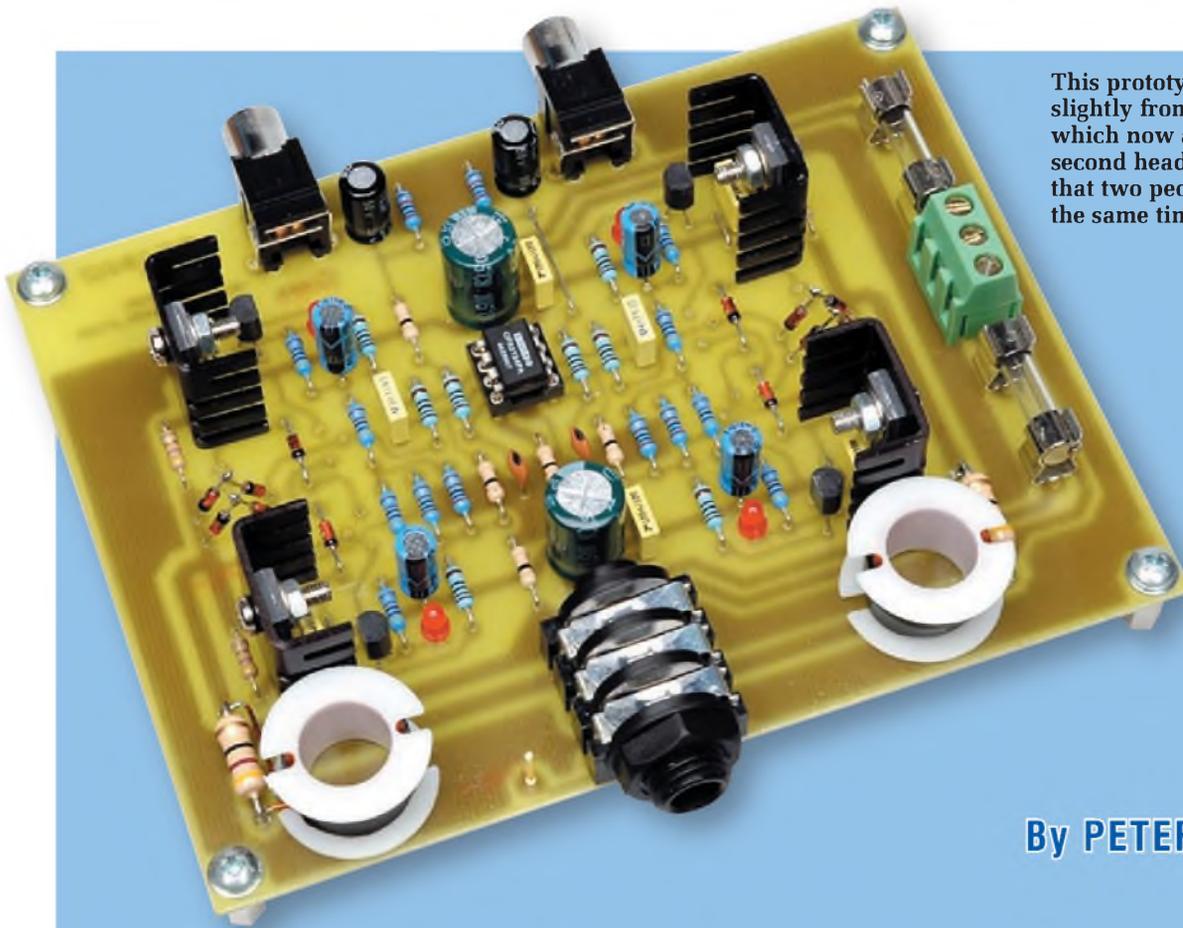


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This prototype unit differs slightly from the final version, which now also features a second headphone socket, so that two people can listen at the same time.

By PETER SMITH

Studio Series – Stereo Headphone Amplifier

A Top-Class Unit For The Audio Enthusiast!

Here's a top-class headphone amplifier that can drive high or low-impedance phones to full power levels, with very low noise and distortion. For best performance, it can be teamed with the Stereo Preamplifier described last month. Alternatively, it can be used as a standalone unit, requiring only a power supply and a volume control potentiometer for use with any line-level signal source (CD/MP3 player). It even includes dual outputs, so you can listen with a friend!

MANY OF OUR HIGH-POWER audio amplifier designs already provide an output for headphones. The additional circuitry required for headphone support is simple; just two resistors in series with the loudspeaker outputs to limit the drive current and protect the phones in the event of amplifier failure.

Considering its simplicity, this resistive limiting scheme works well, although it will cause distortion if the load is non-linear – a likely prospect with most headphones. Apart from eliminating this potential source of distortion, there are a number of other reasons why you might consider building a separate headphone amplifier.

For a start, not everyone owns a pair of top-rated headphones, or even a high-performance power amplifier. After all, an amplifier that equals or betters the performance of this new headphone amplifier will set you back more than a few pounds!

Another reason might be for use with the latest ‘high-tech’ audio electronics equipment. The headphone outputs in much of this gear cannot drive low-impedance phones – or at least not to decent listening levels. In addition, available output power in portable devices is deliberately limited to conserve battery energy. This means that lots of distortion might be present at higher listening levels, even with sensitive headphones.

One way around this is to feed the line-level outputs of this gear into your power amplifier and then plug your low-impedance headphones into that. That works, but then you’re tethered to an immovable object. Besides, the power required to drive headphones is around 1/1000th of that required to drive loudspeakers, so a large power amplifier could be considered a tad oversized for the job!

Design outline

One of the challenges in designing a general-purpose, low-distortion headphone amplifier is catering for the huge variation in headphone specifications. Models with 8Ω (nominal) impedance are common, as are 32Ω, 60Ω, 120Ω and 600Ω versions – plus many in between.

At the high impedance end of the scale, a large output voltage swing will be necessary to develop full power, whereas at the low end, current limiting is needed to prevent driver

Features and Performance

Main Features

- High performance – very low noise and distortion
- Drives high and low-impedance headphones
- High output power (up to 200mW into 8Ω and 32Ω)
- Dual headphone sockets – can drive two pairs!
- Works with a preamp or any line-level audio source

Measured Performance

Frequency response.....	flat from 10Hz to 20kHz (see graphs)
Rated output power.....	200mW into 8Ω and 32Ω, 85mW into 600Ω
Max. output power (current or voltage limited).....	575mW into 8Ω, 700mW into 32Ω, 130mW into 600Ω
Harmonic distortion.....	typically 0.0005% (600Ω load), 0.001% (32Ω load) and 0.005% (8Ω load)
Signal-to-noise ratio (A-weighted).....	-130dB (600Ω), -120dB (32Ω) and -111dB (8Ω) with respect to 100mW output power.
Channel crosstalk.....	better than -68dB from 20Hz to 20kHz at 100mW output power (see graphs)
Input impedance.....	~47kΩ 47pF
Output impedance.....	~5Ω

Note: all tests were performed with the amplifier driven from low source impedance. For crosstalk measurements, the non-driven input was back-terminated into 600Ω.

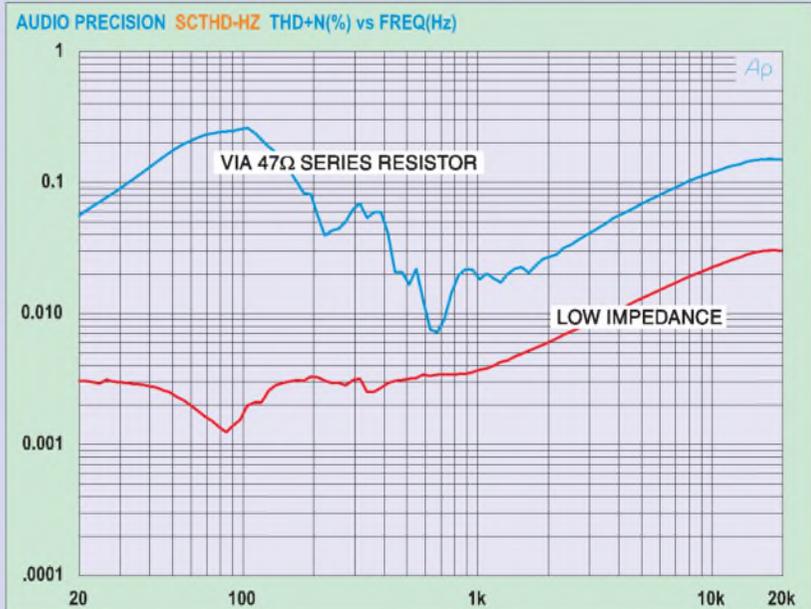


Fig.1: these plots of distortion versus frequency at 100mW highlight the impedance non-linearity of a real pair of 8Ω headphones. When driven directly from the low-impedance headphone amplifier output, performance is very good (bottom curve), as the amplifier’s feedback loop can act to linearise the signal. However, when isolated with a 47Ω series resistor (top curve), the headphone’s non-linearities are immediately exposed!

Parts List – Stereo Headphone Amplifier

- 1 PC board, code 662, size 134 × 103mm
- 2 PC mount switched RCA phono sockets (CON1, CON2)
- 2 6.35mm PC mount switched stereo sockets (CON3, CON4)
- 1 3-way 5mm/5.08mm terminal block (CON5)
- 1 8-pin gold-plated IC socket
- 4 TO-126/TO-220 micro-U heatsinks
- 4 M205 PC mount fuse clips
- 2 M205 500mA fast-blow fuses
- 4 M3 x 10mm tapped spacers
- 4 M3 x 6mm pan head screws
- 4 M3 x 10mm pan head screws
- 4 M3 nuts and flat washers
- 2 11.8mm ID plastic bobbins
- 1 2-metre length of 0.63mm enamelled copper wire
- 1 120mm length of 0.7mm tinned copper wire (for links)

Semiconductors

- 1 OPA2134PA dual FET-input op amp (IC1) (Farnell 791-039)
- 2 BC557 PNP transistors (Q1, Q5)
- 2 BC547 NPN transistors (Q3, Q7)
- 2 BD139 NPN transistors (Q2, Q6)
- 2 BD140 PNP transistors (Q4, Q8)
- 4 3mm red LEDs (LED1-LED4) – see text
- 12 1N4148 diodes (D1-D12)

Capacitors

- 2 470µF 25V PC electrolytic
- 4 100µF 16V PC electrolytic
- 2 10µF 35V/50V non-polarised PC electrolytic (max. 6.3mm diameter)
- 6 100nF 50V MKT polyester
- 2 47nF 100V polyester film (greencap)
- 2 1.2nF 50V MKT polyester
- 2 100pF 50V ceramic disc
- 2 47pF ceramic disc

Resistors (0.25W, 1%)

- 2 47kΩ 4 1kΩ
- 2 7.5kΩ 8 100Ω
- 8 4.7kΩ 2 47Ω 1W 5%
- 2 1.2kΩ 2 10Ω 1W 5%
- 2 2kΩ 4 4.7Ω 0.5W 1%

Additional items

- 2 RCA plugs
- Shielded audio cable
- 1 50kΩ dual-gang log pot (for standalone use)
- 2 panel-mount RCA sockets (for standalone use)

For power supply upgrade

- 2 TO-220 micro-U heatsinks
- 2 M3 x 6mm pan head screws
- 2 M3 nuts and flat washers

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generate sufficient volume when driving low-sensitivity, low-impedance phones, but may well overdrive high-sensitivity and/or high-impedance models at high volume settings. It must also remain stable when driving varying impedances, and be able to develop full power into 8Ω units.

Updated and updated

Although the heart of this design still relies on the old boosted op amp idea, it includes a number of improvements to significantly boost power handling and performance as well. In addition, we've carefully designed the PC board layout to minimise distortion and crosstalk.

The result is a unit that clearly outperforms our previous designs in all areas, yet is still relatively inexpensive and easy to build. Let's look at the circuit in more detail.

Circuit description

The amplifier consists of two identical circuits, labelled 'left' and 'right' to represent the stereo audio channels. To reduce clutter, the circuit diagram (Fig.2) shows only the left channel. Bracketed annotations refer to the right channel.

Note that some components are common to both channels, including the power supply input connector (CON5), fuses (F1, F2), filter capacitors and headphone output sockets (CON3, CON4).

An RCA phono socket (CON1) accepts the audio signal, which is AC-coupled to the circuit via a 10µF, non-polarised (NP), capacitor and terminated with a 47kΩ resistor. A 100Ω resistor and 47pF capacitor form a simple RF filter, after which the signal is fed into the non-inverting input of an op amp (IC1a).

In common with the Studio Series-Stereo Preamplifier, we've used an OPA2134 audio op amp here for best performance. These op amps have excellent load-handling characteristics, with the ability to drive loads down to 600Ω while producing very low distortion. Of course, this falls far short of our 8Ω load requirement, so a current booster stage has been added between the op amp and the amplifier output.

As mentioned earlier, the booster stage is based on a pair of medium-power transistors (Q2, Q4) connected in a complementary emitter-follower configuration. Let's look at the positive (uppermost) half of the circuit first.

or headphone burnout at abnormally high volume settings.

Another consideration is headphone impedance variation with frequency. While distortion due to this effect can be minimised with low amplifier output impedance, this requirement would seem less important than when driving loudspeakers. We're also aware that some manufacturers are producing models that have virtually flat impedance curves over the audio spectrum and so will be unaffected by an amplifier's output impedance. In fact, international standard IEC 61938 specifies that headphones should be driven by a 120Ω source, regardless of headphone impedance.

Alas, it seems unlikely that all headphones will exhibit the ideal 'flat' (purely resistive) impedance response. To test this theory, we drove a pair of reasonable quality 8Ω headphones first

from a low-impedance (5Ω) source and then added a 47Ω series resistor. The results are presented in Fig.1.

Sensitive level

The maximum amplifier output power needed to produce the desired volume level depends on another widely varying parameter: headphone sensitivity. Modern dynamic headphones are very efficient, typically producing 90-100dB SPL (sound pressure level) per milliwatt of input, with many reaching full volume with just a few milliwatts. To cater for varying sensitivity levels, commercial headphone amplifiers are typically rated at between 10mW and 100mW, or more.

Unfortunately, the impedance rating of a headphone pair is not necessarily related to its sensitivity, so a general-purpose amplifier design will ultimately be a compromise. It must

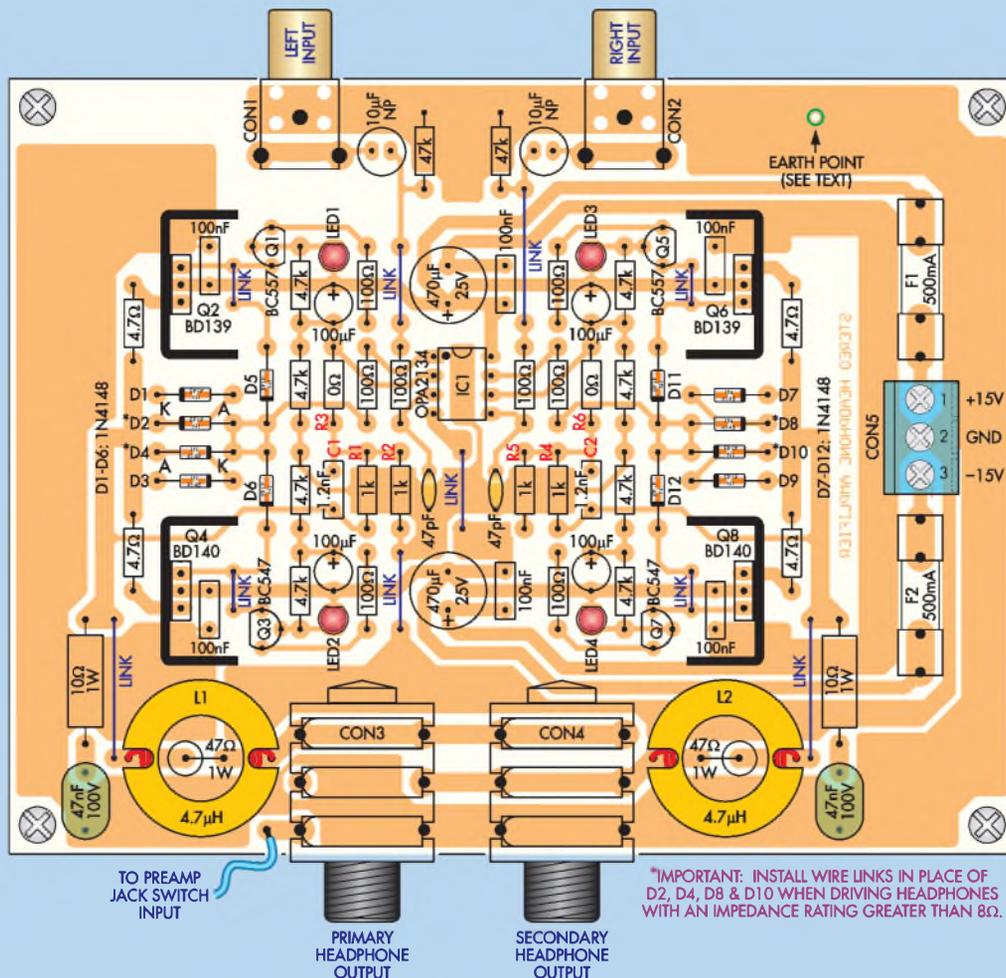


Fig.3: follow this parts layout diagram closely when assembling the headphone amplifier. Be careful not to mix up the different transistor types and double-check the orientation of the diodes, LEDs and polarised electrolytic capacitors before applying power.

reverse voltages from appearing across the circuit during a short-circuit condition. All four diodes are installed for operation into 8Ω

headphones, giving a maximum output current of about two diode drops ($2 \times 0.7V$) divided by the emitter resistance (4.7Ω). For higher impedance headphones, two of the diodes in each channel must be replaced with wire links, halving the maximum current and therefore reducing the chances of accidental headphone damage.

Resistors R1 and R2 set the amplifier gain in the usual manner, giving a gain of +2 ($1 + R1/R2$) with the $1k\Omega$ values shown. This is suitable for use with a preamplifier and/or when driving 8Ω headphones (see the 'Tweaking Your Headphone Amplifier' panel for other options).

In conjunction with R1, the $1.2nF$ capacitor (C1) in the feedback path rolls off amplifier frequency response above the audio spectrum.

Finally, an RLC network at the output isolates the amplifier from headphone reactance and ensures stability under all conditions. The low impedance of the inductor (L1) at audio frequencies also allows the amplifier to drive difficult loads (down to 8Ω) with very good results. We've used air-cored inductors to avoid the signal distortion that would be introduced by ferrite and iron-cored alternatives.

The amplifier's output signal is picked off at the junction of the two 4.7Ω emitter resistors and fed back to the inverting input (pin 2) of op amp IC1a via resistor R1. Including the output circuit in the op amp's feedback loop has two important advantages. First, it allows the op amp to servo the output to near 0V with no input signal, accounting for mismatches in the complementary halves of the circuit. It also results in an overall improvement in linearity and reduces crossover distortion.

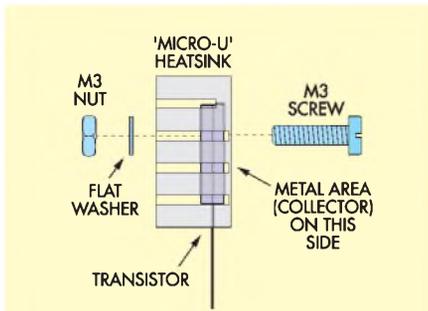


Fig.4: here's how to assemble the heatsinks to the output transistors, which must be done before fitting the transistors to the board. Make sure that the metal face of each transistor mates with the heatsink and be sure to smear both mating surfaces with heatsink compound.



Here's what a completed inductor looks like (you need two), prior to scraping off the enamel insulation and tinning the leads.

Assembly

Assembly is quite straightforward, with all parts mounting on a 134 × 103mm single-sided PC board (code 662). Fig.3 shows the details.

Begin by installing the 10 wire links, then install the 1N4148 diodes (D1 to D12). Note that D2, D4, D8 and D10 are only installed if you intend using the amplifier with 8Ω headphones. For all higher impedance phones, install wire links in these four locations instead (see the 'Tweaking Your Headphone Amplifier' panel).

Make sure that the cathode (banded) ends of the diodes are oriented as shown on Fig.3.

The 0.25W and 0.5W resistors and LEDs (LED1 to LED4) can be installed next. Use wire links for R3 and R6 if you'll be feeding your amplifier from a preamp. Conversely, install 2kΩ values in these two locations if you'll be feeding it from a line-level source via a 50kΩ volume pot. When inserting the

LEDs, make sure that you have the flat (cathode) side of the body oriented as drawn on the overlay.

IC1's socket, the four fuse clips, transistors Q1, Q3, Q5 and Q7, the capacitors and connectors CON1 to CON5 can all go in next. Take care not to mix up the two types of transistors (BC547, BC557), and note that the 100μF and 470μF electrolytic capacitors are polarised and must be installed with their positive leads oriented as indicated by the '+' marking in Fig.3.

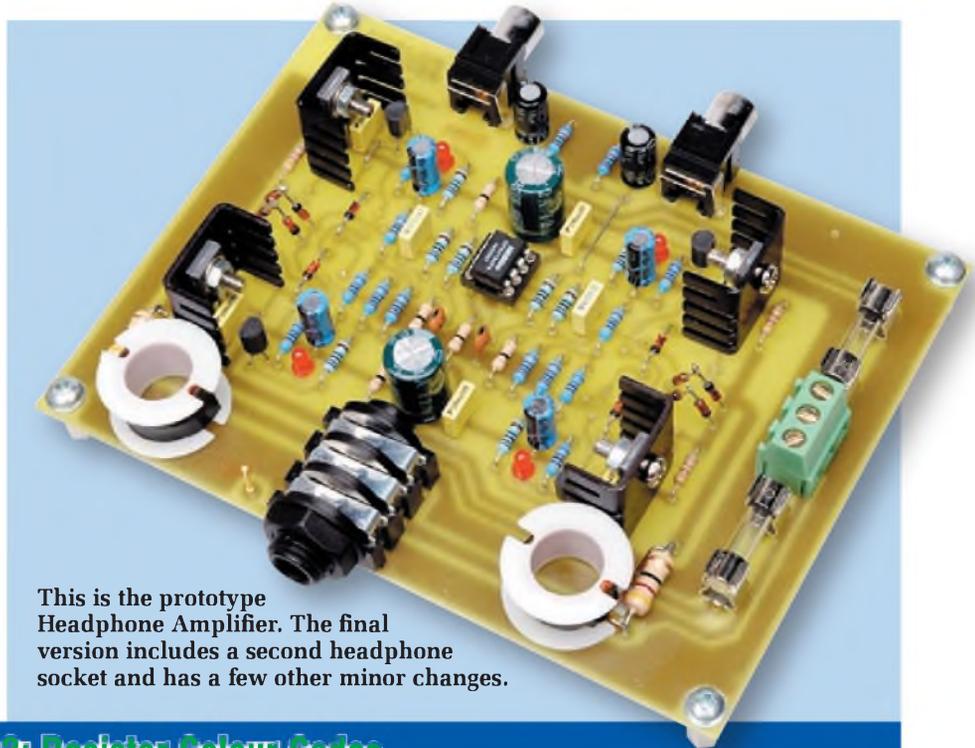
All that now remains to be installed are the 1W resistors, the output transistors and their heatsinks and the two inductors. The transistors and inductors require special attention, so fit the 1W resistors first. The two 47Ω units are positioned in the inductor 'centres' and therefore must be mounted vertically, rather than horizontally.

Table 1: Capacitor Codes

Value	μF Code	EIA Code	IEC Code
100nF	0.1μF	104	100n
47nF	.047μF	473	47n
1.2nF	.0012μF	122	1n2
100pF	NA	100	100p
47pF	NA	47	47p

Transistor installation

The four output transistors (Q2, Q4, Q6 and Q8) are fitted with 'micro-U' style heatsinks *before* installation. To do this, apply a thin smear of heatsink compound to the rear (metal) face of each transistor, as well as the mating surface on each heatsink (do not use insulating washers). Affix each transistor to its heatsink using an M3 × 10mm screw, nut and flat washer (see



This is the prototype Headphone Amplifier. The final version includes a second headphone socket and has a few other minor changes.

Table 2: Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
2	47kΩ	yellow violet orange brown	yellow violet black red brown
2	7.5kΩ	violet green red brown	violet green black brown brown
8	4.7kΩ	yellow violet red brown	yellow violet black brown brown
2	1.2kΩ	brown red red brown	brown red black brown brown
2	2kΩ	red black red brown	red black black brown brown
4	1kΩ	brown black red brown	brown black black brown brown
8	100Ω	brown black brown brown	brown black black black brown
2	47Ω	yellow violet black gold	not applicable
2	10Ω	brown black black gold	not applicable
4	4.7Ω	yellow violet gold brown	yellow violet black silver brown

Tweaking Your Headphone Amplifier

FOR THE BEST listening experience, the headphone amplifier can be fed from the Studio Series Stereo Preamp described last month. With this combination, a pair of top-quality 32Ω (or higher) impedance headphones will provide superb performance.

Good results can also be obtained with 8Ω headphones or even two pairs of 32Ω (or higher) units, if you want to share the experience. In addition, the headphone amplifier can be operated 'standalone', where it connects directly to a line-level signal source (no preamp required). Let's see how to get the best performance in each case.

Using 8Ω headphones

Considerable efforts were made to ensure that the amplifier drives 8Ω headphones with low distortion. To ensure you get the same results, all eight limiting diodes (D1-D4 and D7-D10) must be installed when driving 8Ω headphones! For higher impedance phones, wire links are used in place of D2, D4, D8 and D10 only.

What if you own both 8Ω and 32Ω (or higher) impedance phones and you want to use all of them with the headphone amplifier – without making changes to the board? Well, while 32Ω (or higher) headphones can be plugged into an amplifier that's configured for 8Ω use, you need to be aware of the potential risks. The amplifier is capable of delivering over 1W into 32Ω in this case, which is potentially destructive for headphones, your hearing and ultimately the amplifier as well!

By the way, we do not recommend increasing the amplifier gain (see 'Boosting volume') when driving 8Ω headphones, as this will cause an unavoidable increase in harmonic distortion. With the default signal gain of 6dB, only about 630mV RMS is required at the input to develop the full 200mW into 8Ω, hence

increasing gain for typical line-level signals is pointless.

Boosting volume

Using the component values shown on the circuit and overlay (Fig.2 and Fig.3), the headphone amplifier operates with a voltage gain of two (6dB), which is more than adequate when the unit is fed from a preamplifier. It should also work fine when driving 8Ω headphones, regardless of the audio source.

However, if you want to connect the unit directly to a line-level source via a volume pot (see 'Standalone use' below) and you'll be using 32Ω or higher impedance phones, then you may find that the volume is not loud enough, even with the controls wound right up.

If after building and testing the amplifier you find that more volume is required, then the amplifier gain can be increased to 7.2 (17dB) to allow the full rated output power to be realised in all cases with a 1V RMS input signal. To increase the gain, use the following component values in place of those shown on the circuit and overlay diagrams: R1 and R4 = 7.5kΩ, R2 and R5 = 1.2kΩ and C1 and C2 = 100pF.

One negative aspect of increasing amplifier gain is an accompanying increase in harmonic distortion. Nevertheless, performance is still excellent, with 0.0004% THD when driving 600Ω and 0.004% when driving 32Ω headphones, measured at the full rated output power.

Standalone use (no preamp)

When feeding the amplifier directly from a line-level source, some method of volume control will usually be required. This is easily provided with a 50kΩ dual-gang log potentiometer, inserted in series with the inputs to the amplifier (see Fig.5).

One disadvantage of this scheme is that op amp source impedance varies with changes in volume,

resulting in higher signal distortion. To offset this effect somewhat, 2kΩ values can be used for resistors R3 and R6.

Accounting for feedback resistance, the inverting input will then see about 2.5kΩ ($R1 || R2 + R3$), assuming the default 1kΩ values were used for the feedback resistors. The result is improved matching at the non-inverting input at nominal volume settings.

Note that the same 2kΩ values can be used for R3 and R6 when the amplifier is configured for the higher 17dB gain option (see 'Boosting volume'). In this case, the inverting input will see about 3kΩ.

We acknowledge that the 2.5kΩ to 3kΩ values are only a rough estimation, as the real source impedance can vary anywhere from about 100Ω to 10kΩ. Considering headphone sensitivity variation, it would appear to be impossible to establish a 'typical' volume setting.

Important: when feeding your headphone amplifier from a pre-amplifier or other low-impedance source, resistors R3 and R6 must be 0Ω in value – use wire links!

Dual outputs

The headphone amplifier includes dual 6.35mm output sockets, allowing simultaneous connection of two pairs of headphones. Two important rules must be followed when using both sockets at once: (1) the headphones must be of the same nominal impedance rating; and (2) the impedance ratings must be 32Ω or higher.

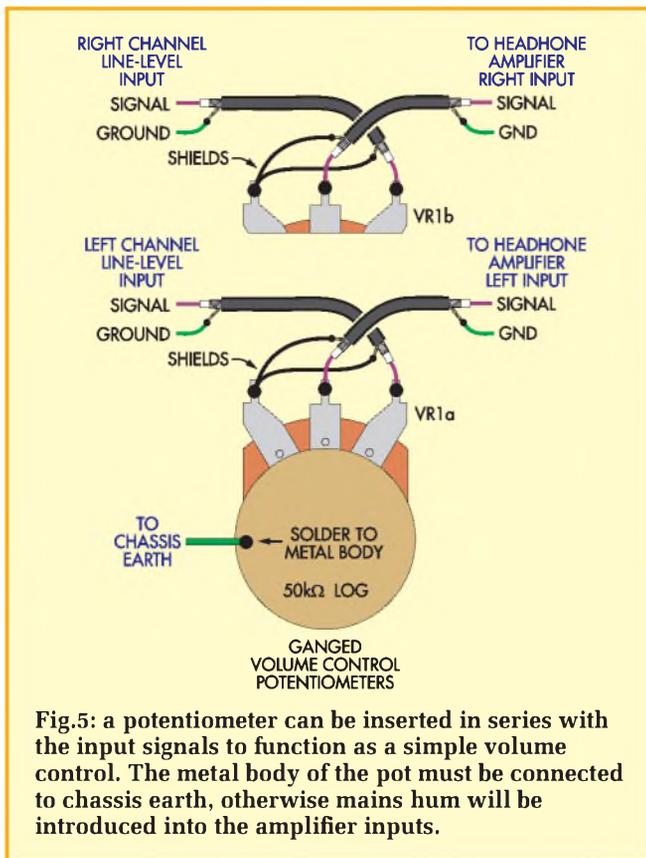
Many listeners will prefer to set their own volume levels and this can be catered for by using headphones with in-line volume controls. Separate volume control boxes are also available from specialist audio outlets.

Note that although the sockets are connected in parallel, the jack switch output connects to the first (primary) socket only, so this socket will control the headphone/power amplifier signal routing relay on the Studio Series Preamp.

Fig.4), allowing just enough slack so that the transistor and mounting screw can move up and down in the heatsink slot.

Insert a transistor into its holes in the PC board (don't mix up the two types), pushing it all the way home, so that the mounting screw is all the way down in

the heatsink slot and the edge of the heatsink is in full contact with the board surface. If you can't achieve this, then you've fitted the heatsink upside down!



Without disturbing the transistor/heatsink assembly, turn the board over and solder the transistor leads. The mounting screw can now be carefully tightened. Don't overdo it; applying too much torque will disturb the package/heatsink position!

Winding the inductors

The two inductors (L1, L2) are hand-wound. Each requires a plastic bobbin, about 1m of 0.63mm enamelled copper wire and electrical insulation tape. Some kit suppliers might provide these items preassembled, in which case you can skip the following instructions.

The insulation tape is needed to hold the windings in place while the assembly is fitted to the PC board. General-purpose tape will be wider than the bobbin, but can easily be made to fit by slicing off the unneeded width with a razor blade. Stick the tape down on a smooth, clean surface first to make the job easier.

Play out the wire before beginning and remove any kinks. Starting at one of the slots, wind on one complete layer, keeping the wire taut as you go. With one complete layer in place, start winding back over the first layer. In all, 21 turns are required, but you'll need an extra half-turn so that the wire exits at the opposite slot to the starting end (see photo).

Wind on two or three turns of insulation tape to hold the windings in place. Finally, scrape the enamel insulation off the ends of the two leads and tin them before mounting the inductor on the PC board.

Hook-up

For best results, the amplifier should be powered from the low-noise power supply described last month as

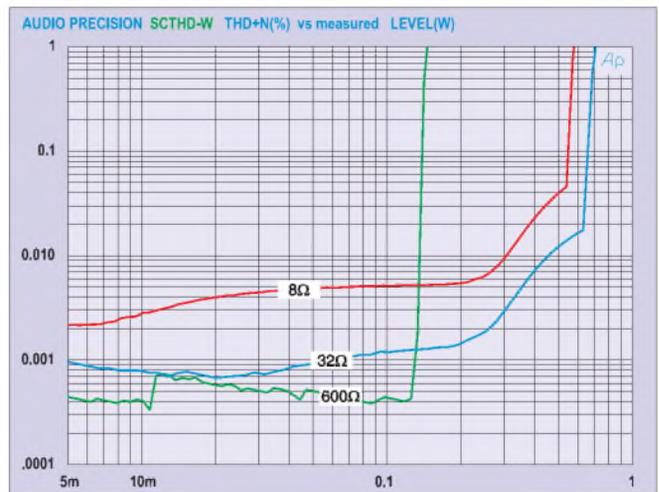


Fig.6: amplifier total harmonic distortion and noise versus output power into 8Ω, 32Ω and 600Ω resistive loads. When driving 8Ω and 32Ω loads, the current-limiting diodes begin to conduct around the 200mW mark, causing a gradual increase in distortion. Once the diodes are fully forward-biased, the output current is aggressively clamped, resulting in an almost vertical rise in distortion. For the 600Ω case, the amplifier abruptly runs out of voltage headroom at about 130mW and hard clipping is the result.



Fig.7: amplifier total harmonic distortion (THD) and noise versus frequency, measured with an output power level of 100mW. As is clear from these curves, the amplifier performs much better when driving 32Ω and higher impedance headphones. Most headphones will reach full output well below 100mW, so you can expect even better performance than these already excellent curves reveal!

part of the Studio Series Preamplifier. Even if you decide to use a different supply, the guidelines in that article regarding mains wiring, housing and general layout also apply here.

An additional step when using the low-noise supply with this amplifier is to fit small heatsinks to the $\pm 15V$ regulators (see parts list). Apply a thin smear of heatsink compound to the mating surfaces during assembly, to aid heat transfer.

We'll assume that you've already assembled and tested the power supply. All that remains is to hook up the amplifier's power and signal inputs.

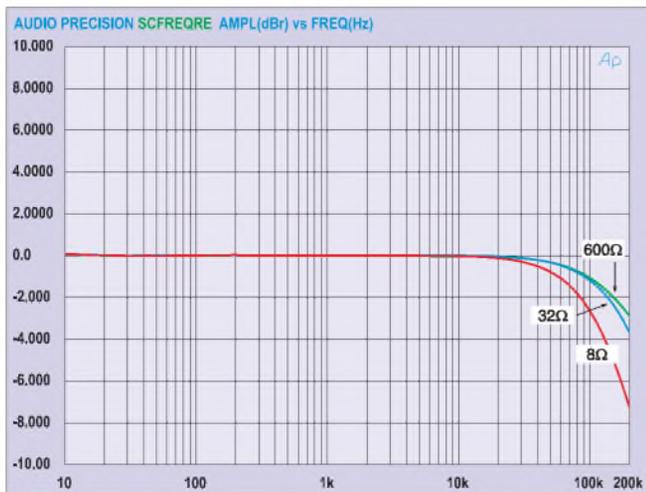


Fig.8: this graph plots the amplifier output voltage versus frequency when driven at 200mW into 8Ω, 32Ω and 600Ω loads and with 6dB of gain. As can be seen, the response is ruler flat over the audio spectrum, gently rolling off at the top end at a rate dependent on the feedback network and output loading.

Connect the +15V, -15V and GND outputs of the supply to the headphone amplifier's power inputs at CON5, using medium-duty, multi-strand hook-up wire. Twist the wires tightly together to reduce noise and improve appearance. Take great care to ensure that you have all of the connections correct – a mistake here will destroy many components on the amplifier board!

Boxing-up

When installing the unit in a case with a preamp module, the headphone amplifier must not be separately earthed – only the preamp board should be earthed. However, if you're building a standalone unit (no preamp), then the headphone amplifier's common (GND) rail should be connected to chassis earth.

This is achieved by running a wire from the pad marked 'EARTH' on the amplifier board to the main chassis earth point. Do not connect any other part of the circuit or power supply to chassis earth (except the volume pot, see below).

For a standalone unit, the volume pot can be wired up next. Use a dual-gang, 50kΩ logarithmic type, connected with audio-quality shielded cable (see Fig.5). The cable may be terminated with panel-mounted RCA phono sockets on the signal input side and RCA phono plugs on the output side, which are then plugged into the RCA inputs on the amplifier board.

Caution!

Continual exposure to very high noise levels (including loud music) will cause hearing loss and can cause tinnitus. Hearing loss is cumulative, gradual and almost symptomless!

The metal body of the pot must be connected to chassis earth to reduce noise pickup. Do *not* connect the body to either of the shielded cables! Normally, the front panel will provide the necessary earth connection. If it doesn't, then connect the pot to a convenient chassis earth point using hook-up wire. Note that solder won't adhere to the nickel plating on the pot, so remove a small area of the plating with an ink rubber or scouring pad prior to tinning.

When used with a preamp, the additional volume pot is not needed. Instead, you simply wire the switched headphone outputs on the preamp to phono plugs using audio-quality shielded cable. These then plug into the phono sockets on the headphone amplifier.

In addition, the 'JACKSW' output of the headphone amplifier must be wired to the 'SWITCH' input on the preamp board. This connection will allow the preamp to reroute the audio signal from the power amplifier output to the internal headphone output when a headphone jack is inserted in its socket. Leave the 'GND' terminal on CON7 of the preamp disconnected.

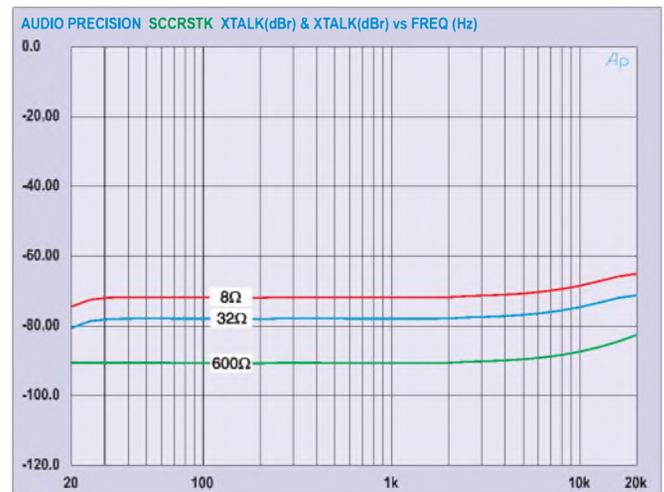


Fig.9: this is the crosstalk, again measured for 8Ω, 32Ω and 600Ω loads. Some of the coupling is due to the commoning of the headphone left and right return (ground) leads at the jack plug. The results (although good) would be better if the headphones used 4-contact jacks, thus allowing separate grounds for the left and right channels.

Testing

To check your completed amplifier, install the fuses and power up. The four LEDs should immediately light up – if not, switch off quickly and check for serious cabling or board assembly problems. If only one LED doesn't light, then the problem is at least restricted to the associated current source/sink part of the circuit.

If all LEDs light as expected, then use your multimeter to measure the voltage between each output and ground. These points are conveniently accessible at one end of the 10Ω 1W resistors. If all is well, your meter should read within ±2mV of 0V.

Next, measure the voltage drop across each of the 4.7Ω emitter resistors (situated adjacent to the heatsinks). All should measure between about 0V and 100mV, representing a maximum emitter current of about 21mA. Note that this measurement assumes the transistors are idling at room temperature. The reading may be higher if the amplifier has been in recent use and the output transistors have warmed up.

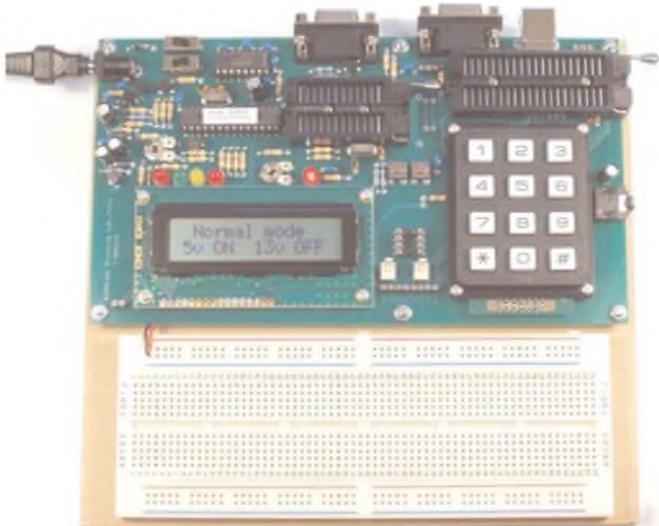
OK, we're done. Now for the best part – the listening test – Enjoy! **EPE**

PLEASE NOTE

Stereo Preamplifier (Feb '08)

Page 27, Parts List. The last entry under 'Additional items': The value of the X2 type suppression capacitor should be **1nF** 250V AC. The power supply circuit (Fig.4) is correct.

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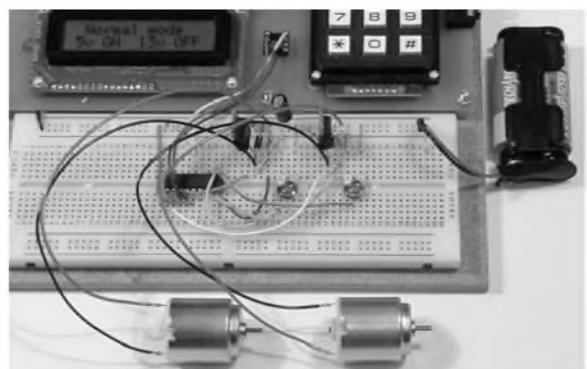
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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

AN ever increasing amount of jargon seems to be an inevitable part of modern life. Jargon is helpful for those 'in the know', as it avoids the need for repetitive explanations, making communication quicker and easier. Unfortunately, it can also act as a barrier to newcomers, who find themselves faced with unfamiliar nomenclature and terminology.

Electronics is certainly not short of jargon, but it is rather less loaded down with gobbledygook than many other aspects of modern technology and life. As yet, 'newbies' are not faced with endless acronyms, and they do not learn to 'surf the circuit board', or anything similar. Inevitably though, there is still a certain amount of essential terminology for beginners to learn, including some acronyms. In this month's article we will consider some of the terms that tend to confound newcomers to the hobby.

Poles apart

Capacitors are relatively simple components that perhaps have more than their fair share of names and terms, which can cause a certain amount of confusion. As an example, what is the difference between a polarised capacitor and an electrolytic type? At times they seem to be used as different words to describe the same thing, but there is a difference. An electrolytic capacitor is an example of a polarised capacitor, but there are other types of capacitor that are polarised, such as the tantalum variety.

A polarised capacitor is one that only operates properly if it is subjected to a voltage of the correct polarity. In practice, this means that it will only work if it is connected the right way round, and an electrolytic capacitor will only work properly if the circuit is designed to use a polarised component.

Always make sure that a polarised capacitor is fitted the right way round, since the component could fail in spectacular fashion if it is not. Be especially careful with the larger and higher voltage types. Connecting one of these incorrectly could result in it bursting with a fair amount of force, which could obviously be dangerous.

Never use a polarised capacitor if the components list specifies some form of non-polarised capacitor. Doing so virtually guarantees that the circuit will refuse to work.

In theory, there is no problem in using an ordinary capacitor instead of a polarised type, but the situation is rather different in the real world. Polarised capacitors are mainly used where high values are required, and non-polarised types of suitable value tend to be either extremely large and expensive, or simply unavailable.

It is not a good idea to use an electrolytic capacitor where a components list

specifies a tantalum type. Tantalum capacitors are superior to normal electrolytic types in several respects. They generally have closer tolerances, much smaller leakage currents, and better performance at high frequencies. There should be no problem if a tantalum type is used in place of an electrolytic capacitor, but it would be somewhat over specified.

Capacitors are often described as something like 'polyester', 'Mylar', or 'ceramic.' A capacitor is basically just two metal plates separated by a thin layer of insulation called the 'dielectric', and the name applied to these components simply indicates the material used as the dielectric. This is not just of academic importance, since there is no perfect dielectric. Real-world capacitors have good performance in some respects, but are relatively weak in others. The circuit designer chooses a type that is well suited to that particular application, and it is unwise to use a different type unless you know what you are doing.

banks of miniature printed circuit mounting switches, some miniature relays, and IC holders.

There are also SIL (single in-line) components which have just a single row of pins, but these are relatively rare. The only common examples are integrated circuits that are designed to handle high powers, and banks of resistors. In the past, there were QIL (quad in-line) integrated circuits, which were much the same as the DIL variety, but with some pins sticking out further from the body of the component than others. This produced what were effectively four rows of pins. This type of encapsulation was usually a bit awkward to deal with, and it is now largely obsolete.

When ordering integrated circuits you do not normally need to specify a DIL or SIL encapsulation as such. Most integrated circuits are available in several case styles, which these days include various surface mount types. In the past, component retailers

only offered the SIL or DIL version of a device, but these days there is often a surface mount version available as well.

The type number of an integrated circuit usually has a suffix that indicates its encapsulation and pinout arrangement. This is typically something like 'CP' for a DIL device in a plastic case, but the exact method of coding varies somewhat from one manufacturer to another. It is therefore necessary to take care that the correct

version of a device is ordered in cases where more than one type is listed. Fortunately, component catalogues usually indicate the case style of each version on offer.

Staying on track

Potentiometers are perhaps used rather less in this digital age than they were in the analogue past, but they still feature in a reasonable percentage of projects. Most types of potentiometers are available in logarithmic and linear varieties, which are often referred to as 'log' and 'lin' respectively. There is also such a thing as an anti-logarithmic ('antilog') potentiometer, but this type is not widely

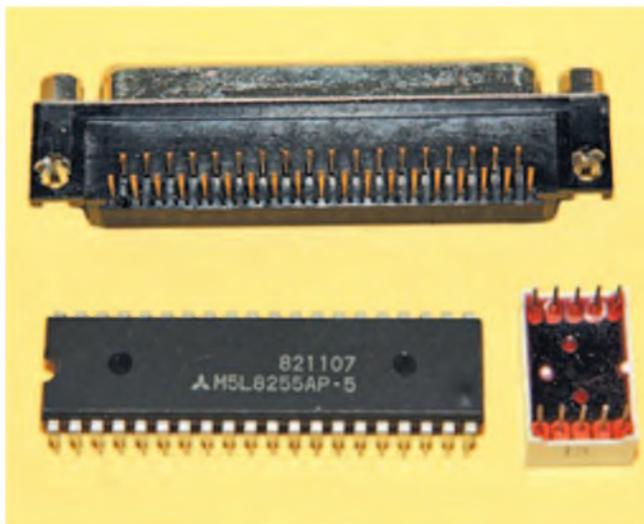


Fig. 1. The term DIL is mostly used to describe integrated circuits (ICs), such as this 40-pin example (bottom left). However, it can be applied to other components, such as this LED display (bottom right) and PCM socket (top)

On the case

The term DIL is one that is likely to be encountered sooner rather than later, and it stands for 'dual in-line'. It is a term that is most often applied to integrated circuits (ICs), but there are other components for which the DIL name is equally apt. The three components shown in Fig. 1 are all in the general DIL category.

Integrated circuits mostly have two rows of pins spaced 0.3 inches apart, or 0.6 inches in the case of large devices having more than about 22 pins. The pin spacing is usually 0.1 inches. The term DIL can be applied to any component that has two lines of pins, such as

available and is little used in practice. The difference between the logarithmic and linear types is subtle, but if you use the wrong type it will usually be fairly obvious that something is amiss.

A normal potentiometer is in the form of a control that is mounted on the front panel of a project. A potentiometer has the alternative name of 'variable resistor', which is basically the function it provides.

However, whereas a fixed resistor has two leads, a variable type has three tags. Two of these connect to opposite ends of a carbon track, and the third connects to an adjustable wiper (moving) contact that can be positioned anywhere along the track via the component's spindle.

Suppose a potentiometer has a value of 100 kilohms. The resistance between the two track terminals will be approximately 100 kilohms, and with the wiper set at a central setting there will be about 50k Ω between the wiper terminal and each outer-track terminal. With the wiper set about 20 percent along the track, there will be about 20 kilohms between the wiper and one track terminal, and about 80 kilohms between the wiper and the other.

This will only be true if the potentiometer is a linear type. With a logarithmic type the two halves of the track will have very different values. I made some measurements using a real-world 100 kilohm logarithmic potentiometer which showed that one half of the track had roughly ten times the resistance of the other half. Much the same thing would be found with an anti-logarithmic potentiometer, but the two resistances would be swapped.

In control

What is the point of having logarithmic potentiometers with their varying track resistance? For most applications they are not needed, and linear potentiometers are used for the vast majority of applications, including most tone controls, temperature controls on electronic thermostats, and so on. The humble volume control is the only common application for logarithmic potentiometers, and they are used for very little else.

Advancing the volume from zero produces a huge initial increase in volume when using a linear control, but large changes in the setting of the control having little effect thereafter. This is not due to any shortcoming in the potentiometer, but is simply a product of the way the human hearing mechanism works. Our hearing effectively becomes less sensitive as the volume level is increased. A logarithmic potentiometer, however, is designed to counteract this compression effect, and provides what seems to be a more even adjustment characteristic.

After a fashion, a circuit will work if the wrong type of potentiometer is used, but there will be an odd control characteristic, possibly making it awkward to use. A potentiometer of the wrong type might be satisfactory as a temporary measure if there are supply problems with the correct part, but it is something that should otherwise be avoided.

Not all types of potentiometer are available with logarithmic or linear laws. Even with the largest of component catalogues you are unlikely to find logarithmic presets listed. Unless stated otherwise, it can be



Selection of rotary potentiometers

assumed that preset resistors are of the linear variety.

Switched on

The most simple switches are often described as something like 'SPST' in components lists and catalogues. Switch abbreviations such as this can be confusing at first, but they are really quite easy to understand, and there are just four of them to contend with. These are the four abbreviations and their meanings:

SPST	single-pole,	single-throw
SPDT	single-pole,	double-throw
DPST	double-pole,	single-throw
DPDT	double-pole,	double-throw

A single-pole switch is a simple on/off type, and a double-throw switch is one which provides what is more commonly termed a changeover action. In other words, there are three tags, and the middle one connects to one or other of the other two tags, depending on the setting of the switch. A single-pole switch has just one set of contacts, whereas a double-pole type has two sets and is effectively two switches that operate in unison.

Fig.2 shows the circuit symbols for all four types of switch, and also shows how these relate to practical switches. The tag arrangements shown in Fig.2 are the most common ones, but there are some switches that use different layout.

With any switch it is best not to jump to conclusions, and to use a continuity tester to determine which tag is which. Component catalogues do not always list all four types of switch, and it is useful to

bear in mind that a DPDT switch can be used to replace any of the other three types. For example, ignore one set of three tags and the other set effectively provide a SPDT switch.

Choked up

The word 'choke' seems to be used relatively little these days, and it is merely an alternative name for an *inductor*. It is mainly used when referring to small inductors of the type used in radio frequency (RF) equipment. It is also applied to larger inductors, such as those used in mains interference suppression.

There are two main categories of inductor, one of which is the low frequency (LF) type that are generally large and intended to handle large currents. The other category is RF chokes, which are intended for high frequency (HF) operation, are relatively small, and can only be used at low currents. When ordering an inductor it is important to make sure that you obtain one that is of the right general type and do not simply settle for any component having the right value. In the case of a low frequency inductor that will carry high currents, make sure that its current rating is adequate.

Being PC

In an electronics context the acronym 'PC' stands for printed circuit and PCB stands for 'printed circuit board'. Many components are described as PC or PCM (printed circuit mounting) types, and this basically just means that they are designed for mounting on a circuit board. In the case of capacitors it means that the component has both leads emanating from the same surface, and that it is mounted vertically. Components that have a lead at each end and are mounted horizontally on circuit boards are 'axial' types. Normal resistors are a common example of axial components.

One slight problem with PCM components is that two parts of the same basic type will not necessarily use the same pin arrangement. Each manufacturer often has its own way of doing things. In many cases this means that a component will not fit onto the circuit board unless it is precisely the right type. Component catalogues often make life easier by providing details of the pinout arrangements of PCM components, so that you can check that a component is suitable without having to try the 'suck it and see' approach.

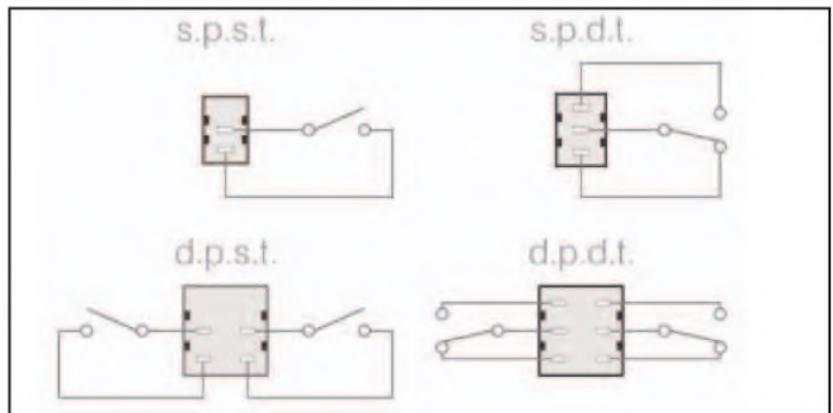


Fig.2. The four basic types of switch. A DPDT type can be used instead of any of the others, and it is just a matter of ignoring the contacts (tags) that are not required

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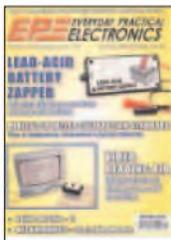
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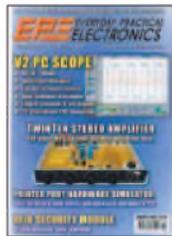
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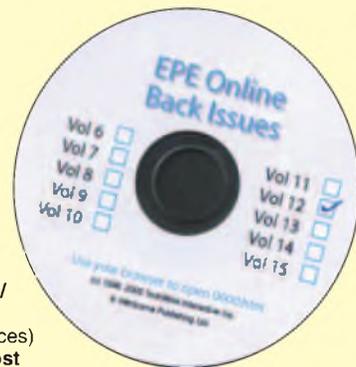
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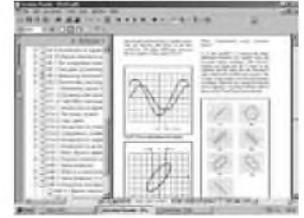
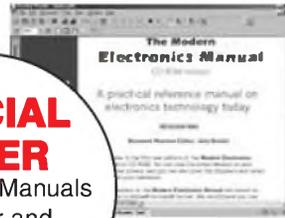
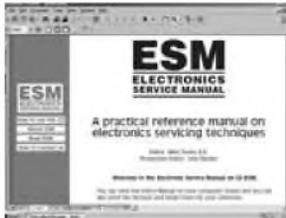
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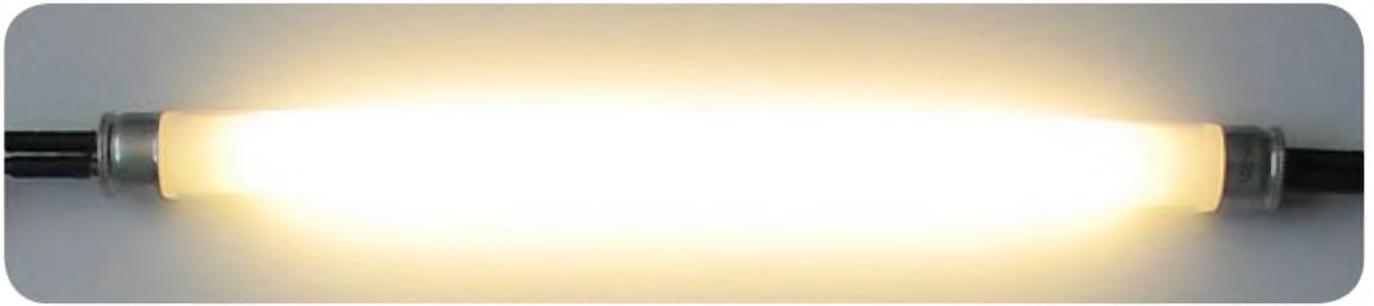
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Fluorescent



Tube Driver

By John Ellis

Ideal for emergency, camping and no-mains lighting applications

Despite the progress being made by solid-state lighting, fluorescent tubes are still one of the most efficient light sources available. Normally operated from mains power, lamp fittings use chokes (coils) to limit the current flow. This is necessary because the fluorescent tube exhibits a negative resistance when turning on, and a low resistance once the arc between the filaments has formed.

As a result, fluorescent tubes appear to be difficult loads for electronic circuits, yet it is possible for small, battery-operated fluorescent tube driver units to be designed with a high efficiency. Many offices and shops now have trickle-charged standby units for emergency use.

The unit described in this article was designed to provide fluorescent lighting operating from a 6V rechargeable battery for emergency, camping and even for 'green' lighting, as it is possible to charge batteries during the day from fairly small solar panels, or for lighting the corners around the house such as in the under-the-stairs cupboard where mains may not be readily available.

Royer circuit

The Royer circuit was mentioned in the June 07 issue of *EPE* – see *Circuit Surgery*. In 1954, G.H. Royer described

a switching power converter using two transistors and a transformer, shown in outline in Fig.1. The transistors switched on and off, one after the other, feeding the primary windings with a square wave. The switching point, where one transistor turns off and the other on, was determined by the transformer.

During each half-cycle, the magnetic field in the transformer core changes from the peak value it just reached, which saturated the core in

one direction, until it saturated in the other. At this point, the feedback signal reduces and prevents the 'on' transistor from staying on any longer. So this transistor turns off, and the collapsing magnetic field turns the other transistor on, repeating the half cycles with the polarity constantly changing.

Sinewave

A sinewave is more efficient than a square wave to operate fluorescent tubes. If nothing else, a sinewave contains no harmonics, which prevents energy being lost in higher frequency harmonics. It is also relatively easy to operate a fluorescent tube from a sinewave using a simple choke coil to limit the current, with little interference from switching spikes which a square wave signal could create.

To operate in sinewave mode, it is necessary to make two important changes to the original Royer circuit. First, a capacitor is added across the primary (or secondary) of the transformer, to form a resonant LC 'tank' circuit. If the transistors were switched across this tank, however, the sinewave oscillations would be shorted out, giving a square wave once again.

To avoid this, the second modification is to add a choke (L1) in series with the primary centre tap. All chokes

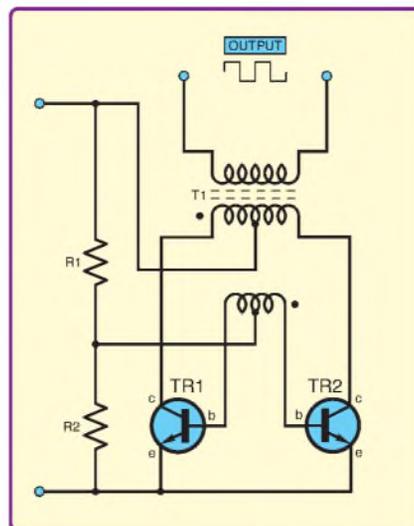


Fig.1: Basic Royer converter circuit, (saturating transformer, two transistors)

or coils oppose alternating currents, in principle, while at the same time have a low resistance to DC which can pass through virtually unhindered. The choke is able to absorb the difference in voltage between the transistors and the sine wave signal in the resonating tank circuit. This enables the transistors to switch on or off while generating a sine wave.

Resonant sinewave converter

The basic resonant sinewave converter is shown in Fig.2. The transformer (T1) primary, comprising coils N1 and N2, are tuned by capacitor C1 to form a tank circuit which resonates with a sinewave oscillation.

Transistors TR1 and TR2 are driven through the feedback winding Nf through the feedback winding Nf to switch alternately on and off. Coil L1 provides the high AC impedance to take up the voltage difference between the transistors, which switch, and the sinewave oscillations. Resistor R1 is only required to provide the peak base current needed by the transistors.

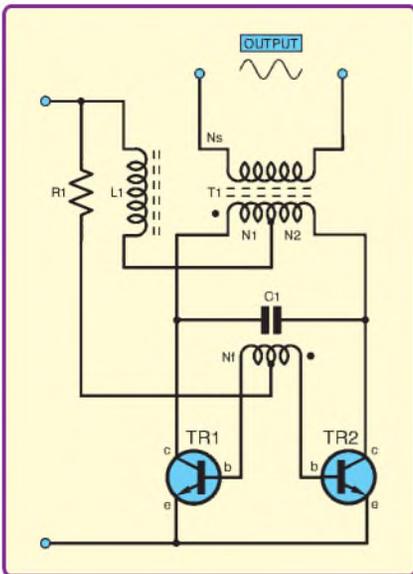


Fig.2: Basic sinewave resonant converter circuit

Fig.3 shows some oscillographs from the complete Fluorescent Tube Driver circuit described below: (a) the signal on the collector of TR1 and (b) the signal at the centre-tap of the transformer primary winding. Note that the transistor voltage in (a) appears to be almost exactly a half sinewave.

When transistor TR1 is on, the voltage across it is held low. When it turns off, the voltage follows the resonant sinewave from the tank circuit, thus creating a series of half sinewaves.

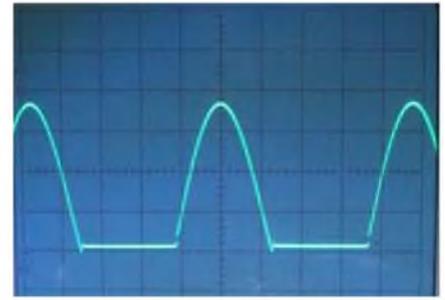
Transistor TR2 conducts in the alternate half cycles, to form the complete sinewave.

The voltage at the centre tap of the primary (b) is made up from both of the half sinewaves, and appears to be a full-wave rectified signal. This circuit is perhaps the closest thing to a full-wave rectifier operating in reverse!

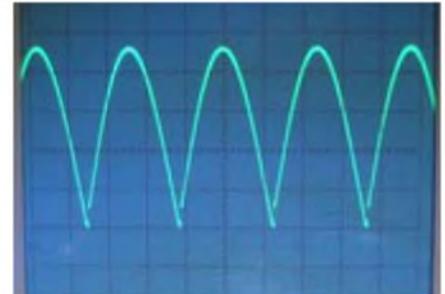
The circulating current in the 'tank' has a high peak value. The 'rectified sinewave' signal at the primary centre tap reaches a peak of about 9.5V, but the transistor voltages reach double this. There is, therefore, approximately 13V AC (RMS) applied across the whole primary winding, with an effective load impedance of about six ohms, which means that the transformer has to be able to handle a current of just over 2A. To sustain its inductance over such a wide operating current means that it should not be allowed to saturate.

Although the circuit is often credited as being a 'Royer', it is different from the original in that the transformer is non-saturating, and the switching point is determined from the voltages in the resonating tank circuit. It seems that this circuit relates to the original in one aspect, in that the transistors still switch on and off. Perhaps this is what is meant by the term 'Royer-class' converter.

The tank capacitor (C1) has to conduct the oscillating current as well as the transformer current. Many of the



a) Horizontal: 5µs/div
Vertical: 5V/div



b) Horizontal: 5µs/div
Vertical: 2V/div

Fig.3: Oscillographs showing signals at a) TR1 collector and b) transformer centre tap

usual types of capacitor are not up to the job, and will become hot as they either do not have a low enough resistance or have a high dissipation factor. The Rifa double-metal type PHE450 capacitor, which has been designed for high current stresses, such as in converters like this and TV circuits, is suitable.



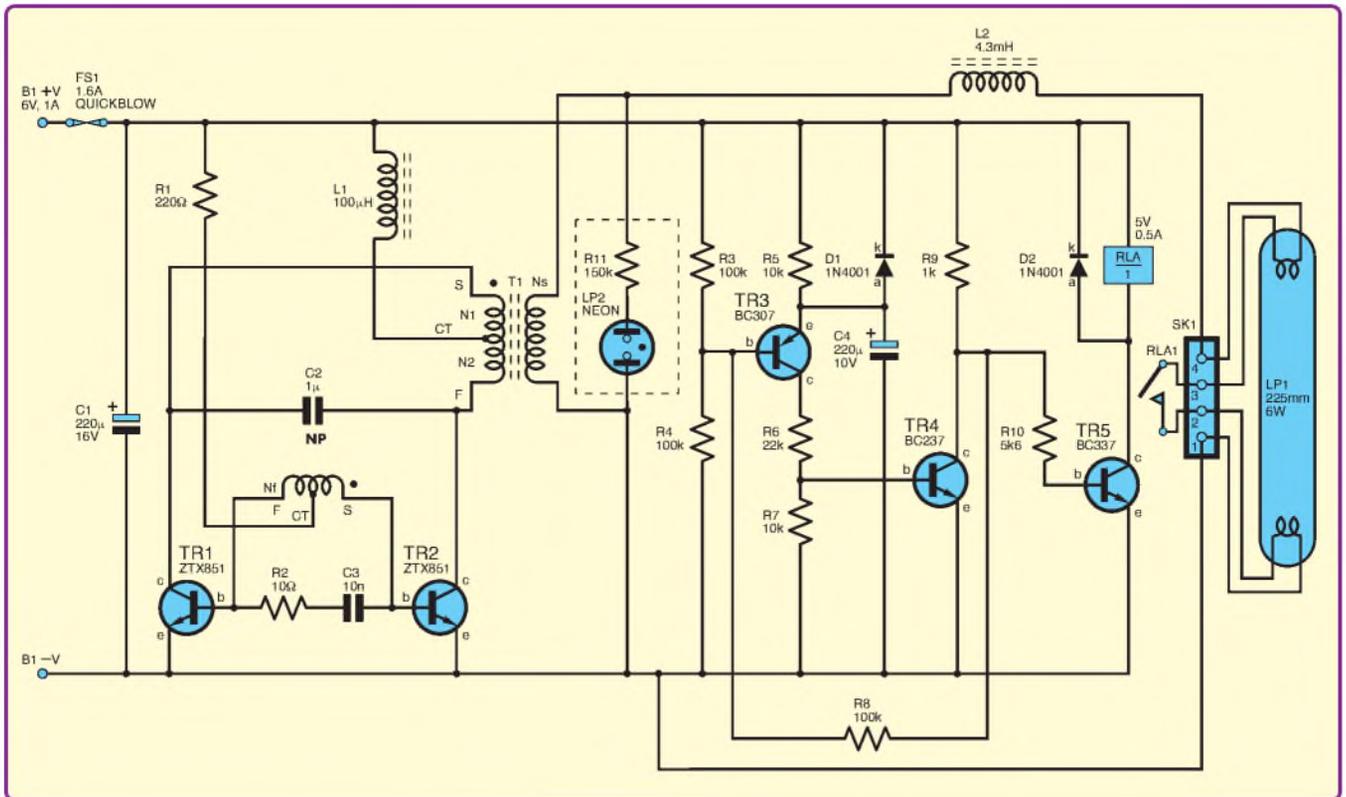


Fig.4: Complete circuit diagram for the Fluorescent Tube Driver

Circuit details

The complete circuit diagram for the Fluorescent Tube Driver is shown in Fig.4. Transistors TR1 and TR2 are the switching pair, and C2 is the resonant tank capacitor. Transformer T1 provides the inductance for the oscillation, the feedback coil to sustain the oscillation and a secondary to provide the high tension for the fluorescent tube.

Note that the transistors' collectors and bases are connected to the primary and feedback windings in opposite phases, as indicated by the black dots. You can interpret these as showing the starts of the windings. Coil L1 provides the sinewave isolation function.

The transistors TR1 and TR2 operate in push-pull. When one transistor is on, the voltage across it is very low, which means that the power dissipated in it is also low; but when off, the current in the transistor is zero, in which case the power is also zero. If the transistors have a low saturation voltage, they will dissipate little power, and with a high gain, the base current required will be small too.

Transistors like the Zetex ZTX851 have a gain of at least 100 at 2A and a saturation voltage of less than 0.25V at 5A. These remarkable devices are

packaged in a small plastic encapsulation which Ferranti, the company that Zetex once was, made famous as their E-line package.

The capacitor and resistor network, R2-C3, across the bases of the switching transistors damps parasitic oscillation, which occurs when the transistors switch off. It is caused by leakage inductance and base capacitance.

Tube strike

Once an AC voltage is provided on the primary side of a transformer, it is possible to choose the output voltage by winding on an appropriate secondary coil. Small fluorescent lamps in the miniature tube range (T-5 size) operate at about 160mA. They are available in 4W, 6W, 8W and 13W ratings, in lengths from 150mm (6 inches) to 530mm (21 inches). For 6V it seemed that 6W would be ideal as this would take about 1A from a 6V battery.

A 6W tube requires an operating voltage of about 37.5V to run. Unfortunately, as mentioned, fluorescent tube loads are not at all friendly, because they are in effect arcs which, once struck, have very low impedances. And, applying 37.5V to the lamp would in all likelihood be far too low to enable the tube to strike.

To initiate the discharge, an operating voltage of at least 150V is required. The secondary is, therefore, wound to provide 150V. Once struck, the arc voltage then requires some form of current limiting, which can be provided by another coil, L2, just as in the normal mains fittings, but this coil is a lot smaller due to the high operating frequency of the unit.

Filament switching

The final part of the circuit provides a pre-heat function. Many years ago, *Practical Electronics* ran an article on a fluorescent tube camping light. It used a single OC23 power transistor, and a small ferrite core transformer. It was pointed out, as far back as then, that fluorescent lamps would blacken very quickly if the arcs were struck instantly from cold. The following month saw a modification with the addition of a pre-heater switch to heat the filaments of the fluorescent tube so as to avoid this problem.

Today, a simple timer function can be added for a few pence, but a little bit more of a problem is the actual means of switching the filaments. In a mains unit, an argon-filled lamp (as opposed to neon lamp) is used to switch the filaments on should the voltage be too high – in other words, at the point of

Parts List – Fluorescent Tube Driver

turning the lamp on, the fluorescent tube is initially off, and the voltage across it can reach 200V or 300V. This lights the argon lamp, which causes a bimetal strip to heat, bend, and eventually short.

Once the contacts short together, a high current (the 160mA limited by the choke) can flow, causing the filaments to heat up. After a short delay, the bimetal strip cools, as there is no power in the argon, and the contacts open. At this point the tube tries to light, and often does. But if not, the process repeats, sometimes causing a flicker.

In this circuit, a single-shot, half to one second timer is used which switches the filaments using a low voltage relay (RLA), as the usual argon-type starter does not work well at high frequencies, even with its suppression capacitor removed. A small 0.3 inch DIL relay rated at 125V, 0.5A was used in the prototype.

Normally, the running voltage of the lamp is less than 40V, which is within the voltage rating, and the operating current is 160mA, within the current rating. But, it is possible that the voltage rating might be slightly exceeded for a brief fraction of a second in the time it takes the relay to pull in immediately after switching on. So far, the author's unit has worked reliably for many operations. The relay has been found to be more reliable and cheaper than using high voltage transistors as a switch.

Many commercially available torches sporting fluorescent tube units are, by comparison, extremely crude. They typically use a high frequency, single switching transistor, a single-ended transformer and do not provide for pre-heating. Lamps tend to blacken very quickly, and it seems that they rely more on the fact that not as many people actually use them as buy them!

Having said that, it is interesting to note that, in fact, such circuits *may* be a little better at running the new cold-cathode fluorescent tubes, which require perhaps 1000 to 5000V at about 5 to 1mA. Cold-cathode tubes are often used in laptop displays, where they provide the back lighting. However, most published driver circuits for these also tend to be of the sine-wave push-pull resonant converter type, similar to the one described in this article.

- 1 PC board, code 661, available from the *EPE PCB Service*, size 170mm x 55mm
- 1 6W 225mm (9in.) fluorescent tube (LP1)
- 1 metal or plastic case, type and size to choice – see text
- 1 5V DIL relay, contacts 125V 0.5A (eg Maplin N99CZ or RS 256-1096)
- 1 wire-ended neon lamp, 65V type T2 (LP2)
- 1 6V 10AH battery (lead-acid recommended – see text) (B1)
- 1 SPST on/off toggle switch (optional – not shown)
- 1 20mm PCB-mounting fuse-holder/clips
- 1 20mm 1.6A quickblow, type F, fuse (FS1)
- 2 T-5 fluorescent tube holders or brass tubing for tube pin connectors – see text

Twin figure-8 wire for fluorescent tube connectors; heatshrink sleeving; battery charger or solar panel to suit battery – see text; solder pins; solder etc

Semiconductors

- 2 1N4001 50V 1A rectifier diodes (D1, D2)
- 2 ZTX851 (Zetex) NPN medium power transistors (TR1, TR2)
- 1 BC237 NPN transistor or similar (TR4)
- 1 BC307 PNP transistor or similar (TR3)
- 1 BC337 NPN transistor or similar (TR5)

Capacitors

- 1 220 μ F radial elect. 16V (C1)
- 1 1 μ F low impedance, high current, non-polarised (NP) (e.g. Rifa PHE450 – RS 544-1327) (C2)
- 1 10nF polyester film, 250V (C3)
- 1 220 μ F radial elect. 10V (C4)

Resistors (0.6W, 1% metal film)

- 1 10 Ω (R2)
- 1 220 Ω (R1)
- 1 1k Ω (R9)
- 1 5.6k Ω (R10)
- 2 10k Ω (R5, R7)
- 1 22k Ω (R6)
- 3 100k Ω (R3, R4, R8)
- 1 150k Ω for neon indicator (R11)

FERRITE TRANSFORMER AND COILS/CHOKES

Transformer (T1)

Core: RM-10, Material: 3C90 Ferroxcube, (Farnell 3056843); or N41 (EPCOS) or F44 (MMG) (RS 231-8757).

Bobbin: 8-pin standard (Farnell 178920; RS part includes this).

Feedback: bifilar 32swg (0.27mm) enamelled copper wire, 1 turn spread along bobbin.

Primary: bifilar 22swg (0.71mm) enamelled copper wire in a single layer of 5 turns (10 in total).

Secondary: 120 turns 32swg or 0.25mm enamelled copper wire.

Air gap 0.3mm (total).

Clips for RM10 (pair) (Farnell 443773; RS part included)

Input coil (L1)

100 μ H coil (RS 308-8839) or

Ferrite Core: RM7, material 3C90, (Farnell 3123431); or N67/N87 (EPCOS).

Bobbin: 4-pin standard, (Farnell 178912).

Wire: 20.5 turns 22swg enamelled copper wire (3 layers x 7 turns per layer)

Air gap: 0.2mm; Clips for RM7 (pair), (Farnell 3123479 – until stocks run out)

Output coil (L2)

Inductance: approx. 4.3mH

Ferrite Core: RM7, material 3C90 or N67, N87 (EPCOS)

Bobbin: 4-pin standard

Winding: 130, 140, 150 turns 32swg enamelled copper wire (or single 140 turns – see text).

Air gap: 0.2mm; Clips for RM7 (pair)

Paper: 80gsm and 120gsm for spacers – see text

Design considerations

The operating frequency was chosen to be in the region of 25kHz as a compromise between ease of design, and silent operation. Most of the older ferrite cores are efficient in this range, but the circuit should also work with newer material intended for higher frequencies. Due to coupling between the load coil and primary, the actual oscillation frequency may be a little higher.

Tank circuit

A resonant tank (in the sense of 'containing a current') is made from the transformer primary and tuning capacitor C2. The transformer is designed with an air gap to prevent saturation and uses a standard RM10 ferrite core. The primary is wound with 5+5 turns of moderately heavy wire, and has an inductance of about 25 μ H.

The feedback and secondary windings are wound with 32swg wire and have 1+1 and 120 turns to give 150V output respectively. The impedance of the circuit at resonance is low and the circulating current can be as much as 3A. The magnetisation in the core is kept below 0.2 Tesla, so although the circulating current may be high, power losses are kept low.

Input coil

The input and output coils in the original circuit used 18mm x 11mm ferrite pot cores, which although still made by EPCOS (formerly Siemens) don't appear to have a UK supplier for the home user now that Electrovalue has ceased trading. Alternative cores were sought and one solution appeared to be to use ready made coils.

The inductance required can be determined very roughly from the impedance required and operating frequency as being at least 12 μ H. Coils larger than this can be purchased or made which have low resistances and do not cause undue loss of efficiency.

RS Components (rswww.com) sell a 100 μ H inductor rated at 2A, which was tested and seems to be fine. Alternatively, a coil can also be made from an RM7 ferrite core, which is similar in size to the original 18mm x 11mm pot core, wound with 21 turns, and using an air gap of 0.2mm to stop it saturating. Farnell (www.farnell.com) sell the RM7, but this is slightly more expensive than the originals.

Output coil

The output coil turned out to be quite critical in terms of operating performance. Two pre-wound coils were tested but neither worked satisfactorily. An RM7 equivalent to the original 18mm x 11mm pot core was designed.

The impedance needed is calculated from the required voltage drop and tube current. With 150V output, and a 40V tube voltage, the voltage drop is 110V, which at 160mA needs 700 ohms impedance at 26kHz, the nominal operating frequency. This needs a 4.3mH inductor. Don't be tempted to use a coil intended for mains suppression as this may not be efficient at 26kHz.

The number of turns needed for an RM7 core with a 0.2mm gap is about 140, very similar to the prototypes using pot cores. The printed circuit board (PCB) allows for the coil to have three taps to allow some selection if required, which is explained in the construction section.

Timer circuit

Referring to Fig.4, transistors TR3 to TR5, and their associated resistors and capacitors in the timer section operate the relay to control the filament pre-heat.

When the unit is switched on, capacitor C4 is initially uncharged. Transistor TR3 is held off, which feeds through to TR4 and prevents this turning on as well. Transistor TR5 therefore turns on, pulls on the relay, which then connects two of the filament terminals together.

After a short interval, capacitor C4 charges up to such a voltage that TR3 turns on, turning on TR4, and switching TR5 off. Positive feedback through resistor R8 provides a firm latch to prevent re-triggering. One slight disadvantage is that transistor TR4 conducts 6mA of current, which is inefficient, but this amounts to only a 0.6% loss.

As this circuit is only a one-shot timer, there is no repetitive flicker, and the timer is set to allow the filaments to heat up using the normal current. It is common to see the ends of the tube glow from ionised gas – not just the hot filament, though this can be seen in a darkened room – just before the relay opens, indicating that the filament is hot enough. Diode D2, across the relay coil, shorts out any back-EMF from the relay when it switches off, while diode

D1 discharges capacitor C4 when the power is disconnected, so as to reset the timer in case the unit is switched on again soon after switching it off.

Construction – coils and transformer

The coils and transformer can be wound using a hand-drill to provide the turns if the bobbins are mounted onto a screwed rod, such as a 5mm or 6mm threaded rod, or a similar fairly long 5mm or 6mm machine screw (threaded all along its length, not to be confused with a bolt, which has threads only at the end). The bobbins can be tightened on the rod or screw using a nut at each end, provided there is some means of preventing damage to the pins.

The author used wood blocks about 8mm to 10mm thick, which were shaped to fit the central part of the bobbins, so that the clamping pressure is applied only to this central section. The pins are able to remain free of the clamp as they fit either side of the shaped wood blocks. A slot was cut in the blocks aligned to the wire lead-outs in the bobbin so that the wires could be taken out. Alternatively, you may be able to fit the bobbin using suitable washers, or a stack of washers or spacers.

The important point is that whether you use wood blocks, or washers or other spacers, they MUST allow the bobbin to be tightly clamped without trapping a thicker ledge, or the pins, or the bobbin might break when the nuts are tightened to hold it in place. The nuts do not need to be overtight, but have to prevent the bobbin spinning on the rod.

Once you have clamped the bobbin on the screwed rod or machine screw, place one end of the rod into the chuck of a hand-drill. (This is not good practice as the chuck will tighten on the threads, but it is a quicker way to wind a coil). Do not be tempted to use an electric drill, because this is likely to spin the bobbin so fast that it may become unstable and fly off, and cause injury to you, someone else, or damage the furniture!

Each coil will need to be taped after winding to hold the winding in place. A good tape for transformers and coils is the standard yellow polyester type, but masking tape can be used at a push. (It has to be said that masking tape for transformers

ought to be a higher temperature grade than the normal household type used for painting, but in this circuit, the components have been designed not to get unduly hot).

Spacers will need to be made to form the air gaps in the cores. For the input and output coils, the spacer needs to be 100µm thick; which conveniently is the thickness of standard 80gsm paper used by office laser printers. The transformer needs to use 120gsm paper, which is also fairly common at stationers, as cartridge or heavy grade paper. This will have a thickness of 150µm.

To make the spacer, 'trace' the outline of the ferrite core onto the paper by placing the paper on the core (over the inside surfaces), and gently roll your finger over the paper, pressing particularly around the edges. Don't use too much pressure – ferrite core edges can be sharp! This will mark the paper, and you can then cut the shapes out.

Coil winding

The coils are wound as follows:

Transformer

A 'power' type bobbin was used in the original, but it seems that supplies are now also likely to be limited. Instead, the transformer winding details are given assuming that you can only obtain the standard type. In this case, the heavy leads are not soldered to pins, because the bobbin won't take them. Instead they are left as 'flying leads', not very satisfactory, but we can make do. An 8-pin bobbin will then suffice for the thinner wire connections. The PCB layout assumes the ordinary bobbin type.

Start with the feedback winding. Wind two 32swg lengths of wire, side-by-side, (called bifilar) onto the bobbin starting at the 'pin' end and finishing on the opposite and, taking the wires out through the bobbin slot after one turn. Spread the turn along the length of the bobbin, so that it lies at more or less 45 degrees. Wind a layer of protective tape over the coil to hold it in place. Label the wires F1S, F2S at the start (pin) side and F1F, F2F for the finish ends by Sellotaping paper notes to them. These wires will be soldered to pins after assembling the core.

Next, wind the primary with two lengths of 22swg (0.71mm) wire, again side-by-side, this time labelling

the starts P1S, P2S. Start these in the same side of the bobbin as the feedback winding. Wind a total of five turns of the pair of wires, which should fit into one layer if neatly wound. Wind a layer of tape over the primary to hold this in place. Label the ends P1F, P2F accordingly. (If you lose track of the identities of the two wires, at least mark the starts and ends. You can match the end of one wire to its start later using a continuity tester: an ohmmeter or a battery and bulb). These wires should be left 'flying' with at least 50mm (2in.) of wire at each end to connect to the PCB.

Finally, wind the secondary. Start the winding in the opposite side of the bobbin to the feedback and primary wires. Proceed to wind 120 turns of 32swg (0.27mm) in neat layers (you should manage about 27 to 30 turns per layer). Leave about 50mm of wire at the ends. These wires will also be soldered to pins. Label the start end simply as 'S' and the finish as 'F'.

Core assembly

Assembling the core is straightforward. Mount the bobbin into one of the two ferrite core halves, then place the paper spacers over the surfaces, using thick ones for the transformer, (150µm); then place the top core half onto the bottom without dislodging the spacers, and clamp the two halves together using the transformer clips. Make sure that the clips have their solder pin ends pointing down in the same direction as the pins on the bobbin.

With reference to Fig.5, solder the wires to the pins as follows: with the bobbin held upside down, looking directly at the pins, orient the core with the primary and feedback windings to your left, and secondary to your right. Take the start of one of the feedback wires and solder it to the bottom right of the left-hand group of pins as described in the paragraph below.

If you have not identified the end of

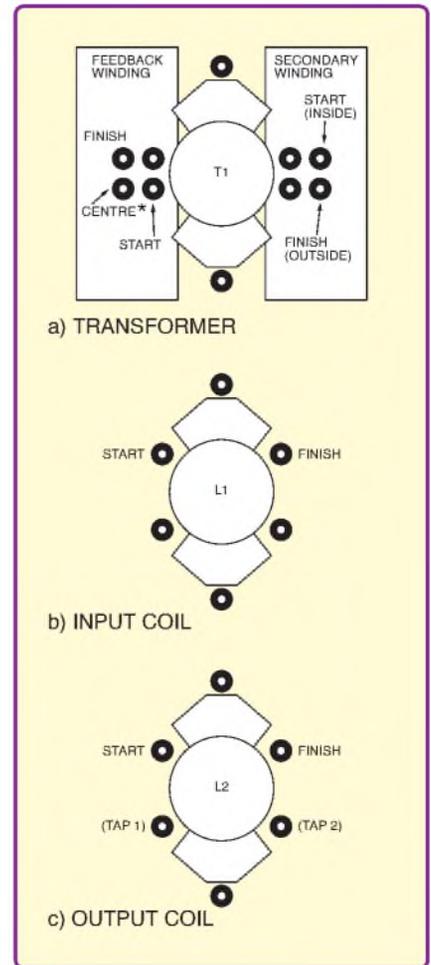
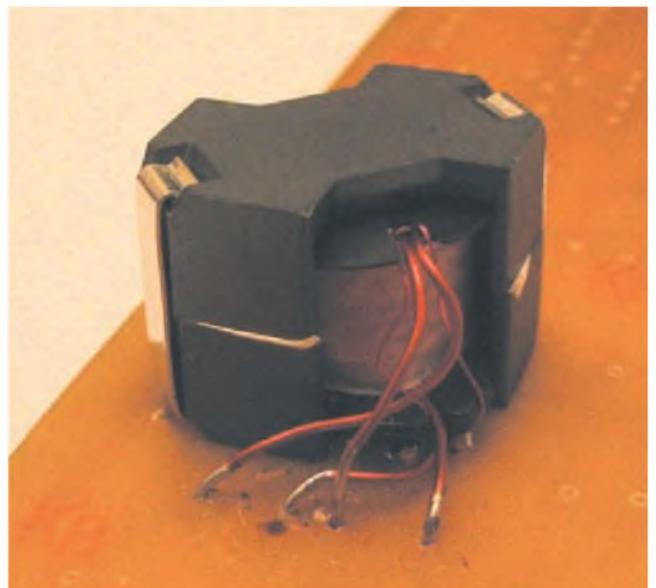


Fig.5. The transformer and coil pin connections (looking at pins). The centre tap marked with an asterisk is the finish of the first coil joined to the start of the second



The completed transformer wired to the PCB

this particular wire, find it by tinning the start and ends of both feedback coils, so that you can make contact to the wires. Use an ohmmeter or battery and bulb (low current only!) to find the end of the first wire. This lead will be joined to the other remaining start wire to form the centre tap, and both wires soldered to the bottom left of the left four pins. Finally, the last end can be soldered to the top left of this group. The secondary leads are soldered to the bottom right and top right of the rightmost set of four pins.

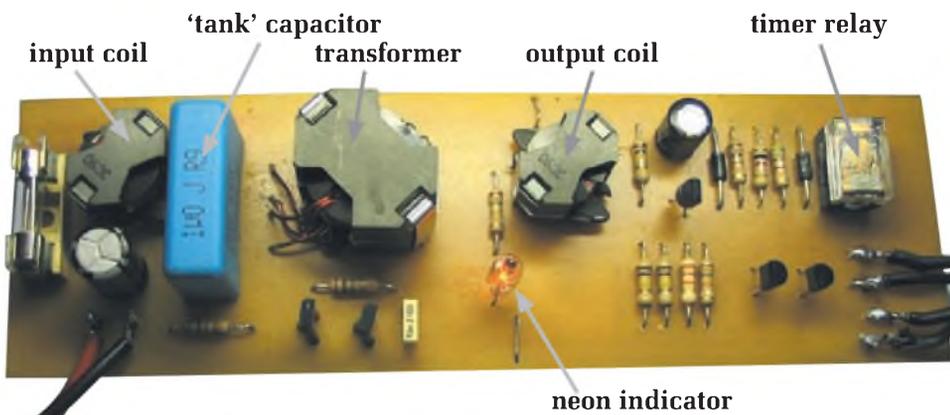
It is good practice to wire the low voltage side (nearest the primary, or inside connection) to the pin which will connect to the negative lead, which is the top right pin. The high tension side, or outside, can then connect to the bottom right pin. You may want to mark the low tension (battery) side and output (high tension) side with a marker pen to help to locate this into the PCB later.

To make a solder joint, start by wrapping the wire partly around its pin, then unwind. This will show where the wire needs to be tinned. Tin the wires using a hot soldering iron, which will vaporise the polyurethane coating. Don't breathe the fumes, and do solder in a well ventilated room as the fumes contain small quantities of cyanide. Professional solder stations today also have air ventilation to remove solder fumes, so try not to breathe these either.

Tin about 10mm of wire starting from the point marked earlier. Once tinned, the wire should be twisted once or twice around its pin, and soldered. Don't try to solder an untinned wire wrapped around the pin, as the temperature needed to dissolve the polyurethane may melt the bobbin. Only solder the feedback and secondary wires to the pins as the heavy wires won't fit.

Input and Output coils

The input and output coils are simple compared with the transformer. The input coil needs 21 turns of 22swg, which is wound in three layers of seven turns. The start wire will be at the pin end of the bobbin, while the finish end should not only be at the opposite end, but also in the opposite window side. This means that actually 20½ turns are used, rather than 21. Again, referring to Fig.5, the wires are tinned and soldered to the pins as follows: looking directly at the pins,



Positioning of the main components on the finished prototype PCB

with the pins in a left-right orientation, wire one end to the top left pin, and the other to the top right.

The output coil, as mentioned earlier, is critical. The prototype coil required 120 turns on the original 18mm x 11mm pot core, but during construction of the second version, it was found necessary to use 140 turns on the RM7 core. Variations of core material and air gap may require the number of turns on this coil to be adjusted, and there are two ways to do this.

One option is to wind a coil with taps. Provided you keep the start pin in the same position, having options to take the finish from one of three possible pins means that you can wind the coil with 130 turns, take a tap out by looping about 2cm of wire out and back into the coil, then adding 10 turns, and taking another tap, and finishing after 150 turns in total. Later you can select the best coil for the fluorescent tube.

If you prefer a simpler construction, wind a straight 140 turns. You can adjust this later if you do not glue the core, or lastly you can wind on 140 turns, and assemble everything full stop. The battery current may be slightly higher than the nominal 1A, running at 1.2A, but this is acceptable.

Refer to Fig.5 to determine the coil winding connections. The only constraint on the output coil is that the start wire needs to be taken to the top-left pin, when the bobbin is oriented as shown. You may want to make a mark on the start pin to help orient this into the PCB. The other end can be taken to any one of the other three pins, unless you have opted for the tapped coil, in which case take one tapping to each pin.

Assemble the input and output coils onto the cores using the 80gsm

(100µm) paper spacers you should have prepared earlier. Finally, clamp the two halves using the clips, again making sure they point in the same direction as the pins on the bobbin. If you are not able to obtain clips, you can glue the core halves, but don't glue the core halves until you have tested it. The paper spacers will take superglue quite readily. For testing, it is possible to hold the core together using, a little crudely, an elastic band, as a temporary measure!

Construction – circuit board

All components, except the 6V 10AH battery and tube, for the Fluorescent Tube Driver are mounted on a single-sided PC board, measuring 170mm x 55mm. This board is available from the *EPE PCB Service*, code 661. The printed circuit board component layout and full-size master is shown in Fig.6.

To assemble the PCB, it is easier to locate and solder in position the diodes first. The cathodes of both (indicated by the black bar at one end) are connected to the DC positive and should be soldered as indicated. Then the resistors can be soldered in, followed by the transformer and coils.

When inserting the transformer, make sure that the pins are oriented correctly so that the primary and feedback windings are wired on the low tension side, while the output is facing the high tension side. The flying leads from the transformer need to be soldered correctly. Fig.6 shows where the wires should go. If you wired the feedback winding correctly, the 'start' should appear at the top of the left group of four pins (looking down on top this time) and this connects to the base (b) of TR2.

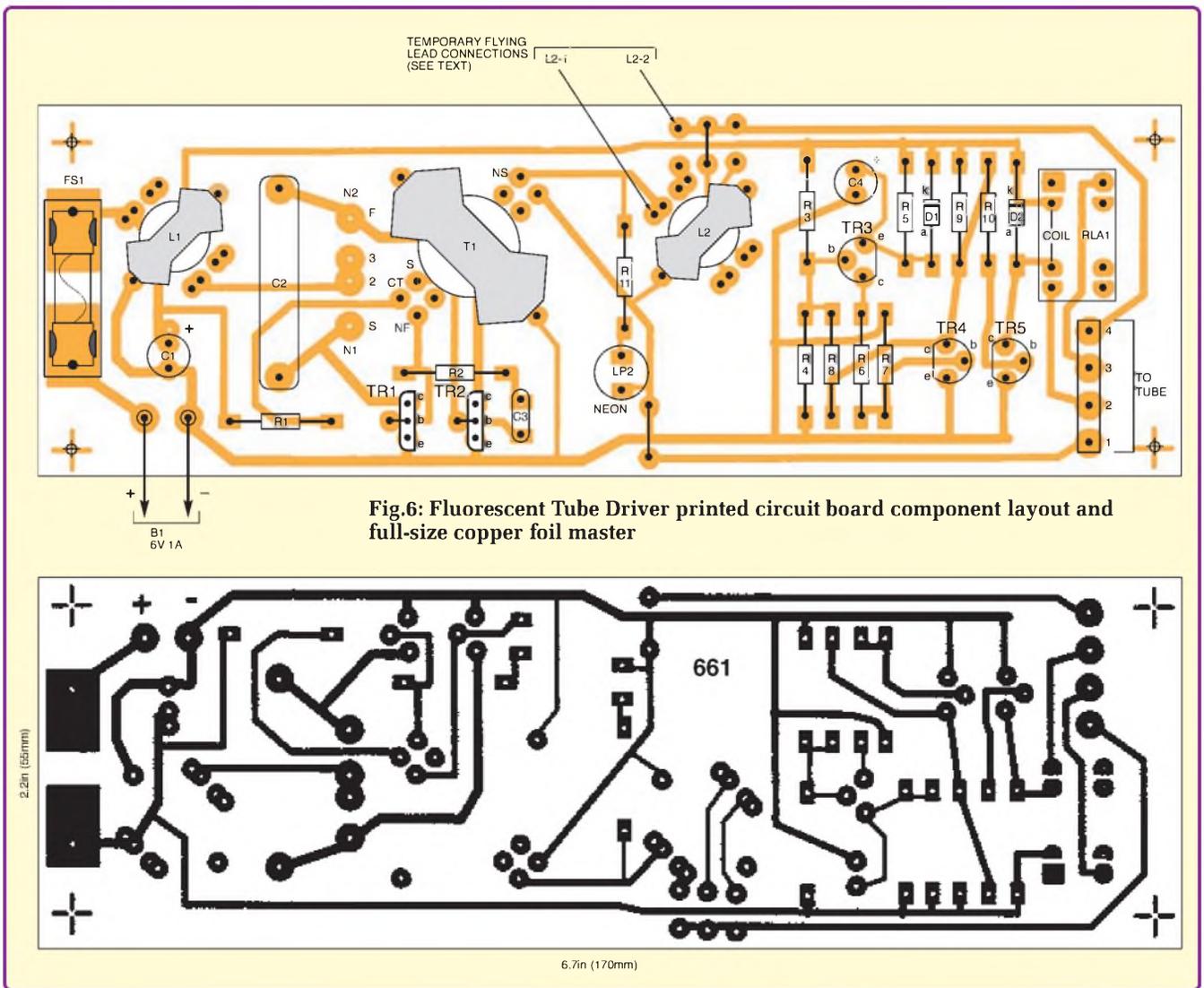


Fig.6: Fluorescent Tube Driver printed circuit board component layout and full-size copper foil master

The 'start' of one of the primary leads needs to be wired to the collector (c) of TR1. This is soldered into the connecting pad marked 'S'. The start lead should be one of the two leads exiting the bobbin at the pin end. The other end of this lead needs to be routed into and soldered to the next hole up. If you did not label the end, find out which it is using an ohmmeter or battery and bulb. You will, of course, need to tin the ends of the wires to measure them.

The other 'start' lead can now be routed to and soldered into the third hole, which is connected in the track on the PCB to the finish end of the first coil. The second 'finish' (or final) end of the primary is then routed and soldered into the last hole marked 'F', which connects to TR2 collector (c). If any of these connections are wrong, the circuit won't oscillate.

The input coil L1 also has to be plugged in the right way round. Check

that the input coil start is inserted facing towards the fuse: top left. Leave the output coil L2 for the moment and continue to solder in the rest of the components.

The capacitors can be added, then complete the PCB by inserting pins or wires into the lamp connectors, and inserting the fuseholder onto the input side. The generous copper pad areas under the fuseholder are intended to allow for a range of holder options. The original design is intended to take a Bulgin low-profile fuseholder, but you can also drill the pads to take small PCB-clips instead. If you prefer, you can also add a neon lamp to show that the HT works by soldering a wire-ended neon (LP2) into the lamp holes, and add a 150kΩ resistor to limit the current. This is shown boxed in the circuit diagram Fig.4.

To check that the output choke L2 is working correctly, before you solder it onto the board, connect the wires

from the start and 130 turn tap pins to the PCB with short flying leads. Solder these to the places they would go to normally, shown as 'L2-1 and L2-2' in Fig.6.

Lamp connectors

Connections to the fluorescent tube pins can be made in several ways. One would be to solder wires directly, but then it is difficult to replace a lamp without a soldering iron. The neatest option is to purchase two T-5 end caps, but these are often sold only in 10s or 20s from RS or Farnell. Sometimes convenient screw-terminal types can be found in second hand or surplus shops, but there are fewer of these around than there once were. Some connectors are designed to take single core wires, as a 'push in once', which makes them less easy to use with flexible wires.

The author made connectors using short lengths of brass tubing. Cut

four 20mm lengths of 2mm to 2.5mm (internal dia.) brass tubing, which is often sold by model shops. Solder the ends of two lengths of paired wires (2-way bell wire or light duty speaker cable is adequate) into one end of the brass tubes, leaving the other ends open. These should slide over the tube pins. If they are too loose, slide them off and use a crimping tool to make a slight indent into the brass fitting. Don't overdo the pressure or the brass won't slide onto the tube pins at all. Complete the ends by using a heat-shrink sleeve over the brass tubes and use the hair dryer to shrink-wrap to finish.

Filament relay

Once again, there seems to be a problem with consistent component supplies, even though the prototype is less than three years' old! The original unit used a 5V, single-pole changeover relay, a Siemens V23101 type (now marketed by Axicom/Tyco). This appears to be no longer available from common suppliers. However, Maplin sell a smaller relay, under part number N99CZ. The PCB has been relaid – as it were – to accept this relay. If you use a different type, the pin configuration may be different.

Some types of relays have the coil connections on one side of the package, others with the coil connections from one side to the other. Some have built-in diodes, and if you use one of these the terminals need to be wired correctly so that the diode cathode (k) is taken to the positive supply line, and the anode (a) taken to the transistor.

You may have to redrill the PCB, cut the copper tracks and re-wire to suit your chosen relay. Use a thin wire, such as the 30swg wire-wrap type, soldered to the tracks. **Be careful around the high tension tracks because the voltages are quite high (150V RMS generates 220V peak).**

Checking

Without soldering the four fluorescent tube wires onto their connectors, you can check that the unit oscillates and that the relay works by wiring an ohmmeter across the tube pins, which will be connected by the relay (nos. 2 and 3 in Fig.6); and if you have a neon lamp this will indicate whether the HT is present. If you have an adjust-

able power supply, set the current limit to 1.5A, the voltage to 6V.

Finally, before testing, make sure that the PCB is placed on an insulating surface, and *keep your fingers away from the board as the voltages reached are high and could cause injury!* When

safe, connect the wires to their respective power supply terminals. If everything is correct, the unit should oscillate and light the neon rather brightly. If you do not have a power supply, but only have a 6V battery, the oscillation can be checked if you use, say, a 10 ohm resistor in series to limit the current in the event of a short.

If the circuit does not work, disconnect and check the wiring. The commonest faults to be expected would be that the transistors are put in backwards, or that the transformer wires are not phased correctly. You should also hear the relay clicking on at switch-on, and off after about half a second later.

If all is well, you can connect the wires to the tube. Make sure that the pair of wires from one filament are soldered to positions 1 and 2, and the other to positions 3 and 4. If you had a protection resistor to test the circuit, remove it. If you did not solder the output coil onto the PCB, solder the flying leads to the pads where the coil would have gone.

Once again, make sure that you will not be able to touch the high voltage wires or tracks. There are two wire jumpers to be soldered on the PCB, one on each side of the board to carry the output to the lamp connections. At this point, wire the earthy jumper into the PCB. Now when switching on, you should see that the filaments glow and then the ends fluoresce, followed by the lamp lighting up once the relay opens.

The author understands that Farnell will no longer stock RM7 clips once the current stock has gone. It is possible to assemble the cores without clips using Superglue, but this will prevent the cores being taken apart once they are glued. You can hold

Specification

Supply Voltage	6V DC
Nominal operating current	1.1A (1A to 1.2A)
Power loss approx.	1W
(A power loss analysis indicates that the transformer core dissipates 0.4W; the output choke 0.15W, transistors 0.15W and the primary wire resistance 0.15W=1W)	
Output power	6W

the core halves together temporarily using elastic bands or taping around the outside for testing, but it is necessary to try to clamp the cores and the spacers fairly tightly, without breaking the core.

The designed current consumption is 1.16A. The prototype unit drew just under 1.1A from a 6V battery. The second unit was slightly less efficient and drew just under 1.2A. This is the maximum current expected, and anything higher would indicate a problem. Using a choke coil with more turns will reduce the lamp current a little and thus reduce the power drain as well.

Power source

A 10AH lead-acid battery is recommended, giving nominally 10 hours operation (but 6 to 8 hours in practice). NiCads can be used if preferred, but lead-acid is normally cheaper for higher capacities. You can use lower capacity batteries, but would not recommend using less than 2AH – and even these will be quickly exhausted, and should be of the high-current type.

Note that you will need five cells for 6V if you use NiCads. But the unit will operate quite satisfactorily from four cells giving 4.8V too, with reduced lamp power.

The efficiency of the prototype was about 90%, one of the best figures the author has obtained in a fluorescent tube driver, but the second, apparently due to transformer core differences, is only about 85%. The high efficiency is due to the Zetex transistors and low impedance capacitor, which as mentioned should be a high current type.

The typical performance which can be expected is shown in the above spec panel.

Completing and troubleshooting

If the unit works satisfactorily, you can solder the output coil onto the PCB, and if you did not obtain clips for it, you can glue the core halves together. To glue, place the bobbin into one half core, dab Superglue onto the spacers and position them on the core faces, using tweezers so that you do not attach yourself at the same time. Next, dab glue onto the upper half core faces, and position this onto the lower half, onto the spacers and press the two together. Note, this will be a permanent step. Once the cores are glued, it will be virtually impossible to dismantle them.

After soldering the bobbin into the PCB, taking care that it is oriented correctly, you may notice that the core will be able to move a little. To stop this, you can squirt some glue from a hot-melt gun between the core and the PCB to hold this firmly.

There is a jumper on the PCB, which needs a short length of tinned wire to connect to the appropriate coil tap. My guess is that the 140 or 150 turn tap is needed, and this will be the pins as indicated. If you had not noticed the jumper on the other side of the PCB, connect this now.

If you find that the battery current is any higher than 1.2A, the tube may be being over-powered. It was found that using the wrong type of capacitor for C2 caused a high current drain too, which is why a high current type is specified. If the capacitor is correct, one possibility is that the coil L2 has too little inductance. This may occur if you used too thick a spacer on L2, or too thin a spacer on the transformer, but whatever the reason, there are some things which can be tried to achieve the expected performance.

If you built the tapped version of the coil, you can try the next higher turns. If you only wound 140 turns, you should dismantle the coil and add 10 turns and try again. Twist the start wire onto the finish of the 140 turns, wind 10 turns in the same direction, and check the new coil. You can add up to 20 turns without too much trouble.

If you still find that the unit takes excessive current, there is no other fault found, and you can no longer adjust the output coil, because you may have soldered it onto the PCB,

or glued it, and you did not wind the tapped coil, there is another option. Unclip the transformer clips, use pliers to bend them away from the core once unclipped, so that the top core half is clear: don't just yank them back or you may crack the lower core half.

Slide the top half of the transformer core off. Place an additional spacer layer over the previous spacers, or use a really thick card spacer (eg 150gsm card) and replace the core. This will increase the operating frequency a little more but the lamp choke will have a higher impedance.

Batteries and chargers

Lead-acid batteries generally require current and voltage limited charger supplies. A 6V battery charger should be clamped at 2.25V to 2.3V per cell, (6.8V max.) and current limited to one-tenth of the capacity in amp/hours – such as 1A for a 10AH unit. Battery chargers should also be able to be left connected even if the mains fails, which requires some design consideration so that the charger does not inadvertently discharge the battery if the mains is switched off. On the other hand, NiCad cells generally only need current limited chargers, but still benefit from voltage monitoring so as to switch the charger off if the voltage were to peak, indicating that the cells are fully charged.

Solar panels can be used to top up the battery, provided that the power is similarly regulated. Some common 12V units can be used to charge 6V batteries with suitable regulation. One crude limiter would be a 6.8V Zener diode of at least 1W (depending on the output of the solar cell) connected across the battery and a series resistor of about 47 ohms, rated at least 5W.

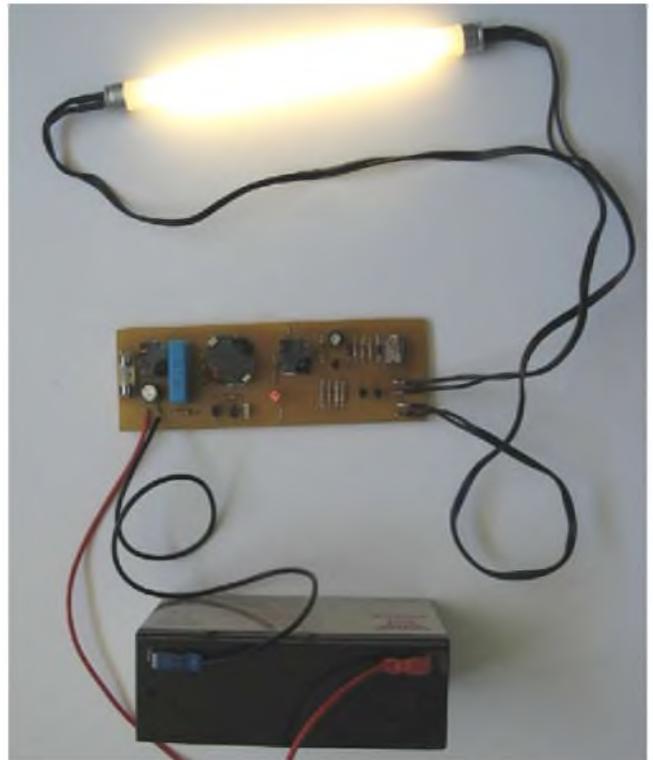
Completion

Once everything is operational, build the board into a project box to

BE AWARE
HIGH VOLTAGES ARE
GENERATED BY THIS
CIRCUIT AND EXTREME CARE
MUST BE TAKEN WHEN
TESTING OR HANDLING THE
CIRCUIT BOARD

prevent accidentally touching the high voltage tracks. There are four PCB mounting holes which should be drilled to take M3 screws. Plastic spacers can be used to stand the board off the chassis or box. If you use metal spacers, make sure that they do not touch tracks on the PCB. If they do, then use a fibre washer or thick card to insulate it.

There are a range of diecast and chassis type cases on the market, but you will need a rather large one, unless you can find a long/narrow case, just to accommodate the length of the board. Larger ones should have room for a battery pack, or switch and so on. If you have access to metal bending equipment, you can make an aluminium case the right size. The battery leads and tube wires can be fed out through drilled holes, using grommets to protect the cable from the metal edges. **EPE**



Testing the operation of the PCB prior to casing up

Circuit Surgery

Ian Bell



Current Sources

User *scott2734* recently asked about current sources on the *EPE Chat Zone* forum (access via www.epemag.co.uk):

My question is can you get a current source to test a real circuit? And if so, how does it just put current into the circuit without putting out some voltage?

I think the current sources in my textbook are imaginary, just to show you how to do the maths: Thévenin and Norton theorems. The schematics have a circle with an arrow inside it showing the direction of the current flow, but do not induce any voltage. I have seen constant current sources made out of a transistor, but do these induce, or put out any voltage?

Most people are familiar with voltage sources (specifically batteries and the mains); unfortunately, there is no similar everyday commonplace current source. However, current sources are very important in electronic circuit design.

Although most electronics hobbyists probably do not include them in designs very often, they are to be found lurking inside almost every analogue IC (such as op amps). There are some applications where you might directly use a current source; these include LED drivers, ramp generators and battery chargers. We will look at the basic concepts, basic circuits and examples of ICs, which are based around current source circuits.

Current sources

As any electrical source 'supplies' both current and voltage if it is doing anything useful, so when we say *current source* we typically mean *constant current source*. Before we look in more detail at current sources it will help to look at voltage sources, so we can see some basic concepts in a more familiar context and then compare the two types of source (see Fig.1 for their symbols).

An ideal constant voltage source can output any current without the voltage changing, or cutting out. As *scott2734* suggests, ideal sources do not exist in the real world (this applies to both current and voltage sources); however, they can be useful in simplified calculations and simulations.

For example, when analysing circuits we often assume that the power supply is an ideal voltage source for simplicity. In practice, of course, a battery's voltage will drop

if you connect a heavy load (low resistance), a bench power supply may cut out or limit the current when overloaded.

Ohm's Law

To pursue this further we need to use Ohm's Law – the basic relationship between current, voltage and resistance. This is $V = I \times R$, or to find the voltage across a resistor (V in Volts) multiply the current through it (I in Amps) by the resistance (R in Ohms).

If we connect a voltage source to a resistor, as shown in Fig.2, it must produce a current given by $I = V/R$. If we connect a resistor with a very low value across the voltage source it must produce a very high current in order to satisfy Ohm's law for the resistor.

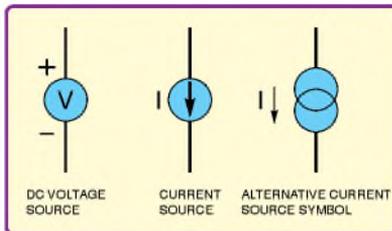


Fig.1. Voltage and current source symbols. These represent ideal sources

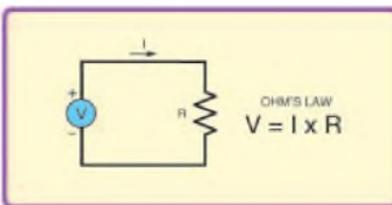


Fig.2. Demonstrating Ohm's Law

For example a 9V battery with a 0.1Ω resistor across it would ideally produce 90A ($9/0.1 = 90$), but a small battery like a PP3 is just not up to the task! So what happens if the voltage source is not capable of producing the required current? Is Ohm's law broken? The answer of course is *no*; what happens is that the voltage source pushes out as much current as it can and its output voltage reduces to the point given by Ohm's law for the load resistance and current involved.

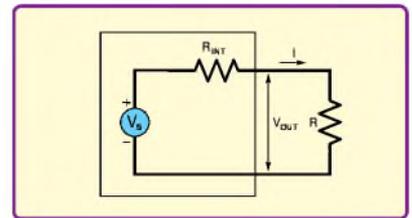


Fig.3. Internal resistance of a real voltage source

Internal resistance

We can understand what is going on using the concept of *internal resistance*. Real voltage sources can be thought of as comprising an ideal voltage source (with voltage V_S) and a resistor (R_{int}), as shown in Fig.3.

So when we connect a resistor to a real voltage source, the current (I) flows through both resistors with some of the voltage dropped across both. The voltage at the terminals of the real source (V_{out}) therefore becomes smaller and smaller as R is reduced and a greater proportion of V_S is dropped across R_{int} . The internal resistance limits the maximum output current to V_S/R_{int} , at which point V_{out} is zero. In practice we cannot physically separate the voltage source and internal resistance.

A battery's internal resistance is noticeable as a drop in voltage as we decrease load resistance, and as its internal resistance increases over its service life the resistance tends to get worse as the battery is used up.

The effective internal resistance of bench power supplies (and regulator chips) can be made very small using (feedback) control circuits. Basically they monitor V_{out} and effectively change V_S so that V_{out} remains constant, compensating for the drop across R_{int} . This cannot go on forever of course, because at some point we reach the maximum current or voltage rating of one or more of the power supply's internal components.

So bench power supplies can sometimes deliver the same voltage (with little drooping) until some maximum current, at which point they cut out. Here, due to the active control circuitry, the maximum output current may be much less than that implied by the internal resistance (V_S/R_{int}) as we discussed before. Thus, a good bench power supply may be a good approximation of an ideal voltage source, but only over a limited range of currents.

Limitations

By now you may have guessed that an ideal current source outputs a particular current irrespective of the voltage, and that real current sources are limited in some way. Real current sources also have internal resistance (see Fig.4), but it appears in parallel with an ideal current source and is usually very large.

The internal resistance of the current source limits its output voltage to $I_s R_{int}$, at which point I_{out} is zero. Real current sources may also have a limited range of voltages over which they can operate (sometimes called *compliance*), determined by factors other than the internal resistance (in a similar manner to the bench power supply described earlier).

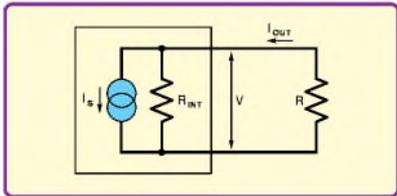


Fig.4. Internal resistance of a real current source

When we include an (ideal) voltage source on a schematic we do not write a current by it because it can output any current. Similarly, when we include an (ideal) current source on a schematic we do not write a voltage by it because it can output any voltage.

If we short a current source then, unlike a voltage source, it has no problem – its output current simply flows through the wire. If we connect a large resistance across an ideal current source, then, by Ohm's Law, it must develop a large voltage across the resistor. For example, if we connect a $1M\Omega$ resistor across a $1mA$ current source it would have to produce $1000V$ across the resistor to maintain the required current. If a current source is open circuit then it cannot operate (unless it can produce arcing!).

Ideal conditions

An ideal voltage source delivers infinite current to a short circuit, and an ideal current source produces infinite voltage across an open circuit. Note the opposites here: voltage sources have an 'easy life' with open circuits and a 'hard time' with short-circuits, for current sources it is the other way round.

Current sources connected to ground, through which current flows to ground, are sometimes called *current sinks* (See Fig.5).

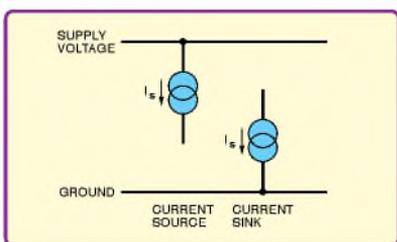


Fig.5. Current sources and sinks

Thévenin and Norton

In his question *scott2734* mentions the Thévenin and Norton theorems. Thévenin's theorem states that any network of current sources, voltage sources and resistors, which has two output terminals, can be represented as a single ideal voltage source with a single series resistance (as in Fig.3). This is known as the *Thévenin equivalent circuit*. Norton's theorem is similar except that the equivalent circuit comprises an ideal current source and a parallel resistor (as in Fig.4).

It is possible to convert between the Thévenin and Norton equivalents. The internal resistor value R_{int} is unchanged and the source values are calculated using:

$$V_{Th} = I_{No} R_{int}$$

$$I_{No} = V_{Th} / R_{int}$$

in which the subscripts for the sources Th and No refer to the Thévenin and Norton equivalent circuits respectively.

For example, if we have a $9V$ battery with a 2Ω internal (series) resistance this is equivalent to a $4.5A$ current source with a 2Ω internal parallel resistance. We can check that these are indeed equivalent by calculating what happens when we connect a load resistor across the terminals. If we use 400Ω in both cases we get a current of $22.4mA$ through the load resistor and a voltage of $8.96V$ across it, reduce the load to 300Ω and we get $29.8mA$ and $8.94V$.

We see these voltages are very close to the Thévenin equivalent voltage, but a long way from the Norton equivalent current, with the change in load causing a large proportional change in load current (+33%), but changing the load voltage only a little (-0.2%). As we might expect, our battery is behaving as a reasonable constant voltage source, but as a very poor constant current source.

Thévenin and Norton equivalent circuits are used in circuit analysis to reduce complex circuits to a simpler representation for the purpose of further analysis. Using one or the other equivalent does not imply a circuit acts anything like an ideal current or voltage source; but if you do find these equivalent circuits, the internal resistance value will indicate if the circuit may behave more like one ideal than the other.

Transistor current source

Transistors provide us with a ready means of creating a current source. Bipolar transistors work by using a voltage at the base to control the current flowing from collector (c) to emitter (e). If we make the voltage on the base (b) of a transistor constant we get a constant collector current, so the collector is the output of a current source (see Fig.6a).

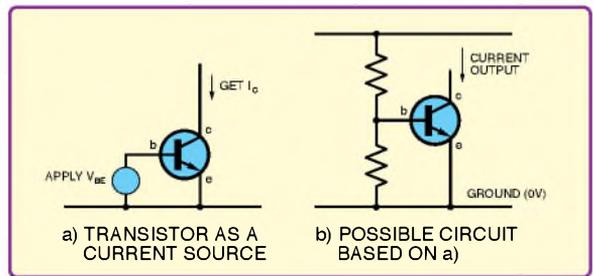


Fig.6. The transistor as a current source

You may be thinking that it is the base current which controls a transistor's collector current, but there is a fixed relationship between base-emitter voltage and collector current, so a given base voltage results in particular base current. The reason we often think in terms of base current is the simple relationship between base current and collector current (the transistor's current gain), whereas the base-voltage to collector-current relationship involves an exponential equation.

We could obtain a fixed voltage for our transistor's base using a potential divider (see Fig.6b). This circuit does not work very well because the current changes with temperature – all semiconductor devices such as diodes and transistors are very temperature sensitive. The current will also change quite a bit if the supply voltage changes due to the exponential base-voltage to collector current relationship.

A better approach uses another transistor. If we 'push' a current into the transistor's collector at the same time as providing it with some means of taking whatever base current it needs, then a particular base voltage will develop (see Fig.7a). This may seem a bit strange as we normally think of the collector as the output, however, there is a one-to-one mathematical relationship between base-emitter voltage and the collector current; so if we control one, we control the other.

If we combine the ideas in Figs 6a and 7a we arrive at the circuit in Fig.7b. In this circuit, a current is pushed into transistor TR1, causing a certain voltage at its base. The second transistor has the same base-emitter voltage as the first transistor because their bases and emitters are connected.

Current mirror

If the two transistors in Fig.7b are identical, then because their base-emitter voltages are the same they will have the same collector current (except for a small error

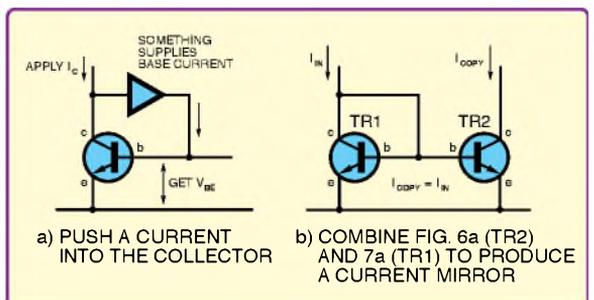


Fig.7. Producing a current mirror circuit

due to the base current of TR1). This circuit is known as a *current mirror* – circuits like this are very important in analogue integrated circuit design. Current mirrors take a current and produce a copy of it.

What exactly do we mean by *identical* transistors? Transistors are identical, or more realistically very similar (known as matched transistors), if they have the same parameters (gain etc.) and the same physical conditions (temperature etc.). This can be achieved by making them the same size and shape and close together on the same piece of silicon. Chip designers know various tricks to make sure transistors are closely matched.

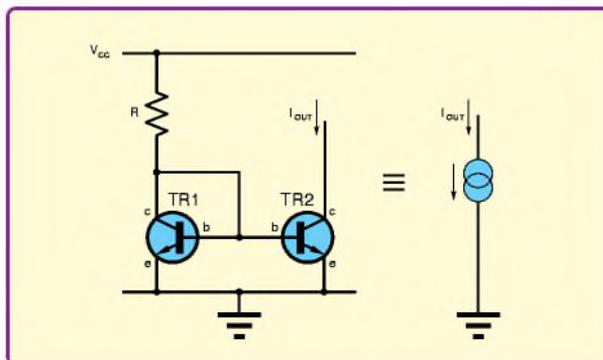


Fig.8. Current source based on a current mirror. Transistors TR1 and TR2 are a matched pair.

We now have a current mirror, but not a current source. To get a current source we

have to supply a fixed reference current as I_{in} in Fig.7b. It turns out that this is quite easy to do; all we need is a resistor from the supply to the collector/base of TR1 (see Fig.8). To calculate the value of R we assume that the base-emitter voltage of the transistor V_{BE} is fixed, and in the range of 0.6 to 0.7V, the output current is then:

$$I_{out} = (V_{CC} - V_{BE})/R$$

Next month, we will look at some more details of current source circuits and then consider some current source applications and the ICs that can be used to implement them.

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SP10	100 x 1N4148 diodes	SP147	5 x Stripboard 9 strips x 25 holes
SP11	30 x 1N4001 diodes	SP151	4 x 8mm Red LEDs
SP12	30 x 1N4002 diodes	SP152	4 x 8mm Green LEDs
SP18	20 x BC182B transistors	SP153	4 x 8mm Yellow LEDs
SP20	20 x BC184B transistors	SP154	15 x BC548B transistors
SP23	20 x BC549B transistors	SP156	3 x Stripboard, 14 strips x 27 holes
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SP25	4 x 555 timers	SP161	10 x 2N3906 transistors
SP26	4 x 741 Op Amps	SP164	2 x C106D thyristors
SP28	4 x CMOS 4011	SP165	2 x LF351 Op Amps
SP29	4 x CMOS 4013	SP166	20 x 1N4003 diodes
SP33	4 x CMOS 4081	SP167	5 x BC107 transistors
SP34	20 x 1N814 diodes	SP168	5 x BC108 transistors
SP36	25 x 10/25V radial elect. caps	SP172	4 x Standard slide switches
SP37	12 x 100/35V radial elect. caps	SP173	10 x 220/25V radial elect. caps
SP38	15 x 47/25V radial elect. caps	SP174	20 x 22/25V radial elect. caps
SP39	10 x 470/16V radial elect. caps	SP175	20 x 1/63V radial elect. caps
SP40	15 x BC237 transistors	SP177	10 x 1A 20mm quick blow fuses
SP41	20 x Mixed transistors	SP178	10 x 2A 20mm quick blow fuses
SP42	200 x Mixed 0.25W C.F. resistors	SP181	5 x Phono plugs - ass'dt colours
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SP103	15 x 14-pin DIL sockets	SP186	8 x 1M horizontal trim pots
SP104	15 x 16-pin DIL sockets	SP189	4 x 5 metres solid-core wire
SP109	15 x BC557B transistors	SP192	3 x CMOS 4066
SP112	4 x CMOS 4093	SP195	3 x 10mm Yellow LEDs
SP115	3 x 10mm Red LEDs	SP197	6 x 20-pin DIL sockets
SP116	3 x 10mm Green LEDs	SP198	5 x 24-pin DIL sockets
SP118	2 x CMOS 4047	SP199	5 x 2.5mm mono jack plugs
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Make no mistake, 'flight sims' (FS) and many 'flight combat games' (FCG) are complex software applications.

You'll typically learn to master them by throttling all engines (assuming a multi-engine plane!) by the same

amount at the same time. But as any pilot will tell you, that is simply not realistic. You need to be able to control the engines individually.

Before we proceed further, a few words about controlling flight simulators are appropriate. A twist-handle USB joystick (4 axes – aileron, pitch, rudder and throttle) is absolutely

By Robert Gott

essential, even for the beginner. Taxiing, take-offs and landings are pretty miserable without proper rudder control on the joystick.

Don't be tempted to buy cheap basic joysticks. You'll regret it! Common good brands are: Microsoft, CH, Saitek and Logitech. All of these now use the USB port.

Assuming you've mastered the basics of flying using one throttle control that varies all engines' RPM simultaneously, it's now time to proceed to individual throttle control. Unfortunately, though, that control is not available on typical joysticks.

That's where this project comes in. It allows the 'pilot' (you!) to vary the individual engine speed (measured in revolutions per minute or RPM) using Microsoft's proprietary Control Panel settings in Windows. It would be wonderful if Microsoft would embody say eight or sixteen arbitrary 'axis' and the same number of 'buttons' in their next incarnation of Windows, but for the moment 4 + 4 is the best available.

Proprietary Throttle Quadrants such as CH USB 300-133 (shown above) use their own software, but the cost is almost as high as the planes fly – circa US\$150! With this project, we will achieve a modicum of reasonable results – but much cheaper.

In fact, we believe it should cost no more than about £14 or so: four pounds



If you have the 'readies', this commercial throttle unit (CH USB 300-133) is regarded as one of the best around. Ours is just a tad simpler and a whole lot less expensive!

for the four pots, a similar amount for the four switches and the balance for a box to put it all in. You'll also need a multi-way cable with a 15-way D-connector, but these can often be sourced from the junk box. OK, if you want to go all out and add knobs and a fancy label, you might stretch it to £16 – but not much more.

The games

Many of the older excellent games, like the renowned 'European Air Wars' by Microprose, or 'Battle of Britain' and 'Red Baron 3D' by Sierra, will not now install or run properly in Windows XP Pro, the author's

OS. Sometimes, a game will run in Windows 'Compatibility' mode. (Right click desktop games icon >PROPERTIES>COMPATIBILITY>follow prompts.)

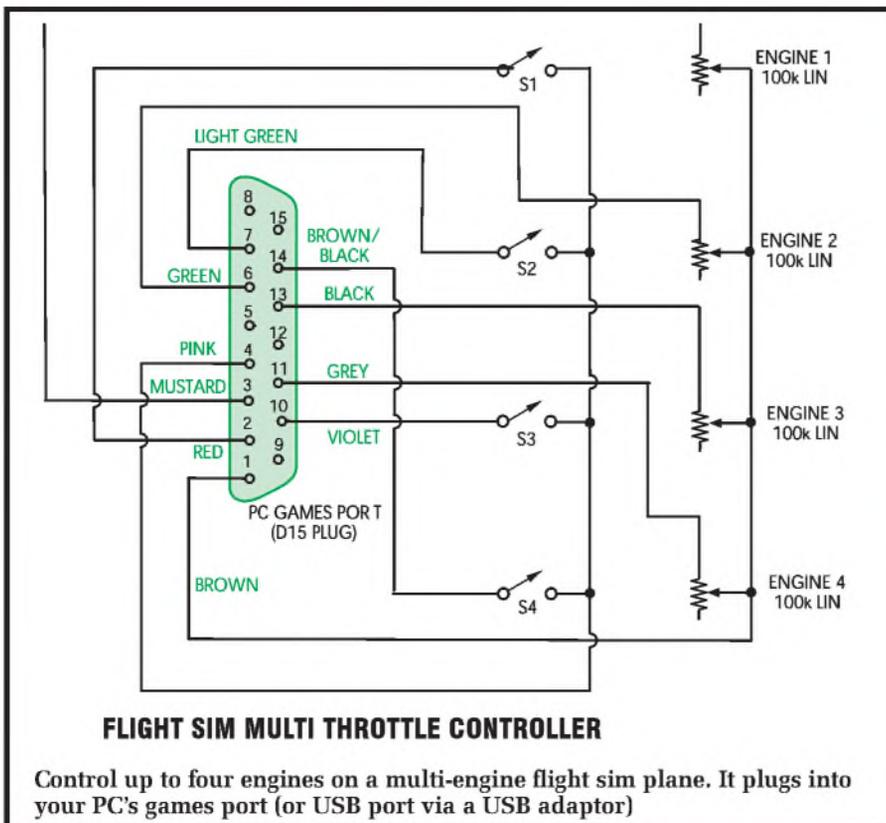
Other software – called 'Wrappers' – try to emulate the original game playing software, not very successfully in the author's experience. The FS table, which is by no means exhaustive, gives some hints and where this project will work, the author has personally tested the games using Multi Throttle.

PC Hardware and software.

My PC is a four-year-old AMD XP1800+, with 768MB RAM, 64MB

PC Flight Sims





GF3 Ti 200 AGP with games port, USB 1.1 and USB 2.0 sockets. The joystick is a Microsoft Sidewinder Precision Pro USB (Twist stick rudder control) running Windows XP Pro with SP1 and DirectX (9c). The Multi Throttle unit has *not* been tested with Windows 98SE, but the joystick configuration in Control Panel may work.

Note: older PCs with integral graphics (no separate graphics card) may

struggle to play the named games anywhere near fully optioned. Modern PCs are better, but even Celeron and Sempron PCs, with integrated graphics, may use main swap memory and struggle with the latest FS.

To be realistic, any PC older than a Pentium II 350MHz would not do justice to many, if any, of the games listed here.

Construction

There's not much to construction – no PC board, no difficult wiring. That's mainly because there are few components – just the four switches and four pots wired to the 15-way D-connector.

Using the photographs as a guide, mount the hardware first, because the wiring simply connects between it. Any plastic box of about 130(W) × 70(D) × 45mm(H) or larger will suffice.

Position the potentiometers and switches on the lid, allowing for the size of chosen knobs and enough clearance for your fingers. Mark out and drill appropriate holes, four each for the pots and switches.

Drill one hole in the preferred end of the box for the 15-core cable. It's best to secure the cable with a cable clamp, which will need an extra hole. If you normally use a joystick with your right hand, then the controller is best placed with the cable on the left side for use with your left hand. Mount the components and push on the indexed knobs.

Next, prepare the cable using the commercial games extension cable.

Parts List – Flight Sim Multi Throttle

- 1 ABS box, size 130 x 70 x 45mm approx.
- 4 100kΩ rotary carbon potentiometers, linear
- 4 knobs to suit pots, with index lines or pointers.
- 4 SPST toggle switches (low voltage)
- 1 plastic cable clamp
- 1 10mm M3 screw, washer and nut
- 1 1.8m 15-way D-connector male-to-female game cable extension, or 2m D15 PC joystick extension cable (eg Maplin TA50E)
- 1 D15 to USB Converter, if required (eg Maplin UA22Y)



Here's a view inside the 'opened out' controller

Flight simulators and combat flying games

Game/Publisher	Windows version	API: Direct X OpenGL, 3DFX	CPU: Pentium or equiv AMD	Playable multi-engines 2 or 4	Tested with Multi Throttle?	Comments
FS 2004, Microsoft	XP	DX 9.0c	P4 or AMD64	2 and 4	No, but should be OK	Should work OK – needs latest mid-price graphics card minimum.
FS 2002, Microsoft	98 ME XP	DX 8.0a	P4	2 and 4	Yes	Needs good graphics card, plenty of memory.
Wings of War, Gathering	98 ME XP	DX 9.0	P4 1.8G	None	Yes n/p *	GeForce 4 graphics; pity 2 engines not playable
B17 Flying Fortress, Atari	95 98 ME XP	DX 8.0	P3 800	2 and 4	Yes	Fantastic game with realistic crew
CFS 3, Microsoft	98 ME XP	DX 8.1	P4	2	Yes	Battle for Europe
CFS 2, Microsoft	95 98 ME	DX 7.0a	P3 600	2	Yes	Pacific theatre
CFS 1, Microsoft	95 98	DX 6.0	P3 600	None	Yes n/p *	European theatre, will not work with Multi Throttle connected to PC
FS98, Microsoft	95	DX 5.0	P2 350	2	No	
IL2 Sturmovik Forgotten Battles, Ubisoft	98 ME XP	DX 8.1 OpenGL	P3 800	2 and 4	Yes n/p *	Pentium III 800 or above, GeForce 3 or 4 or above
IL2 Sturmovik, Ubisoft	98 ME XP	DX 8.1	P3 600	2	Yes n/p *	GeForce 2 card or above
Flanker 2	98SE	?	P4	2	No	Screen lock-up, try XP
F18E	98SE	DX 6.1	P3 600	2	No	Will NOT play in Win XP
F22	98SE	?	P3 600	2	No	Demo played OK
Red Baron 3D	95 98SE Not XP	DX 5.0 3DFX	P2 350	None	Yes n/p	Run in compatibility mode for Win 98SE
European Air Wars, Microprose	98SE	3DFX DX 6.0	P2 350	2	Yes n/p *	Will play in Direct X
Crimson Skies, Microsoft	95 ME XP	DX 7.0a	P3 800	2	Yes n/p	NOT Win 98 or SE
Flight Unlimited II	98SE	OpenGL	P3 800	2	No	Not Win XP
Battle of Britain	98SE	?	P3 800	?	No	Will NOT play in Win XP

Notes

n/p = not possible as tested by author:
Multi Throttle configuration is NOT possible in this game.

API = Application Programme Interface; software written for games. Note: The minimum version of Direct X required is indicated. Sometimes the game plays only or best in that version, but as the latest version is supposed to be backward compatible, ALWAYS use the latest version first. Most Microsoft games play with Direct X 9.0c, the latest version at the time of writing. The other two common APIs are 3DFX Glide and OpenGL.

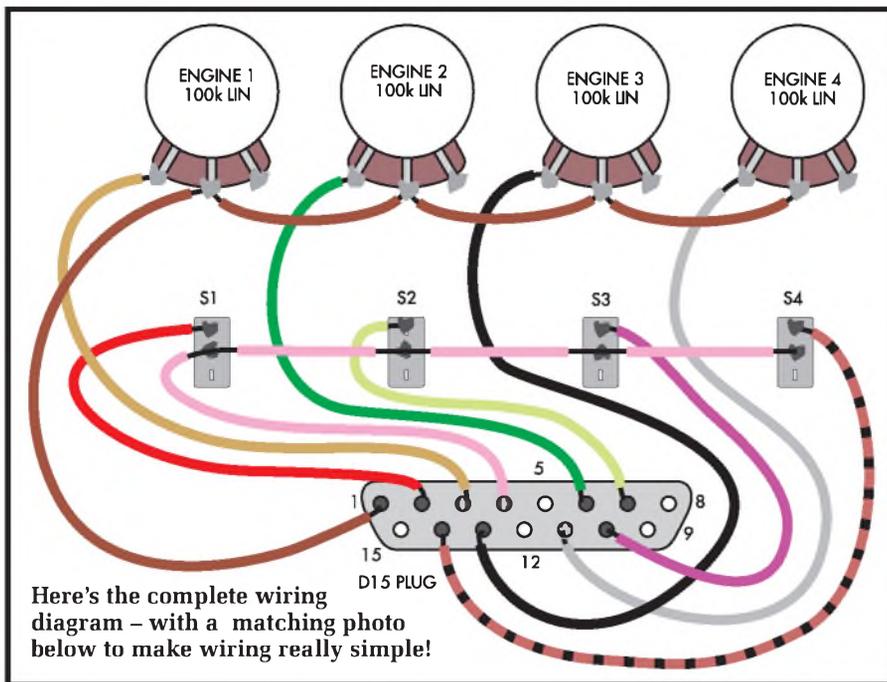
CPU = Intel or AMD minimum recommendation to play reasonably well optioned.

MEMORY: 512MB absolute minimum.

OPERATING SYSTEM (OS): Although Windows 95 is listed above, it must be OS2 to work with USB. Quite frankly, Win95 is now so old hat that it should be avoided where possible. Win 98SE is much better, while Win98Me is quirky!

ENGINES: By implication, ALL games listed have SINGLE engine aeroplanes. Only those games listed in the 'Multi-engines' column have flyable aircraft.

* Do NOT connect the Multi Throttle unit to the PC as it causes wrong configuration, so I found – and the joystick does not get the correct assignments. (If you really must stick your neck out, install and try the game without the Multi Throttle first. If everything works OK then plug in Multi Throttle. Should you not be able to juggle the assignments satisfactorily, unplug Multi Throttle, uninstall then reinstall the game. You're on your own!)



you switch on your PC – assuming Windows XP Home or Pro – it will detect new hardware.

You may follow the prompts, but the preferred method is to CANCEL the automatic install and proceed as follows: CONTROL PANEL>GAME CONTROLLERS>ADD>CUSTOM >JOYSTICK>AXES 4>BUTTONS 4>CONTROLLER NAME (what you want to name the controller is up to you – I called mine RobertMultiThrottle)>OK.

Reboot the PC and ensure that the new controller is listed in GAME CONTROLLERS and its STATUS is OK. We assume your joystick or any other controller attached shows STATUS OK also.

So far, so good! Now calibrate the Multi Throttle exactly the same as you would a joystick.

As previously mentioned, don't be too worried whether clockwise rotation of your pots give exactly what you expect.

It is important that the full excursion of the axes is recognised and saved. Similarly, the switches need to be recognised as the relevant 1,2,3,4.

Flight sim assignments

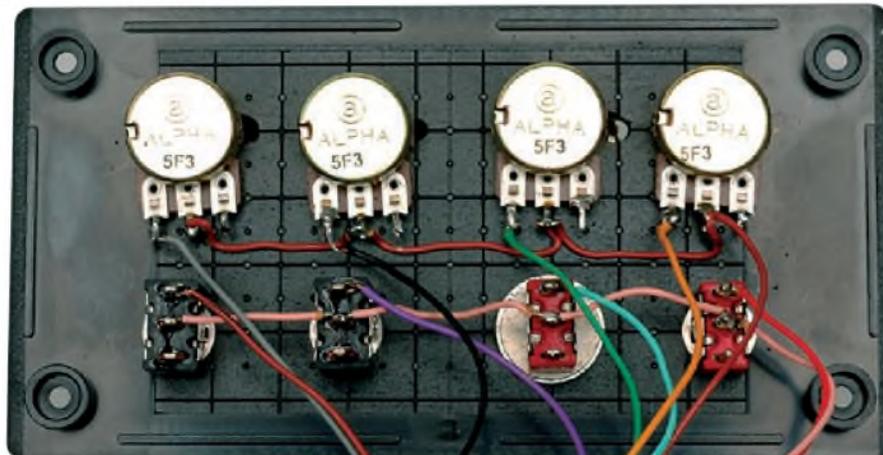
It is beyond the scope of this simple project to give more than a few hints. Most who 'fly' the games listed earlier will have some, if not good experience of changing keyboard and joystick assignments. It is largely a matter of experiment. What follows is mainly for beginners.

When a game is installed it usually loads its default or standard CONFIGURATION of controls. Unless you tell it otherwise, often the joystick will be detected as the primary controller.

However, with other controllers connected, when assignments are altered in 'preferences' or 'options', then to alleviate the frustration of setting up every time the game is played, many games allow you to SAVE the CONFIGURATION with a new given name, say Multi Throttle. If this is not automatically the default when you next play the game, then select it manually.

USB operation

For those PCs without a games port, simply plug the Multi Throttle unit's 15-pin D-plug into a USB converter D-socket, then plug the



WARNING: Before you cut the cable, use a test meter or battery and lamp to check that all 15 conductors are wired.

Ensure that you chop off the unwanted end(!). Leave about 250mm of cable connected to the socket, because you may find a use for the discarded bit (like wiring wire!), and remove a generous 150mm or so outer sheath, and strip off 3mm of insulation on all the conductors.

Now trace out which colours go to which pins on the 15-way D games port plug.

The colours shown on the circuit and wiring diagrams were those on the prototype, but we cannot guarantee all cables/connectors will be the same. So, double check which coloured wire goes to which pin, and if necessary correct the circuit and wiring diagrams to avoid later confusion.

The circuit is basically standard game port wiring without using the MIDI terminals, therefore only 10 wires out of the 15 are employed.

The five 15-way D-connector pins not used are pins 5, 8, 9, 12 and 15. Identify which wires go to these pins and chop off the bared 3mm on the 5 unwanted conductors to minimise the chance of short circuits.

Anchor the cable inside the box with a plastic cable clamp, then solder the wires as shown in the circuit diagram and wiring diagram.

The logical designation of pots and switches is: left to right equals port (left) to starboard (right) engines.

Calibration

Check and double check your wiring and if satisfied, plug the 15-way connector into the games port of your computer when it is turned off. When

Flying a B17

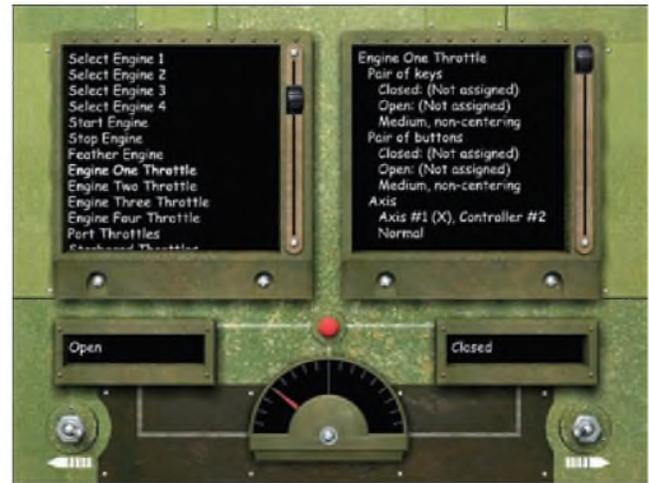
This is chosen to demonstrate assignments, as it is typical of the user-friendly type of icon based games. (ie, non-menu type) It is also a very cheap re-released game with four propeller engines. Actual crew can be seen and moved around in the fuselage. A truly exciting game if you are not a die-hard purist simmer! Using the default assignments, the Multi Throttle unit switches appear to work immediately as 'Select Engine 1 - 4'. If not, reconfigure as such.

Throttles wired as previously mentioned, clockwise potentiometer rotation gives 100k-0k, which configures in 'Engine One Throttle' = 'Axis #1 (X), Controller #2, Normal.' 'Normal' means that with clockwise pot rotation, the propeller increases RPM. Configure the other three throttles similarly.

Note: step-by-step instructions for 'Engine One Throttle.' Click on 'Engine One Throttle' and it highlights. In the opposite panel, click on 'Axis'. As it scans, rotate the Engine 1 pot fully a couple of times. This will be detected as shown.

In B17 all propellers turn the same way - clockwise, as seen by the pilot. This is not always the case. Some twin engine aeroplanes have the propellers turning in opposite directions to counter the torque effect. With a Lancaster bomber (A FS2004 add-on) the pull to port must be countered by opposite rudder or decrease starboard revs - not something you would do with maximum bomb load!

In the early days, getting B17 engines to start caused the author great frustration. At the bottom RHS of the game screen is an icon - a picture (gif) - of a PC. This means that the PC is on AUTOMATIC and controls the flight. Press keyboard key 'M' and the



icon changes to a hand meaning - you've guessed it! - MANUAL control. At this point in external view, select Engine 1 on the Multi Throttle unit, RPM minimum, then press key 'A'.

From this point, B17 controls the start procedure beginning 'Master Switch ON', etc, finally 'meshing' (cranking!) and away she goes. To stop an engine, again select the appropriate switch on Multi Throttle, then press key 'S'. B17 controls selected engine shut down. Feathering, so that propeller stops windmilling, press key 'D'. Now you are cooking with gas!

FS2002

This is a much more sophisticated simulator, used for 'real life' flying rather than a game. (FS2004 is similar) They are not as user friendly as other icon based set-ups, but their menu type assignments are very comprehensive.

With a little trial and error, the Multi Throttle unit is fairly easy to configure. The basic FS2002 has two- and four-engine jet engine planes, but no such prop models. The Lancaster bomber, as previously mentioned, is an add-on.

Rather than the B17's style (top right), Microsoft uses 'tabs' and drop down menus to choose between joystick or keyboard assignments. It also has a separate window for setting sensitivities and deadbands, and many more keyboard commands.

Observe 'Joystick type' shown in right screenshot. Note that RobertMultithrottle has been selected. In the 'Assignment list' Microsoft specifies a throttle as an axis. Click on 'Engine 1 Throttle axis.' It highlights. Click on 'Change assignment.' Rotating Throttle 1 potentiometer will cause the x-axis to be recognised. Save the assignment. Engines 2, 3 and 4 are recognised as y-axis, Throttle and Rudder (not visible) respectively. It may be necessary to use the 'Reverse' mode (shown checked - an X within the box) to get correct throttle increase (clockwise=increase RPM).



converter USB plug into any PC USB port. The green object on the left side of the desk (opening photo) is such a converter. It happens to be from Maplin (UK), but they are also often seen on eBay and other places on the net.

Set the converter to MODE 3 before booting the PC.

Conclusion.

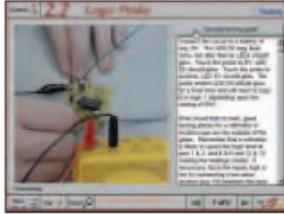
The Multi Throttle Controller gives added interest to flight sims at little extra cost and may overcome the problem of 'no games port'. The Multi Throttle unit may work with other flying games, but ask the retailer to verify before purchase or check the websites.

I'm not an expert on flight Sims, and I'm still grappling with their complexities! However, the ability to control engine RPM individually has given me a real buzz and makes 'flying' that much more pleasurable. Happy simming! **EPE**

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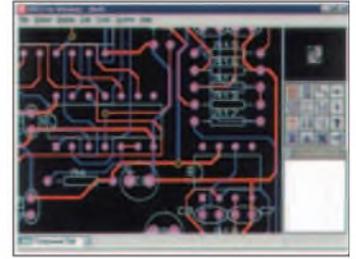
ELECTRONICS PROJECTS



Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK schematic capture, circuit simulation and p.c.b. design software is included. 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.

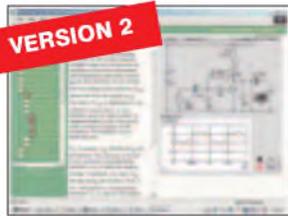
ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots, etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

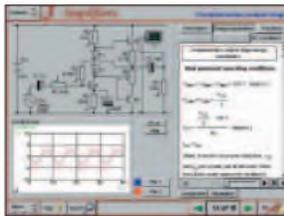
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

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 & 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

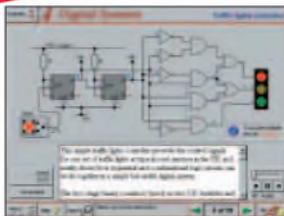


Complimentary output stage

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.

DIGITAL ELECTRONICS V2.0



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), 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
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

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Prices for each of the CD-ROMs above are:

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Institutional (Schools/HE/FE/Industry).....	£99 plus VAT
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PICmicro TUTORIALS AND PROGRAMMING

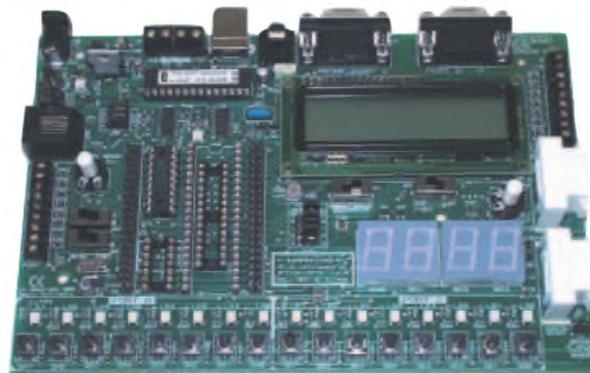
HARDWARE

VERSION 3 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
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- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)



£158 including VAT and postage, supplied with USB cable and programming software

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£40 OFF Buy the Development Board together with any Hobbyist/Student or Institutional versions of the software CD-ROMs listed below and take £40 off the total (including VAT) price.

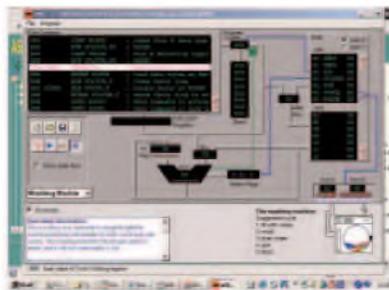
SOFTWARE

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 microcontroller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

- Comprehensive instruction through 45 tutorial sections
- Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator
- Tests, exercises and projects covering a wide range of PICmicro MCU applications
- Includes MPLAB assembler
- Visual representation of a PICmicro showing architecture and functions
- Expert system for code entry helps first time users
- Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.)
- Imports MPASM files.

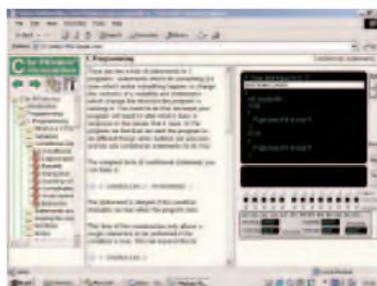


'C' FOR 16 Series PICmicro VERSION 4

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.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

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



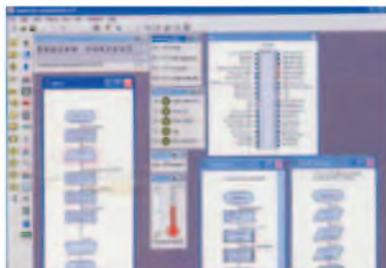
Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

FLOWCODE FOR PICmicro V3

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A Powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and I.c.d.'s. The use of macros allows you to control these devices without getting bogged down in understanding the programming.

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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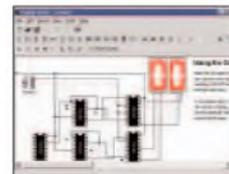
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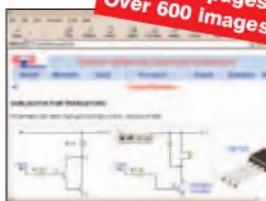
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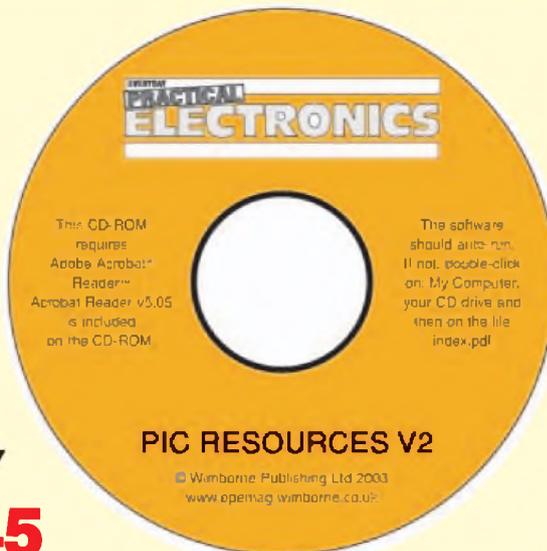
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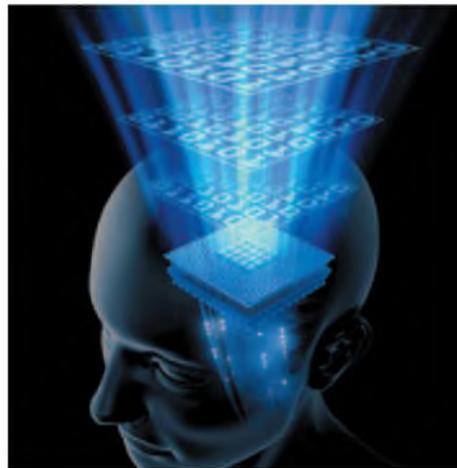
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Teach-In 2008

Part Five – Introduction to timers, BCD counting and equality checking

JOHN BECKER



In the first four parts of *Teach In 2008*, we have covered a fair bit of ground, introducing most of the available PIC commands, and showing how they can be used in a practical situation.

Last month, we showed how an Event Counter could be simply implemented. We continue now in Part 5 showing how a similar technique can be used to create a simple frequency counter, basically for use with audio frequencies, in the range of about 20Hz to 20kHz.

Although in principle it may seem that a PIC can be used to assess any frequency, in reality it runs at too slow a rate, even with a clock frequency of 20MHz, and its routines have no chance of keeping up with the rate of change of higher frequencies.

Certainly a PIC *can* be used to monitor frequencies significantly above 20kHz, but it needs to be used with normal digital logic chips such as counters, as they have much faster response times.

Clock division

A complication arises in that the one second timing routine is governed by a division factor relating to the timer. This factor divides the number of clock cycles generated by the PIC by multiples of two.

Unfortunately, a clock rate of 4MHz, which the PIC has been using, cannot directly provide a timing of exactly one second.

If a clock rate of 3.2768MHz is used, then the timer's division can provide periods of exactly one second. We therefore need to use a crystal of this value to control the PIC's clock rate.

On the Control board, connect a 3.278MHz crystal across the pins provided. The clock frequency generation is now under control of the crystal in conjunction with that board's capacitors C1 and C2.

Circuit diagram

The circuit diagram for the simple frequency counter is shown in Fig.5.1, and its breadboard layout in Fig.5.2.

The connections shown at the left-hand side of Fig.5.1 connect to the PIC Master Control PCB.

The signal whose frequency is to be counted may come from the output of other digital circuits. It is fed into the DC In point in Fig.5.1. It may swing between 0V and say +5V, although voltage levels somewhat above +5V are prevented from exceeding the PIC's maximum input voltage level, nominally +5V, by the inclusion of resistor R1 and diode D1.

Resistor R1 and diode D2 similarly prevent signals from swinging below about -0.6V and upsetting the PIC. If it is known that signals are swinging symmetrically above and below 0V, then they should be input via AC In and capacitor C1.

LCD X1 is the same alphanumeric type whose control was described in Part 4. It is connected to the PIC Control PCB in the same way as before. It shows the frequency value in Hertz (Hz) of the input signal on its top line, and the typical timing of the periodic cycles within the waveform, in microseconds.

Load **TEACHINE01.HEX** and run it. Refer to Listing 5.1.

Counting cycles

There are three bytes used as counters in a chain, COUNT0, COUNT1 and COUNT2. Between them they produce a value which can be up to 24 bits long, representing a value of up to 16,777,215 ($256 \times 256 \times 256 - 1$), the same value as available with last month's Event Counter, although it can never be reached with this design.

Initially, the counter is reset to zero and started. For a period of one second, as set by a timer, the counter counts the number

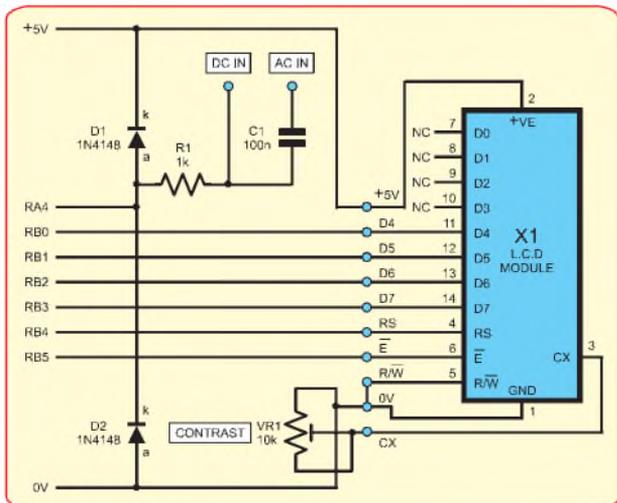


Fig.5.1. Frequency counter circuit

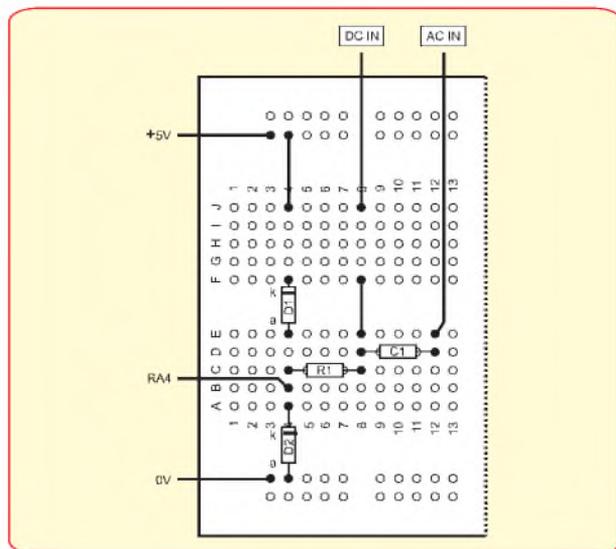


Fig.5.2. Breadboard layout for Fig.5.1.

Listing 5.1

; TEACHINE01.ASM 09JUN07 – TEACH IN 2008 PT5

```

__config h'3F21'          ; external xtal oscillator (3.2768MHz)

MAIN    movlw 25
        movwf CLKCNT
        clrf COUNT0
        clrf COUNT1
        clrf COUNT2
        movf PORTA,W      ; get current val of PORTA
        andlw b'00010000'
        movwf PREV       ; put into prev
        clrf INTCON      ; clear TMR0 overflow

MAIN0   btfss INTCON,2   ; has a timer time-out been detected?
        goto MAIN0A      ; no
        bcf INTCON,2     ; yes
        decfsz CLKCNT,F  ; dec counter, is it zero?
        goto MAIN0A      ; no
        goto MAIN3

MAIN0A  movf PORTA,W     ; is PORTA = prev?
        andlw b'00010000'
        movwf TEMP

        xorwf PREV,W
        btfsc STATUS,Z
        goto MAIN0       ; yes

        movf TEMP,W
        movwf PREV

        incfsz COUNT0,F  ; inc COUNTA, is it = zero?
        goto MAIN2       ; no, goto MAIN2
        incfsz COUNT1,F  ; yes, so inc the next counter byte (NSB), is it = zero?
        goto MAIN2       ; no
        incfsz COUNT2,F  ; yes, so inc the next counter byte (MSB), is it = zero?
        goto MAIN2       ; no
        call OVERFLOW
        goto MAIN

MAIN2   btfss INTCON,2   ; has a timer time-out been detected?
        goto MAIN0       ; no
        bcf INTCON,2     ; yes
        decfsz CLKCNT,F  ; dec counter, is it zero?
        goto MAIN0       ; no

MAIN3   bcf STATUS,C    ; clear carry flag
        rrf COUNT2,F     ; divide answer by 2
        rrf COUNT1,F
        rrf COUNT0,F

        call BIN2DEC     ; decimalise answer
        call LCD1        ; set LCD for display from line 1 cell 1
        bsf RSLINE,4    ; and tell it to expect display data
        call BLANKKIT
        call SHOWDIGIT8
        movlw 'H'
        call LCDOUT
        movlw 'z'
        call LCDOUT

        call PERIOD

        call BIN2DEC     ; decimalise answer
        call LCD21       ; set LCD for display from line 2 cell 1
        bsf RSLINE,4    ; and tell it to expect display data
        call BLANKKIT
        call SHOWDIGIT8
        movlw 'u'
        call LCDOUT
        movlw 's'
        call LCDOUT
        movlw '/'
        call LCDOUT

```

of changes in logic level of the incoming signal. There are two changes, of course, for each waveform cycle. From logic 0 to logic 1, and then from logic 1 back to logic 0, or vice versa.

At the end of each second, the counter is stopped and the value held is divided by two to get the total number of complete waveform cycles occurring during that second. This number, of course, is the value in Hertz.

The BIN2DEC routine used last month is then called and the value, which is in binary, is converted to a decimal format and output to the LCD screen, on line 1, followed by the message 'Hz'.

The frequency shown may not be exactly that which would show on a more sophisticated frequency counter, due to the fact that crystal controlled frequency is only correct within a certain tolerance. There is also the fact that the PIC's software cannot, in this simple program, respond as fast as that which is governed by the response rate of normal digital chips. The value shown, though, is sufficiently accurate for most simple purposes.

Listing 5.1 continued

```

        movlw 'c'
        call LCDOUT
        movlw 'y'
        call LCDOUT
        movlw 'c'
        call LCDOUT
        movlw 'l'
        call LCDOUT
        movlw 'e'
        call LCDOUT

        goto MAIN

; GET PERIOD TIMING
PERIOD  movlw h'40'
        movwf REGA0
        movlw h'42'
        movwf REGA1
        movlw h'0F'
        movwf REGA2
        clrf REGA3

        movf STORE0,W
        movwf REGB0
        movf STORE1,W
        movwf REGB1
        movf STORE2,W
        movwf REGB2
        clrf REGB3

        call DIVIDE32

        movf REGA0,W
        movwf COUNT0
        movf REGA1,W
        movwf COUNT1
        movf REGA2,W
        movwf COUNT2
        return

        include LCDroutines.inc
        include MATHSroutines.inc

        END

```

Cycle conversion

Immediately following the display of the frequency, a routine is called in which the frequency detected is converted to an equivalent timing of each complete cycle, in microseconds, using the formula $t = 1000000/f$, where t = time and f = frequency, and the 1000000 factor is the value needed for converting seconds to microseconds.

The frequency-to-cycle timing conversion routine involves a division function to be used. While it is possible to do simple division and multiplication with a PIC, the code required for large numbers is complicated. Consequently, it is preferable to use routines that have been previously written for the job, and are available for public use as library routines.

The code was written by Peter Hemsley, referred to last month in connection with the BIN2DEC routine, who provided *EPE* with suitable division and multiplication routines. These cope with values up to 32 bits long, the length of the values involved in the frequency-to-period conversion now needed.

The files are imported at the end of the program code with the command **include MATHSroutines.inc**. The file says which registers are needed for it to be used, and these have been added to the head of the main program in the CBLOCK section.

The **MATHSroutines.inc** file can be used in your own programs if you wish.

The LCD shows the cycle period timing as the value in microseconds, followed by the message 'us/cycles'.

Timer TMR0

Time now to examine one of the PIC16F628's timers, TMR0. We've been using it to provide the delays needed with the LCD, to provide slowing down delays in some demos, and just now for the frequency timing. It has many uses, providing different timings for different purposes.

The PIC16F628 has a special register reserved for use as an 8-bit timer, TMR0 (Timer 0). It divides its input frequency (originating from the PIC's clock rate timing) by 256 and can be both written to and read from. In most situations though, it is unlikely that you will need to use the read/write facility, but note that if TMR0 is written to, the timer is inhibited from counting for two clock cycles.

Probably more useful than writing to TMR0 is to use its output as it occurs naturally at the 1:256 division rate, and then to use the prescaler to subdivide that rate as required. The prescaler divides its input pulses by presettable powers of two. There are eight possible division ratios, which are set in binary form via bits 0, 1 and 2 of the OPTION register.

When used with TMR0, the prescaler division ratios are 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, 1:128 and 1:256.

The prescaler can alternatively be allocated for use with the Watchdog Timer (WDT – discussed in a future part), in which mode each of these ratios is halved (minimum is thus 1:1 and maximum is 1:128).

Note that the OPTION register should not be equated as such, since Microchip previously had a command actually named OPTION and the use of this term

in an ASM file assembled by MPASM causes an error condition. Consequently, it is preferable that the register should be equated as OPTION_REG (Microchip's equated term in their INC files), as we have been using already through Microchip's named .inc file. You may still sometimes come across the term OPTION, or even the equated name OPShUN instead.

It should also be remembered that bit 7 of the OPTION register controls the PIC's light pull-ups facility and should be set high to turn it off, as previously discussed.

The PIC effectively runs at one quarter of the stated clock frequency, internal or external. Thus a clock of 4MHz will cause the PIC to run at 1MHz.

When TMR0 is used as an internal timer, the pulses it counts also occur at one quarter of the clock frequency. So, if the clock frequency is running at 3.2768MHz, TMR0 will count at 819200Hz and its 1:256 roll-over rate will be 3200Hz. This rate is then divided by the ratio set into the prescaler. If we divide by 32, for example, we obtain the convenient rate of 100Hz.

In TMR0 mode, when the prescaler rolls over to zero, a flag is set in the INTCON register, at bit 2. The setting of this

bit can be used as an interrupt, which automatically routes the program to another specified routine, irrespective of which routine is currently being processed, returning to the same point after the interrupt procedure has been finished.

The interrupt can also be turned off and INTCON bit 2 read by the program to establish its status, taking action accordingly.

Using the timer and the prescaler, you can specify that some actions will only be performed at specified sub-divided values of the clock frequency. Among other things, this allows the PIC to be used as a real-time clock, as well as a frequency counter.

Note that the TMR0 rate is set into the OPTION register while in BANK1 mode. This is always the case with this PIC, and many others.

First, let's illustrate the effect of setting different prescaler ratios and, using the LEDs connected to PORTB on the Control PCB, show what happens. Load **TEACHINE02.HEX** and run it. Refer to Listing 5.2.

The program is a modification to that used as the third demo in Part 2, using the PIC's internal 4MHz oscillator. Disconnect the 3.2768MHz crystal and the LCD. Also

Listing 5.2

```
; TEACHINE02.ASM 09JUN07 – TEACH IN 2008 PT2

__config $3F30                ; internal 4MHz oscillator

STARTIT  clrf PORTB           ; clear Port B data register
         BANK1                ; BANK 1
         clrf TRISB           ; Port B direction register for output
         movlw b'10000000'     ; timer 1:2, pull-ups off (bit 7 = 1)
         movwf OPTION_REG
         BANK0                ; BANK 0
         clrf RATE            ; start with a rate of 0
         movlw 32              ; starting value for COUNT
         movwf COUNT

         bsf STATUS,C         ; set the Carry bit in STATUS

         call DELAY           ; brief pause

LOOP     rlf PORTB,F          ; rotate left PORTB
         call DELAY
         decfsz COUNT,F       ; repeat
         goto LOOP           ; timer rate
         movf RATE,W         ; timer rate
         BANK1                ; BANK 1
         iorlw b'10000000'
         movwf OPTION_REG
         BANK0                ; BANK 0
         incf RATE,F          ; inc rate value
         bcf RATE,3           ; restrict rate val to 7 max
         movlw 32             ; reset COUNT val
         movwf COUNT
         goto LOOP           ; repeat

DELAY    movlw 50             ; set delay counter to 50
         movwf CLKCNT
         clrf INTCON         ; clear interrupt flag

DELAY2   btfss INTCON,2      ; has a timer time-out been detected?
         goto DELAY2         ; no
         bcf INTCON,2        ; yes
         decfsz CLKCNT,F     ; dec counter, is it zero?
         goto DELAY2         ; no
         return              ; yes
```

reinstates the LED link wire to bring the LEDs back into play.

In this program we read the status of INTCON bit 2 rather than using the interrupt facility. The program calls a delay routine at DELAY, clears INTCON,2, then it loops until the bit goes high, to indicate a timer rollover. The essential commands are:

```
drf INTCON      ; clear full intcon register
```

```
(or just bcf INTCON,2      ; clear intcon register bit 2)
```

```
DELAY2 btfss INTCON,2      ; is bit 2 high?
```

```
        goto DELAY2      ; no  
        bcf INTCON,2      ; yes,  
clear bit 2 to allow time to start again
```

(program continues with whatever the user wants)

This occurs 50 times a second, as set by this routine into the counter CLKCNT, and then the program continues from where the delay was called, with the command RETURN.

Initially, you will see a fairly fast LED movement occurring. It is created with the timer *in-circuit* with the prescaler set for a minimum division ratio of 1:2. This is because OPTION_REG bits 0 to 2 are set to 000.

This rate of counting continues for four cycles of the LEDs rotating through their 8-LED range. The ratio is then set at 1:4 (prescaler value 001), and again another four cycles occur. Similarly, the other ratios are set. The difference in the resulting LED movement rates will become obvious.

Having completed the slowest LED movement cycles, the timing speeds up again and the process repeats.

The routine can be speeded up, or made slower, by putting a different value into CLKCNT (range 0 to 255). Leaving out CLKCNT entirely speeds the routine to the fastest for the timing value held by the timer.

Be aware that in the demo the initial flash rates of the LEDs are quite fast.

Binary Coded Decimal counting

So far we have illustrated how a count can be increment or added to in binary mode. This resulted in the need for a binary-to-decimal conversion routine in order to show the result on a suitable display, such as an alphanumeric LCD. It is equally possible to count directly in decimal, removing the need for a BCD converter, although the counting rate is slower when using BCD compared to using a binary count. We will now demonstrate the process.

We could keep the counted units in one byte, tens in another, hundreds in another, and so on, but, to conserve precious byte space, it is equally possible to use each byte as two 4-bit nibbles, keeping units in bits 0 to 3, and tens in bits 4 to 7. Hundreds and tens of units would be treated similarly in a second byte.

For simplicity, now, we concentrate on counting up to 99. First considering the use of two bytes. In 8-bit binary, a value of

decimal 9 is expressed as 00001001, decimal 10 is 00001010, decimal 16 is 00010000. It is obvious that with decimal values we have no single symbol for a number greater than decimal 9. When a value one greater than decimal 9 occurs, we reset the units digit to 0 and add one to the next digit, ie ten is written as 10.

While counting in BCD, we can do a similar thing. When the byte holding the units reaches ten, we reset that byte to zero and add one to the next byte. In 8-bit BCD and at a count of nine, the two bytes would read 00000000 (tens) and 00001001 (units). At the count of ten, the bytes become 00000001 (tens) and 00000000 (units).

When using two nibbles of an 8-bit byte (instead of the above two bytes), a BCD value of nine reads as 00001001, but a BCD value of ten reads as 00010000. And, for example, a BCD value of 37 reads as 00110111, ie the left-hand nibble (MSN – Most Significant Nibble) holds a value of 3 and the right-hand nibble (LSN – Least Significant Nibble) holds 7.

A value of 99 is expressed as 10011001. For a value of 100, both nibbles are reset to zero (00000000) and if there is a byte for hundreds and tens of hundreds, its right-hand nibble (LSN) would be incremented, and so on.

Thus, when counting in BCD, we have to check the four bits of the LSN on their own and see if their value is greater than 9. If it is, that nibble is reset and the MSN incremented. The MSN is then taken on its own as a 4-bit value and checked if it is greater than 9. If so, this nibble is reset and the LSN of the next byte incremented accordingly.

Nibble check

There are (as in many programming matters) several ways of checking the nibbles for excess values, of which we shall describe one: an additive checking routine. We said earlier that there is a Digit Carry (DC) flag in the STATUS register which signals if the binary value of the LSN has become greater than 15 following an addition. We can use this fact by temporarily adding a number to the LSN which will make the answer greater than 15 if the basic value of the LSN is greater than 9.

The number to be added is 6, eg $10 + 6 = 16$ with the DC flag set; $9 + 6 = 15$ with the DC flag clear. Therefore, to check if an LSN value is greater than 9, we temporarily add 6 to it and check the DC flag. If the flag is clear, the LSN is left as it is. If the flag is set, we increment the MSN and clear the LSN.

There is a short cut to doing this, taking advantage of the fact that $10 + 6 = 16$, 00010000 in binary. If you look at this answer, the LSN is now zero, while the MSN has been incremented automatically, so representing decimal 10 in BCD. Thus, when we add 6 to the byte as a whole, if the DC flag is clear, no further action on that byte is needed (or on any subsequent bytes for that matter).

If, though, the DC flag is set, we simply replace the existing value in the byte with the value now stored temporarily. These commands do the job:

```
INCF COUNT,F      ; increment file value
```

```
MOVLW 6          ; move 6 into W  
ADDWF COUNT,W    ; add it to new file value but keep answer in W  
BTFSS STATUS,DC ; is the Digit carry flag clear?
```

```
MOVWF COUNT      ; no, it's set so move W into file, replacing previous value
```

The above check is done in respect of the LSN, but when the DC flag is set, the resulting action changes the value of the MSN, which then has to be checked to see if it (as a 4-bit nibble) is greater than 9, ie if the BCD value of the whole byte now equal to or greater than decimal 100?

Again, there is an easy additive technique. If we translate the binary value of BCD 100 (10100000) the decimal answer is 160. If we temporarily add 96 (256 – 160) to the whole byte, we can then check the Carry flag (C) to see if it has been set, which it will be if the binary answer has rolled over beyond 255. As before, if the flag is clear, the byte can remain as is; if the flag is set, we replace the value with the temporary one. (Note that the DC and Carry flags are unaffected by an INCF or INCFSZ command.)

Here's the extended routine. Note the inverted logic for checking Digit Carry and Carry flags, **BTFSS STATUS,DC** in the first instance, **BTFSS STATUS,C** in the second.

```
INCF COUNT,F  
MOVLW 6  
ADDWF COUNT,W  
BTFSS STATUS,DC  
GOTO ENDADD  
MOVWF COUNT  
MOVLW 96  
ADDWF COUNT,W  
BTFSS STATUS,C  
MOVWF COUNT  
ENDADD  
(program continues)
```

Let's look at the BCD additive technique in practice, triggering it from the timer routine:

```
MAIN BTFSS INTCON,2  
GOTO MAIN  
BCF INTCON,2  
INCF COUNT,F  
MOVF COUNT,W  
ADDLW 6  
BTFSS STATUS,DC  
GOTO OUTPUT  
MOVWF COUNT  
ADDLW 96  
BTFSS STATUS,C  
CLRF COUNT  
OUTPUT MOVF COUNT,W  
MOVWF PORTB  
GOTO MAIN
```

In the above listing, note the use of CLRF COUNT before OUTPUT at the end. This can be used here since we know that adding 1 to the count is occurring, rather than adding values of 2 or greater. In the latter instance, the resulting temporary answer must be MOVED into COUNT.

Let's go back to the use of the 3.2768MHz crystal, as we can now move forward to

looking at a realtime clock, requiring timed periods of one second, as used with the frequency counting. The `config` setting is automatically changed by the `.hex` to suit this external crystal. We can continue with the LED display for the moment.

Load `TEACHINE03.hex` and observe the count incrementing on the LEDs. The prescaler is now run at a fixed ratio of 1:128 and a seconds timing routine is used.

XOR command

There is another technique for checking values, using the command XOR. Let's examine it in principle.

The command XOR (Exclusive OR) checks for *equality* between two numbers. There are two commands, XORLW (XOR Literal with W) and XORWF (XOR W with value in specified File). The latter is followed by the file name, a comma, and the destination (W or F), eg `XORWF STORE,W` and `XORWF STORE,F`.

You probably know that in electronics there are XOR gates included in the digital logic chip families, and you will no doubt have read descriptions of truth tables relating to just two inputs of an XOR gate (two bits):

```
0 XOR 0 = 0
0 XOR 1 = 1
1 XOR 0 = 1
1 XOR 1 = 0
```

As far as a PIC's XOR function (8 bits) is concerned, the result of XORing two bytes of eight bits is the condition being checked. It is easier here to show the principle by means of switches and an LCD rather than by truth tables. The circuit and breadboard diagrams are shown in Figs 5.3 and 5.4.

We use PORTA to monitor the switches, just four of them, S1 to S4, on PORTA bits 0 to 3, along with their biasing resistors, R1 to R4. Biasing is normally low when the switches are unpressed. The appropriate PORTA input goes high when a switch is pressed.

Insert the switches and resistors into the breadboard as shown in Fig.5.4. Reinstall the LCD, and disconnect the LED activating link wire. Load the PIC with `TEACHINE04.hex`, and let it run. Its listing is shown in Listing 5.3.

Register TESTVAL is used to hold the basic value against which the value set by the switches is compared. Its value is shown on LCD line 1. The value is set into the program and cannot be changed without reprogramming the PIC.

The value set by the switches is held in register VALSTORE and the value is shown on LCD line 2, immediately below the fixed value. The LCD also indicates whether or not the two values are equal, indicated by the STATUS register Z flag. Just a simple technique for showing the binary bit logic is used in the subroutine `SHOWBINARY`.

The message '= 0 NO' is shown to indicate that the truth of the Z flag is false if equality between the two values does not exist. The message '= 1 OK' is shown to indicate that the truth of the Z flag is true if equality between the two values *does* exist.

In this listing, the value on PORTA is input in the usual way. The next command (`ANDLW B'00001111'`) is necessary to

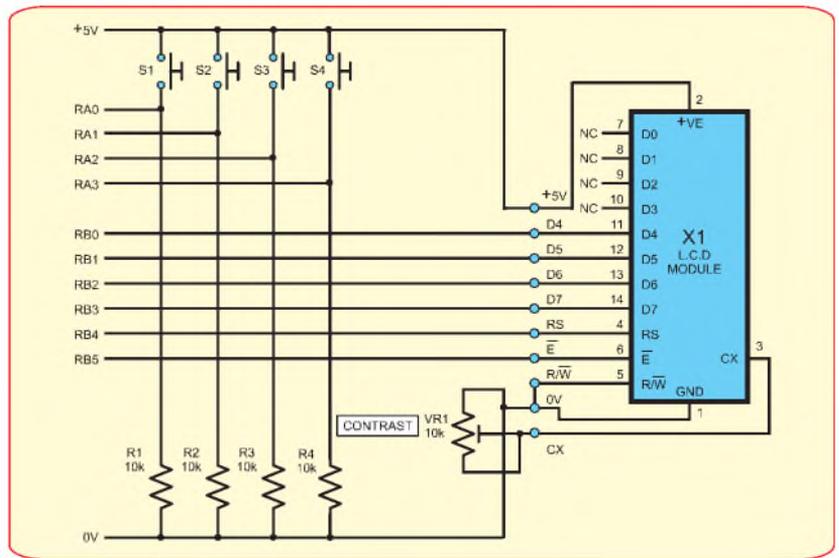


Fig.5.3. Circuit for XOR Demo

this demonstration, since we only want to use the first four bits of PORTA. If PORTA had eight bits that could be used together with associated switches, the AND command would be omitted. The status of each switch is being XORed with the respective bit in TESTVAL, switch 0 with bit 0, switch 1 with bit 1, and so on.

If any bit of PORTA is equal to that of the same bit in the XOR command, the same bit in the W register will be cleared. Thus, two zeros will produce a 0, and two 1s will produce a 0. If the bits are dissimilar (1 and 0) the Z bit is set (1).

Suppose that the switches produce binary number 0111, the ANDed result in W is 00001111, the sequence of events is:

```
MOVWF PORTA,W
```

```
answer = xxxx0111
ANDLW 00001111
```

```
answer = 00001111
XORLW 00001000
```

```
answer = 00001000
```

Bits that are equal to their counterparts have their corresponding display bits set, those that are not equal have their bits cleared. Take another example:

```
MOVWF PORTA,W
```

```
answer = xxxx0010
ANDLW 00001111
```

```
answer = 00000010
XORLW 00000010
```

```
answer = 00000000
```

Here each bit is equal to its counterpart, therefore the answer is zero and, importantly, the Zero flag will have been set accordingly. Therefore, we can

check for equality by checking the Zero flag following an XOR command. Non-equality clears the flag, equality sets it. Consequently, following an XOR command you simply check STATUS,Z and route accordingly.

Command OR

Although we shall not meet it until later, it is now appropriate to mention that there is an 'ordinary' OR command available. It is more correctly termed *Inclusive-OR* (as opposed to Exclusive-OR). It has two versions, IORLW (Inclusive OR Literal with W) and IORWF (IOR W with value in specified File). The latter is followed by the file name, a comma, and the destination (W or F), eg `IORWF STORE,W` and `IORWF STORE,F`.

Seconds counting

Moving on from decade counting between 0 and 99, it is an easy step to count in BCD from 0 to 59, accurately simulating the seconds count of a real-time clock.

Load `TEACHINE05.hex` and observe the LCD display. You will see the twin-nibble BCD count on line 2 progressively stepping from zero to BCD 59 (01011001), then

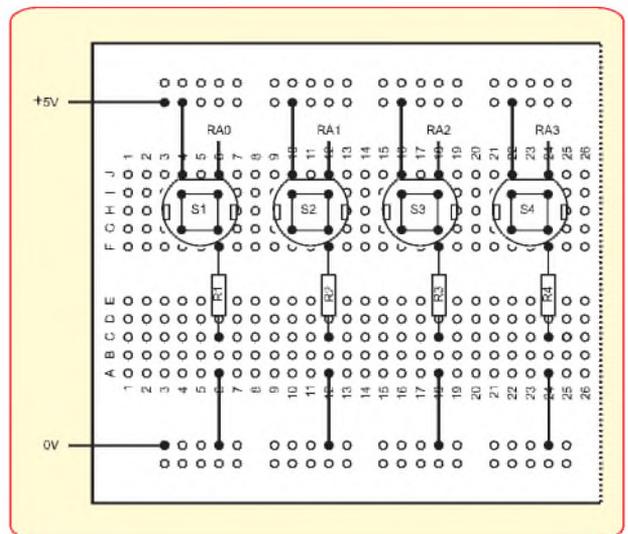


Fig.5.4. Breadboard layout for Fig.5.3

Listing 5.3

```

MAIN    movf PORTA,W
        andlw b'00001111'
        btfsc STATUS,Z
        goto MAIN

        movwf VALSTORE
        movwf TEMP

        call LCD21
        bsf RSLINE,4           ; set LCD for display data
        call SHOWBINARY
        movlw ' '
        call LCDOUT
        movlw '='
        call LCDOUT
        movlw ' '
        call LCDOUT

        movf TESTVAL,W
        xorwf VALSTORE,W

btfss STATUS,Z
        goto M2

        movlw '1'
        call LCDOUT
        movlw ' '
        call LCDOUT
        movlw '0'
        call LCDOUT
        movlw 'K'
        call LCDOUT
        goto M3

M2      movlw '0'
        call LCDOUT
        movlw ' '
        call LCDOUT
        movlw 'N'
        call LCDOUT
        movlw 'O'
        call LCDOUT

M3      movf PORTA,W
        andlw b'00001111'
        btfsc STATUS,Z
        goto M3
        goto MAIN

SHOWBINARY movlw 8
        movwf LOOP

SB2     bcf STATUS,C
        rlf TEMP,F
        movf STATUS,W
        andlw 1
        xorlw 48               ; convert to ASCII value
        call LCDOUT
        decfsz LOOP,F
        goto SB2
        return

PAUSIT  movlw 5                ; set delay counter to 5
        movwf CLKCNT          ; (for 1/25th sec x 5)
        clrf INTCON           ; clear interrupt flag
PAUSE   ; initial 1/5th sec wait before setting up LCD
        btfss INTCON,2        ; has a timer time-out been detected?
        goto PAUSE            ; no
        bcf INTCON,2          ; yes
        decfsz CLKCNT,F       ; dec counter, is it zero?
        goto PAUSE            ; no
        return                ; yes

```

EXTRA COMPONENTS NEEDED FOR PART 5

3.2768MHz crystal
100n ceramic capacitor, 5.00mm pitch
(C1)

restart again at zero. On line 1 a seconds count in decimal increments at a rate of one per second, just as an ordinary seconds clock would and, indeed, it should take one minute for the full cycle to occur.

In this program, the prescaler rate has been set for 1:128, providing an INTCON,2 pulse rate of 1/25th of second. A counter, CLKCNT, counts down from 25 in response to the pulses. When it reaches zero, it is reset to 25 and a seconds counter, CLKSEC is incremented in BCD.

Checking for the BCD count becoming ten is performed by the additive (+6) technique we have already shown. However, checking for the count being at BCD 60 is done using the XOR equality testing method (XOR 01100000 = BCD 60). If equality exists, the CLKSEC counter is reset to zero.

In the routine, which shows the decimal count for the seconds, observe how the byte's MSB (tens) is first extracted using the SWAPF command to temporarily swap the two nibbles. ANDLW isolates the new LSN. It is ORED with 48, which converts the value to the ASCII form so that the LCD shows it correctly. CLKSEC is now copied into W, it too is ANDED to extract the LSN units), and Ored with 48 and then output to the LCD.

Another thing to think about

You have a few more concepts to play with now as a programmer. What can you do with the following problem? You have a coin-operated exit control at a car park. Ignoring any offer to accept the fixed payment by plastic card, use switches to represent the value of coins inserted (they are assumed to be legal!).

Indicate the coin value accepted and the total value received, opening the barrier when the correct amount has been received. Use a decimal readout on the display. If you think you can provide change, do so! And allow any other features that you might think are necessary. No specific questions or answers – it's all up to your imagination.

You could also think about how you would allow the number of cars coming in and out of a car park to be monitored, preventing its maximum capacity from being exceeded.

PLEASE TAKE NOTE

Teach-In '08 Part 2 (Dec'04)

In Listings 2.1 to 2.3, near the top – CLKCNT should be ranged left (in line with STARTIT), not indented. The CBLOCK and ENDC statements must be indented as shown.

Part 3 (Jan '08)

In Listing 3.1 and TEACHIN C01.ASM amend _config \$3F30 to _config h'3F30' and movlw \$07 to movlw h'07'

PIC N' MIX

MIKE HIBBETT

Our periodic column for your PIC programming enlightenment

Checksums and CRC checks

When we build microcontroller-equipped projects, we often connect them to other devices (measuring sensors, displays) or PCs using a serial interface – more often than not, the venerable RS232. Typically, the connection to a PC will involve communicating with a custom program written by ourselves to extract data from the microcontroller, or download configuration data.

If you have ever designed and built such a system you will be familiar with one of the common stumbling blocks that we all face: how to exchange information between the microcontroller and the remote device in a reliable manner. Reliability is an important issue because no matter how you write your code, if a single byte of data gets lost in the exchange between the two devices you face the whole system failing, requiring a reboot.

There are many reasons why communication can be unreliable and cause data errors. Electrical noise, intermittent electrical connections, even differences in relative speed between the processors involved. (*An amusing story is relevant here. If you transfer serial data between a PIC processor, running at 4MHz, and a 1GHz PC, which one is more likely to lose data? Yes, it's the PC. The Windows operating system sometimes goes off and does housekeeping tasks, and fails to notice data coming into the serial port. Software can be strange!*)

While dial-up telephone links and radio interfaces are clearly going to be noisy and susceptible to interference, there are many other less likely interfaces that need protecting. The connection between a processor and an EEPROM on the same board, where information is being transferred at high speed, can often be susceptible to corruption by electrical noise on the printed circuit board. Fast signals moving between ICs generate voltage spikes on PCB tracks that can interfere with the real signals being transferred. The point, simply put, is that it's not just signals travelling along long, noisy cables that require some form of error detection and recovery.

Parity bits

One of the simplest forms of error detection is a *parity bit*, often used on serial communication interfaces such as dial-up modems. Parity bits are used to protect individual characters being sent over a link. In this case a character is a binary number consisting of seven data bits with the parity bit being the last, eighth bit – making it fit nicely into a byte.

Parity bits have a number of problems, however. First, they require each character being sent to be

restricted to only seven data bits, which makes their use rather difficult when dealing with binary data. Second, they only protect individual characters – so if your communication link loses a complete byte (such as when a PC's serial interface drops a character because the operating system is too busy), then a parity check is no help.

Parity bit checking comes in two flavors: odd and even. They work by counting the number of '1' bits in the character, and setting the parity bit to make the number of '1' bits in each character either even (for even parity) or odd (for odd parity). Clearly this is a very simplistic check but it does mean that it is easy and fast to implement in software or hardware.

Parity checks find uses in many areas today, protecting the contents of memory chips for example, but are not much use if you are trying to protect the communication between a PC and an embedded device consisting of many bytes of data. We have to look elsewhere, such as checksums or cyclic redundancy check digits.

Checksums

A checksum is typically a single byte that is added to the end of a message (a series of bytes) that is passed from one device to another. There are various algorithms for computing a checksum, but the simplest method is to simply add up all the other bytes in the message, and use the lower eight bits of the result. This works quite well in an embedded system with limited memory or processing power: for each data byte transmitted, add the value into a single byte 'accumulator' variable. When you have transmitted all of the message data bytes, send the value stored in the accumulator variable.

The receiving device performs a similar calculation, adding up the data bytes as they are received and then comparing its calculated checksum with the one present at the end of the message. If they are different, then an error in the transmission has been detected and the message can be discarded.

For such a scheme to work your receiving device has to know the *structure* of the message being sent, so that it knows when the message ends and where the checksum is. There are many ways in which you can do this; there are standards and algorithms available on the Internet that you can use.

Msg Id	Length	Data	Data	Data	Checksum
0x32	0x03	0x8A	0x52	0x7C	0x8D

Fig. 1. Example message with simple checksum

Message protocols

These are called *message protocols*, since they describe how two devices will talk to each other. You can, of course, 'roll your own' protocol and this is indeed what many of us do. A simple message format for sending variable length messages between two devices is shown in Fig. 1.

Here, the message consists of a number of different parts. The first bytes sent (shown on the left) is the message identification. It will tell the receiver what the message contains, so it knows what to do with it. The second byte is a length identifier – it holds a number indicating how many data bytes follow. After the specified number of data bytes, the final byte is the checksum.

What the message identifiers mean and how many data bytes get sent is, of course, completely up to you. You just need to make sure that both your embedded software and the code running on the PC follow the same rules, and implement the same checksum algorithm, for data communication to work with error detection.

Having received a message with a checksum, the receiver will need to tell the sender that it was received correctly. And if not, what to do about it. A simple yet effective method for doing this is shown in Fig. 2, which shows the sequence of data transmission between two devices (a PIC and a PC.)

The vertical lines represent time, running from the top and working downwards. The horizontal lines show the direction in which a message is being sent. Every time a message is sent from one device to another, the receiver returns an acknowledgement, indicating either success or failure. This can be done by returning a single byte, as shown in Fig. 2, where a value of '1' means good and '2' means bad. You can use whatever values you want. Because these responses are very short we tend not to bother adding a checksum to them – things might start to get rather complicated if we did!

When a returned acknowledgement indicates that there was a problem with the message, the sender can simply re-send the message, or perhaps end the communication session. Again, it's up to you.

Timeouts

If you code a scheme as described above, you should take care to make sure you allow timeouts for all messages. For example, what would happen if the length byte in a message was corrupted from 23 to 33? The receiver would wait patiently for the remaining data bytes to arrive, but they never will. So it is important to also add some kind of timer while processing received data, so that if a data byte has not been received within some sensible time (such as a few seconds perhaps) then an acknowledgement of 'failure' should be returned.

Errors like this can also occur with the returned acknowledgement bytes; what should the sending device do if it fails to receive an acknowledgement from the remote device? Should it assume the message was clearly received, resend the message anyway or give up communicating? The answer to this will depend on what the receiver will do with the message, and again it is entirely up to you.

As you can see, there are some complex issues around the subject of sending messages, obvious in our example even though we are only just scratching the surface. There are many standard ways of solving this problem, referred to as the *data link layer* model, such as PPP and HDLC. These are *very* complicated algorithms, which take a lot of code to implement. For a hobby project, however, a system based on what we have described should be good enough.

The simple 'addition' based checksum algorithm has some flaws, however. As with any checksum system, it can never guarantee that the message is uncorrupted – only that it has not detected a problem. As we are only adding bytes together, two errors that complement each other will cancel each other out. And odd though it may seem, errors such as this are not unusual. Fortunately, there are better algorithms available.

CRCs

Cyclic Redundancy Checks, or CRCs, improve on the simple checksum algo-

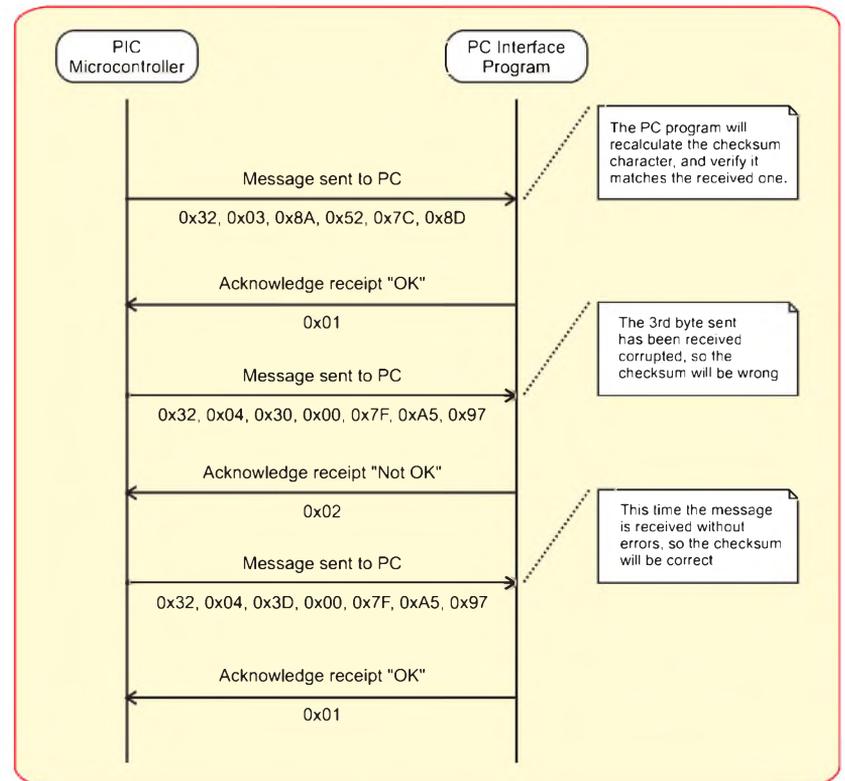


Fig.2. Example message exchange using checksums

rithm by using a division method rather than an addition process to derive the final check digit. The net result is the same – a routine examines all the data bytes, and produces a single byte or word result that is appended to the message – however, the way it produces the result is much more complex, using a form of division between the message bytes and a constant divisor.

The mathematics behind this is beyond the scope of this article, but thankfully it results in an algorithm that is relatively simple to implement in both hardware and software. Different CRC algorithms can produce 8, 16 or 32 bit results, with the larger ones producing better error detection capabilities.

Designs and code for CRC algorithms are freely available on the Internet, both in C and assembler language. Always remember, however, that a checksum or CRC algorithm can never confirm that a message is free of errors, just that it probably is. Some form of checksum or CRC should always be used though to protect against the more common forms of errors (noise, bad connections, data loss) that plague all PC serial interfaces.

Simple checksum algorithms are very easy to implement and have worked well for the author in a number of commercial applications. CRC algorithms, while requiring in the order of 1KB code space, can provide a much more robust solution. The choice, of course, is yours.

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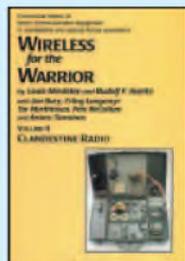
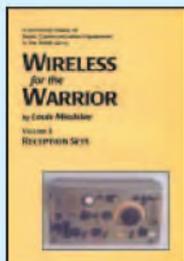
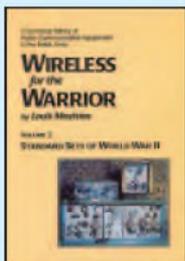
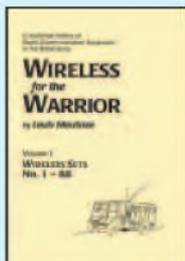
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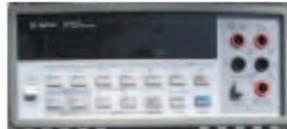
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MIDI DRUM KIT



BY JOHN CLARKE

PART 4 -
THE SOFTWARE...
AND DRIVING IT!

Operating the MIDI Drum Kit via a computer requires software to be installed. In the last article in the series we describe this final aspect of the MIDI Drum Kit.

AS MENTIONED in earlier parts, if you want to use the MIDI Drum Kit with a computer, as distinct from a MIDI instrument with its own synthesiser, you will need to install sequencer software and perhaps a serial port driver (with the option to install a USB driver).

The sequencer software provides the means to send a MIDI signal to the computer and to drive the sound card's synthesiser.

There are many sequencers available on the market; we have tested the MIDI Drum Kit using Propellerhead's Reason, the Computer Muzys CM Studio, Traktion and Rave.

Rave is, by far, the easiest-to-operate sequencer. Of course, you can use other sequencer software. However, we recommend using Rave first unless you

are already well versed in using the others. Rave for Windows is available as a free download from the net.

This software (or another sequencer program) is the only software you will need to install if you are connecting

to the computer using the sound card input via a games port. In this case, make sure the port settings on the MIDI Drum Kit are <MIDI PORTS>.

Many sequencers are a little daunting when you start them up, due to their complex control features. However, the Rave sequencer is ideal for first-time users to get the MIDI Drum Kit up and running. It really is easy to use with the MIDI Drum Kit.

If you want added features, then you must use a commercial sequencer.

The Computer Muzys CM Studio, for example, is available on the CD supplied with *Computer Music* magazine from Future Publishing in the UK. (www.computermusic.co.uk). Check it out at your newsagent. The software requires a 500MHz PC or Mac.



While there are many sequencers available, Rave is the one we recommend for beginners and novice users. It's by far the easiest to operate.

Reason can be found at www.propellerheads.se and the Traktion sequencer is found at www.rawmaterialsoftware.com or at www.mackie.com/traktion.

What, no games port?

Few computers these days have a games port. If you are in this position, you can connect via a serial port, or failing this using a USB port via a USB adaptor.

Note, however, USB connection is the most finicky way of operating the MIDI Drum Kit and if you have a serial port it is recommended to use it rather than via USB.

For USB use, there are two options. First, you can use a serial-to-USB converter and use it in conjunction with the MIDI serial driver. Software to set up a USB-to-virtual serial port driver will be required, and this is normally supplied with the serial-to-USB converter. (See the separate breakout panel for the USB installation).

For this option, the Port settings on the MIDI Drum Kit will need to be set to <SERIAL PORT>.

Alternatively, if you use a MIDI-to-USB converter (available from music shops or on the net) then you only need to install the sequencer software and the MIDI-to-USB driver. In this case, make sure the Port settings on the MIDI Drum Kit are <MIDI PORTS>.

The MIDI-to-USB converter connects directly into the MIDI outlet on the Drum Kit. Installation of the software for this will be included with the converter when you buy it.

We will only describe setting up the serial-to-USB converter, since this is the cheapest option.

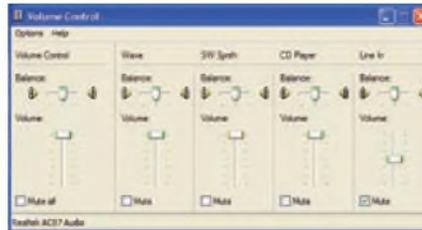
Checking computer settings

When installing any programs or drivers, you need to be logged on to your computer as an administrator. Before installing the sequencer software, it is best to check the settings in your computer to make sure that the sound card is set up correctly for MIDI.

For Windows XP, select Start/Control Panel. If it is set in the 'category view' mode, switch to 'classic view'. Now select sounds, speech and audio devices/audio/MIDI music playback.

In the MIDI music playback, select an MPU-401-compatible synthesiser (eg, Microsoft GS Wavetable SW synth).

Also, make sure volume is up for the synthesiser.



Do this by selecting volume in the MIDI music playback box and checking settings for the SW Synth.

This is similar for Windows 98. In this case, select Start/Settings/Control Panel/Multimedia/. In the multimedia properties select MIDI and an MPU-401-compatible synthesiser for internal synthesis (eg, ESFM Synthesis (220)).

Also, check that the volume control level for the synthesiser is up (double click the speaker's icon on the taskbar).

Driver signing

Later versions of Windows include driver signing. You need to check that this is not set to block programs from being installed.

To check the settings in Windows



XP, select Start/Control Panel/hardware/driver signing. Click on the Warn only button, if not already selected.

Screen saver and power management

When running the sequencer software, be sure to turn off any screen savers and any power-down energy management set for your computer. You can check these settings in the Control Panel and look for the Display options.

If you are playing your Drum Kit and the screen saver starts or energy management shuts down a system, expect some huge latency in the sound output.

Rave installation

The Rave sequencer program is available from the website <http://www.files1.sonicspot.com/rave/rave.zip>. The zip file is 647kB and can be unzipped in the normal way. The software was written to run on Windows 3.1, so unless your computer is very old, it should run on just about any computer using Windows.

We have tested the software on Windows 98, Windows Me and Windows XP. The only problem we have experienced is during installation, where error messages are shown because the DOS help file is not installed on the computer. This is just a software glitch that only occurs because the software was written for Windows 3.1. This operating system relied on having DOS installed.

Once the Rave software is installed, the error messages do not affect the operation of the Rave sequencer.

Download and save the rave.zip file from the location shown above to a directory (or folder) called C:\rave (or similar) and unzip in the normal way.

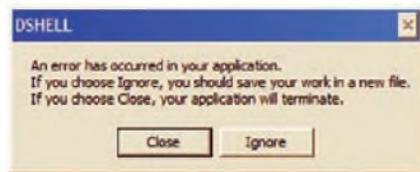
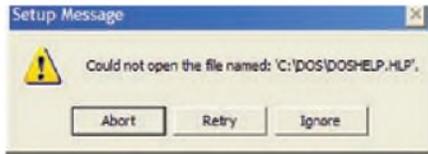
To use the wizard, it is usually only a matter of double clicking onto the rave.zip file and following the prompts to unzip to the rave folder. If you are using Windows 3.1, then use Pkzip to extract the zipped files.

When the file is unzipped, double click on the setup.exe file. This will install the software to the C:\rave folder. During installation, the computer may ask if you want to run this software with an unknown publisher. In this case click on the Run tab.

As mentioned, if you are using a current version of Windows that does

not include DOS, there will be an error message saying could not open the file c:\dos\doshelp.hlp. Click on ignore. A similar DOS shell error will also be shown. Again, click on ignore. Click on close after the general protection fault error is shown.

The three screens below show the error messages:



When installation is complete, navigate to the folder *c:\rave*. Single click onto *rave.exe* (*c:/rave/rave.exe*) then to 'File' and then select create shortcut from the list of options. Drag the shortcut to the desktop (this does not apply with Windows 3.1). Also copy the *midout.driv* file (found in the *c:/rave* folder to the *c:\windows\system* folder).

Serial or USB operation

If you are connecting to the serial or USB port, you will need to install the requisite drivers now. Details are in the separate serial port driver section and serial-to-USB section. Do not forget that if you are using the serial-to-USB converter, the MIDI serial driver will also be required. For a MIDI-to-USB driver, install as per the instructions supplied with the unit.

Setting up Rave

Once you've started Rave in the normal way, select 'Options' and the 'midi thru' box to bring up a tick against the MIDI Thru. The sound card synthesiser will not produce any sounds unless this box is ticked.

Check that the Options/Metronome/Bars Count In is set to at least 1 (if this is set to zero you will not be able to record)



Check in the Options/Output Assignments. The settings should show the MIDI Mapper.



You will need to add in (check the Add New box) the assignment 10 that is mapped in channel 10, as shown in the set output assignment box. Click OK to place this into the output assignment selections list.

Playing the MIDI Drum Kit

You are finally ready to play the MIDI Drum Kit. Connect the serial, USB or games port lead between the MIDI Drum Kit and the computer, switch on the MIDI Drum Kit and check that you can play the instrument and hear it through the soundcard output using headphones or loudspeakers. If you cannot hear anything, make sure the volume is turned up on the computer and that the sound works on other mediums, such as the CD player.

If the CD player works and sound still cannot be heard with the Drum Kit, double check that 'MIDI Thru' is ticked in the Rave/Options settings and that you

have selected the correct port in the settings menu on the MIDI Drum Kit. You should also check the settings mentioned in the MIDI serial driver section and the serial-to-USB sections.

Recording

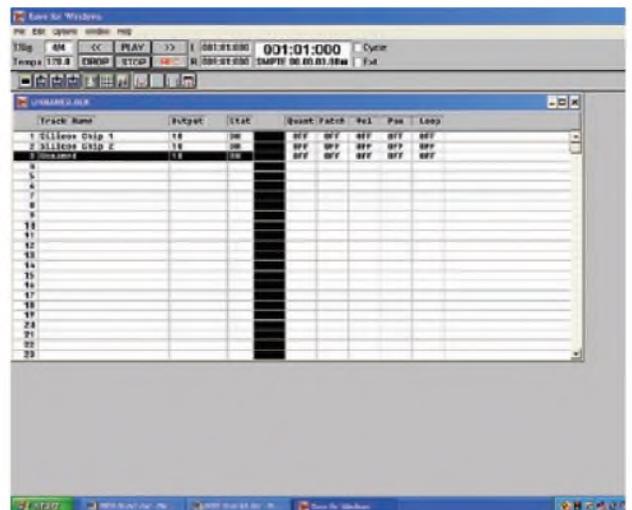
To record, select File/new. Save as '*yourfilename*.blk'. The following track details will be displayed. Where the Output is shown, change the number to 10, otherwise the drum sounds will just be instrument notes. This channel selection also applies to the Computer Muzys and Tracktion sequencers.

Click onto the REC(ord) button to begin recording. The tape transport position marker will start to count up after a second or so, and you are now recording.

The play, fast wind and stop buttons operate the same as any tape or video recorder, so you can stop, rewind and play the composition. Selecting File/save saves the recorded composition.

You can multi-track record if you want to. This lays down another recording alongside the original recording, leaving the original intact. So you can playback with more than one track, as if there is more than one Drum Kit playing, or you can record another instrument such as a keyboard to accompany the Drum Kit track.

To multi-track record, left-click the mouse pointer in the track name block (eg where 'Silicon Chip 2' is positioned in the screen grab below) to select the second track. These are initially set with an unnamed label, but they can be renamed by right clicking on the word, using the backspace to delete the word and rewriting your



required name. The selected track can then be recorded as a separate track with the original recording.

Up to 32 tracks can be recorded. In the right hand blocks, there is the option to change the patch (instrument), the volume, pan and quantisation. The easiest way to understand the changes is to play with them!

Latency

Latency is the delay between the MIDI signal being sent to the sequencer and when the sound is heard. The Rave sequencer does not have a facility to adjust latency, but most other sequencer programs do.

Note that latency is sound-card dependent. The Realtek sound card in our test computer could only provide a latency of 32ms minimum when used with Propellerhead's Reason. Choosing a shorter latency caused sound break-up.

The other commercial sequencers we tested did not provide a suitable reduction in the latency. Ideally, a sound card that supports ASIO (Audio Stream Input Output) should be used, to allow adjustment for minimal latency.



To set latency in Computer Muzys select System/Audio Hardware. Then select the Driver Type as either a Direct Sound or ASIO driver if the output device supports it. Select the Device Setup tab to alter the latency and use the right or left mouse button to increase or decrease the value respectively.

The drum sounds will become broken up if this latency is set too small in value. Just increase the latency until the drums sounds are correct and the latency is at a minimum.

Latency problems

Note that if the latency does not appear to change, regardless of the setting, it is probably due to the

sound card. It may not be ideally suited for direct MIDI input with low latency.

Try to update the driver from the manufacturer's website. If this does not help, use a sound card that supports ASIO drivers.

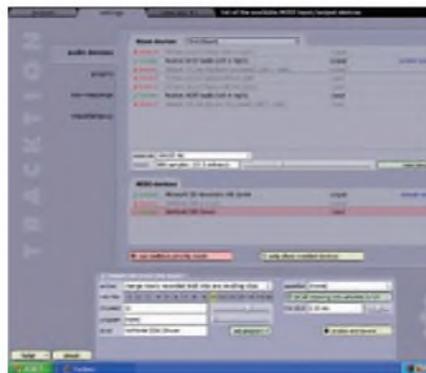
When setting the latency for other sequencers, you usually select Edit\ Preferences\ then select the audio section and change the sound card driver.

The slowest sound card driver is the MME type, while the ASIO types are the fastest. If your sound card does not support the ASIO driver then select a Direct Sound driver. The latency figure is usually shown as each driver is selected.

Also, the buffer size must be adjusted so that it is at a minimum, but not so small that the sound for the drums becomes broken up.



The Traktion sequencer has a direct latency adjustment that is found under the settings selection. Choose a low latency that also works without affecting the sound.



This screen shot shows the set up for operating the MIDI Drum Kit. To enable sound you must select channel 10, the enable end to end tab and the e-to-e box.



Note that any of the settings made on the MIDI Drum Kit, such as the patch, volume and pan will not be implemented if the changes are made when the sequencer is not running. Switch the Drum Kit power on and off if you need the new settings to be activated.

Also, you may need to adjust the Repeat and Threshold settings on the MIDI Drum Kit to allow the pads to be played at as fast a rate as possible and to prevent one sensor pad from triggering another. Details on these adjustments can be found in Part 1, Dec '07.

This is a basic rundown on how to use the software, sufficient to enable you to play and record, plus do some multi-tracking.

We hope you enjoy using your MIDI Drum Kit.

Macintosh Computers

Although we have not tried it, Mac users should be able to use the MIDI Drum Kit by using a Mac version MIDI sequencer – for example the ComputerMuzys CM studio, Traktion and Reason.

There are at least two options when making the connections between the MIDI Drum Kit and the Mac. You may need to visit a music shop and purchase a cable or converter. The simplest option is to use a MIDI-to-printer-port cable. The Mac already has MIDI drivers installed for this connection, but it is only useful if you have a printer port.

For USB connection, you will require a USB-to-MIDI converter, such as the Yamaha UX96. This converts from the MIDI outlet on the MIDI Drum Kit to USB format. The driver supplied with the converter will need to be installed.

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Installing the MIDI Drum Kit serial driver

The serial driver is commercial software, written by Yamaha Corporation for their MIDI musical instruments. It supports Windows 95, 98, Me, NT, 2000 and XP. The driver automatically detects your operating system and installs one of two versions best suited for your computer. Both files are contained in a file called `cbxdrv201w.zip`. This is a 971kb file and is designed for use with a COM1 or COM3 port. When using a serial port connection, make sure that you have a free COM1 to COM4 communications port on your computer before installing the driver.

If you are already using a COM port (eg, for a serial mouse and external modem), you may have to free up one of these ports so you can use the MIDI Drum Kit with this serial port driver. In general, the modem connection could be used, or if you only have one serial port, use this and connect your serial mouse to a USB port using commonly available USB- to-serial converters (or buy a USB mouse).

When used in conjunction with a USB-to-serial converter, the COM port numbers apply to the virtual serial port created with the USB-to-serial driver software (see its installation in the separate section).

The Yamaha serial driver file can be obtained from www.yamaha.co.uk/xg/download/tools/cbxdrv201w.zip. Save the file to a directory (or folder) called `c:\midicbx` (or similar) and unzip in the usual way.

A readme file will be unzipped to one of the folders (`c:\midicbx\cbxdrv201w\setupdir\009\readme.txt`) and this describes in detail how to set-up the driver for the various Windows operating system versions. In abbreviated form, double click on the `setup.exe` (found in the setup folder) file and follow the prompts.

When the 'select COM ports' dialog shows, check the COM port that you are going to use.

The selection is dependent upon how many serial ports you have and which one you are going to use for the MIDI Drum Kit connection.

Note that if you are connecting via USB, then select a COM port number that does not correspond to a serial port that is already installed.

Click on the Next button and the MIDI output ports dialog will be shown. For our purposes, select the 'Use single MIDI' output port.

Click on Next and that completes the installation.

This dialog box will be displayed. Normally, it reminds the user to select the PC-2 position on the Yamaha MIDI unit's 'TO HOST' select switch, but for our MIDI Drum Kit, it reminds us to select the serial port setting on the Drum Kit. Restart the computer to finalise the installation.



Correct installation can be seen in the sounds and audio devices properties box.

For Windows XP, select Start/Control Panel, then switch to Classic View if set in the Category View mode. Now select Sounds, Speech and Audio Devices/Audio/MIDI music playback.

In the MIDI music playback, select the down arrow to check if the Yamaha CBX A Driver is installed. Do not select this driver

– we are just looking to see if it is there, so keep the original SW Synth setting.

Once installed, you can change settings and disable the driver without uninstalling it. To do this, select Start/Control Panel and double-click on the Yamaha CBX driver icon.



When you double-click on the Yamaha CBX Driver Icon, the CBX Driver Setup box will be displayed. You can select the COM port (again) and enable or disable the driver. The greyed out selections cannot be used.



When using this driver with Rave, you can see if it is connected correctly by selecting Options/Synchronisation. If correct, the Yamaha CBX Driver will be displayed in the Synchronisation input port box.

Removing the Yamaha CBX driver

Navigate to the `c:\midicbx` folder and double-click `setup.exe`. The Setup dialog will appear. Follow the prompts to remove the driver. Restart the computer to complete the removal.

USB operation (via serial-to-USB converter)

When connecting the MIDI Drum Kit using a USB port, you

will need a USB-to-serial (DB9) converter. This unit converts the serial signal from the MIDI Drum Kit's serial port output to a USB signal. The software supplied with this converter then produces a virtual serial port on the computer, which can be read by the Yamaha MIDI serial port driver that is already installed.

Both the virtual serial port and the MIDI serial port driver must be set to the same COM port number. Note that if you have a serial port on your computer, it is preferable not to select the same COM port number for the virtual port.

To install the USB-to-serial converter and the software, plug in the USB unit. The computer will alert that new hardware has been installed. In Windows XP, the Add New Hardware wizard will start up and assist in setting up the USB converter. When prompted, insert the CD ROM and select the 'USB to serial cable'\WN DRIVER\98-2009-2K20021 folder. Click next to install.

If you have problems with this method, disconnect the USB-to-serial converter, wait ten seconds and reconnect. When the new hardware has been detected and the Add New Hardware wizard opens, select the install from a list or specific location, then click onto next.

Select 'Don't search I will choose the driver to install'. Click onto Next. Click on 'Have disk' then browse to the CD ROM\WN Driver\98-2009-2K20021\serspl.inf. Click onto open, then OK and Next.

A warning may appear to say that the software is not logo tested for compatibility with Windows. Click on the 'Continue Anyway' button.

Uninstalling or reinstalling

Make sure the USB-to-serial driver is plugged into the computer and select Start/Control Panel/system. In the system properties select hardware/device manager/ ports (COM & LPT). Select the 'Prolific USB-serial-bridge'. Double-click on this, then select Driver/uninstall and OK when it prompts you to uninstall. You can reinstall using this method by selecting the update driver button and going to the folder on the CD ROM as before.

To change the COM port setting on the USB-to-serial converter, select Start/Control Panel/system. In the system properties select Hardware/Device Manager/Ports (COM & LPT). Select the 'Prolific USB-serial-bridge'. Double-click on this, then select port settings/advanced. Select the COM port number from the drop down menu. Note that the port number must match the port number selected for the Yamaha MIDI serial port driver. You can only select the ports that the Yamaha MIDI serial port driver allows. In our case, as shown in the Yamaha CBX driver setup, this is COM1 or COM3.

Notes on the USB connection

1. You can connect the USB-to-serial converter to the MIDI Drum Kit in one of two ways. First, you can use a DB9 extension cable. The cable connects to the MIDI Drum Kit serial outlet and the socket end connects to the USB-to-serial converter. Plug the USB end into the computer.

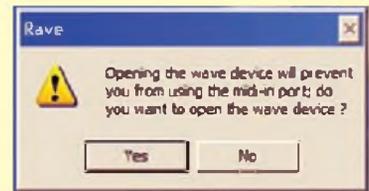
Alternatively, if you only require a short connection, the USB converter can be directly connected to the MIDI Drum Kit serial outlet. In this case, the retaining screws on the MIDI

Drum Kit serial outlet will need to be removed. A 1.8m USB 2.0 A-to-A extension cable can be used to make the computer connection.

2. If you plug the USB-to-serial converter into a different USB port on the computer, you will need to install the driver for that USB port. It's better to always plug into the original USB port where the driver was installed.

3. Avoid plugging the USB-to-serial unit into the computer while the MIDI Drum Kit is switched on, or the computer may sometimes decide the device is a mouse or similar 'human interface device' rather than the USB converter. If this happens, you will need to reinstall the USB-to-serial converter software as detailed above or click onto the driver 'roll-back' button instead of the 'reinstall button'. This last option reverts the driver to the previous USB-to-serial driver and installation is quicker as you do not need the CD ROM.

4. If you see this panel when starting Rave, it means that the MIDI Drum Kit will not (at present) work with the USB converter. The panel indicates that the virtual port data is corrupted. It could be that the serial-to-USB converter is not connected, or simply that the USB converter has to be reset.



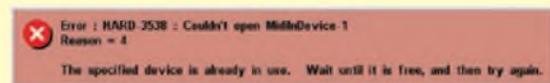
Alternatively, the COM ports selected for the Yamaha serial driver and the USB-to-serial driver may not be the same number.

In the first two cases, click on the 'No' button and then OK on the copyright panel when Rave starts. Exit from Rave in the normal way.

Unplug the USB connection and wait for the disconnect confirmation, then reconnect it and start Rave again. The wave device-warning panel should not appear this time.

5. If you switch off the MIDI Drum Kit while you are within Rave, then the only way to have the MIDI Drum Kit play again is to exit from Rave and then restart it.

Similarly, in Computer Muzys, you may receive this error when starting.



In this case, exit from the program, disconnect the USB connection and reconnect it. Restart the program.

The Computer Muzys MIDI port is set using the System/MIDI Hardware selection and the MIDI Hardware set-up panel will be shown. Make sure you also select channel 10 for MIDI In by right clicking on the input box and selecting channel 10 from the pull-down menu. **EPE**





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READOUT

Email: 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!

All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

Thoughts on Power Generation

Dear EPE,

Following Mark Nelson's comment regarding Tesla and power transmission Oct '07, here are a few historical thoughts on the subject that may generate interest.

"Electric power is present everywhere in unlimited quantities and can drive the World's machinery without the need of coal, oil, gas, or any other fuels." – *Nikola Tesla 1898*

When Faraday had become world famous for his invention of the dynamo in the 1850s he was not satisfied with his limited success. Faraday wrote the following after testing the magnet powered generator,

"There is a wheel in the physical mechanism of the action that is missing, whereby electricity (energy) should be derived from magnetism without the expenditure of mechanical energy.

For my own part, considering the relationship of a vacuum to the magnetic force, and the general character of magnetic phenomena external to the magnet, I am much more inclined to the notion that in the transmission of the force there is such an action, external to the magnet, than that the effects are merely attraction and repulsion at a distance. Such an action may be a function of the ether; for it is not unlikely that, if there be an ether, it should have other uses than simply the conveyance of radiation." – *Michael Faraday*

"Modern physics views the vacuum of empty space not as a void but as a plenum of randomly fluctuating electromagnetic fields known as the zero-point energy (ZPE)." – *Harold Aspden*

"It is characteristic of fundamental discoveries, of great achievements of the intellect, that they retain an undiminished power upon the imagination of the thinker. The memorable experiment of Faraday with a disc rotating between two poles of a magnet, which has borne such magnificent fruit, has long passed into every day experience; yet there are certain features about this embryo of the present dynamos and motors which, even today, appear to us as striking and are worthy of the most careful study." – *Nikola Tesla*

"Empty vacuum – pure 'emptiness' so to speak – is filled with rivers and oceans of

seething energy, just as Nikola Tesla pointed out. It is running off the fact that vacuum space-time itself is nothing but pure massless charge. That is, vacuum has a very high electrostatic scalar potential – it is greatly stressed.

To usefully tap the enormous locked-in energy of that stress, all one has to do is crack it sharply and tap the vacuum oscillations that result. The best way to do that is to hit something resonant that is imbedded in the vacuum, then tap the resonant stress of the ringing of the vacuum itself.

In other words, we can ring something at its resonant frequency and, if that something is imbedded in the vacuum, we can tap off the resonance in vacuum stress, without tapping energy directly from the embedded system we rang into oscillation. So what we really need is something that is deeply imbedded in the vacuum, that is, something that can translate 'vacuum' movement to 'mass' movement." – *John Bodini*

"Every disturbance of the ether, including radiation as one type of disturbance, is originated by translatory motion of electrons through the ether. The ether is a perfect fluid endowed with rotational elasticity.

I surmised that round a magnetic loop the ether is circulating, not necessarily quickly, but circulating, as a curtain ring might be spinning in its own plane, or like the rim of a spinning top or fly wheel; and that the energy is represented by this circulation." – *Sir Joseph Larmor*

"There is indeed a situation here whereby energy is being obtained from a previously unknown and unexplained source. This is a conclusion that most scientists and engineers would reject out of hand as being a violation of the accepted laws of physics, and if true has incredible implications." – *Robert Kincheloe*

"The vast interplanetary and vast interstellar regions will no longer be regarded as waste places in the universe. We shall find them to be already full of this wonderful medium; so full that no human power can remove it from the smallest portion of space or produce the slightest flaw in its infinite continuity". – *James Clerk Maxwell*

"Maxwell and Faraday, the pioneers of electromagnetism, believed that the fields consisted of matter in motion. This is stated in no uncertain terms in Maxwell's book *A Dynamical Theory of the Electromagnetic Field*. In fact, Maxwell used a dynamical model to derive his famous equations. This fact has all but been lost in current books on electromagnetic theory. The quantity which Maxwell called electromagnetic momentum is now referred to as the vector potential." – *Sir Gordon Lodge*

"The theory I propose may be called a theory of the electromagnetic field because it has to do with the space in the neighbourhood of the electric or magnetic bodies, and it may be called a Dynamical Theory, because it assumes that in that space there is matter in motion, by which the observed electromagnetic phenomena are produced.

In speaking of the energy of the field, however, I wish to be understood literally. All energy is the same as mechanical energy, whether it exists in the form of motion or in that of elasticity, or in any other form. The energy in electromagnetic phenomena is mechanical energy." – *James Clark Maxwell*

"There are secrets and mysteries surrounding magnets and collapsing field energies, and only after exhaustive studies of these two phenomena in practice, do these mysteries unravel themselves and emerge in their glory." – *Robert Adams*

"The key to understanding and explaining the baffling situation of anomalous excess electrical energy generated in free energy machines, lies in a reinterpretation of magnetism as not being a property of the magnet, but of space itself. The spatial distortion induced into the homogeneous Primordial Energy Field by the anisotropy of the magnet is what we call magnetism." – *Bruce DePalmer*

"I think it is possible to utilize magnetism as an energy-source. But we science idiots cannot do that; this has to come from the outside." – *Werner Heisenberg*,

Raymond Dale, via email

Thanks for these Raymond. Readers, any further thoughts?

Flowcharts

Dear EPE,

Further to Mike Hibbett's look at flowcharts in *PIC n' Mix*, Rapid Electronics lists a flow chart stencil (along with lots of other traditional items, intended for education) in their current catalogue. Even after adding VAT, it's not expensive!

Godfrey Manning G4GLM, Edgware, via email

Thanks Godfrey, that was a great piece of detective work! I'm sure others will be interested to know they can still be purchased.

Mike Hibbett, via email

Thanks from me too Godfrey.

Witricity

Dear EPE,

Techno Talk Oct '07 makes reference to Tesla and his original ideas in this regard. There is no doubt that transmission of energy without wires, albeit in waveguides, is possible, as your humble microwave oven shows. It is all a matter of frequency, power density and acceptable losses if my memory on Radar theory serves me right.

A relatively recent book by Gerry Vassilatos, entitled *Project HAARP and Beyond*, expounds some fascinating (conspiracy?) theories regarding the transmission of gigawatts of energy derived from Alaskan oil, by means of radio energy in waveguides, to sites in the USA thousands of kilometres distant. The idea is to 'write' a waveguide in the earth's magnetic field lines by means of lasers, from the transmitter site in Alaska to the receiver site. The waveguide will contain a 45 degree reflecting 'mirror', also laser-written, to beam the energy towards earth. The magnetic lines are, of course, vertical near the poles, permitting the writing of the waveguide down to ground level.

Sounds far-fetched, but according to Vassilatos the CIA, the USA Govt and others are behind it because of its military potential.

Leon van der Merwe, Pretoria, South Africa

Interesting concept Leon, thanks

Commands and Instructions

Dear EPE,

I note with interest your new *Teach In* series. A point of contention I have is the use of the term *Command*. When teaching or explaining about microprocessors, the reference to their basic operation is that of fetching and executing *Instructions* and not *Commands* as quoted in the text.

Since the 1970s I have lectured in Electronic Engineering, specialising in microprocessors and have always stressed the importance of using the term *Instruction*. The term *Command* implies a higher level of operation and not the basic operation of a microprocessor. It can be

noted that manufacturers relate to the *Instruction Set* of a microprocessor and not to a *Command Set*.

Terry Apps MSc., CEng., MIEE (Rtd)

Thanks Terry. I have been programming for well over 30 years and have always used the term Command. I have never been queried on this point before. Old habits are hard to change, and I doubt that I shall.

Anti-Static Measures

Dear EPE,

To amplify Robert Penfold's *Practically Speaking*, Nov '07, on the topic of electrostatic damage protection, I should say that all semiconductor devices must be treated as if they are static-sensitive, regardless of datasheet or long-held belief. It is not widely understood that static damage does not necessarily result in instant or total destruction of a device, it may equally result in latent damage which may manifest some time later, after a product has been manufactured and tested and is in field operation.

Obviously, this is of great concern to a commercial organisation, where a high rate of in-service premature failures will be of significant damage to the company's reputation, but it is not exactly convenient for the amateur either.

While it is true that the older technologies were far more robust (the insulating layers were much thicker), it is better to take precautions as a habit than to make decisions about it each time.

The article did mention, but I will emphasise here, the need for personal safety. Workstation mats and earthing leads have built-in resistances of several megaohms, designed to prevent injurious currents electrocuting the user if he or she happens to touch something live. After all, it is not a good idea to provide a current path to earth through the body!

Improvising with tin (aluminium) foil is not recommended, especially if you want to power up your creation on the test bench! If you must (something is better than nothing), then I suggest you DO NOT connect it to mains earth. What is needed is an equalisation of voltages, and not necessarily a grounding of them. Therefore, by connecting yourself to the foil work surface (rest a hand on it from time to time) the danger is neutralised without personal risk.

Ken Wood

Yes Ken, many of us more experienced constructors know this, but it is not widely publicised.

SMS Controller

Dear EPE,

I refer to the question by James Cells (Nov '07) asking if any other readers experience problems with the *SMS Controller* switching off the phone randomly. My business in South Africa is manufacturing and selling SMS controllers (five models) using our own PIC programs and

refurbished Nokia 5110 phones. The phone does not switch off at all by itself unless the battery of the phone is flat, when the power supply was off so that the battery of the 5110 could not be charged by the built-in charger with automatic on/off control.

If that happens, our controller will identify comms lost when the power supply is restored, switch on the built-in charger and then switch on the phone over the FBUS. I suppose that is the benefit of using your own PIC program instead of soldering wires to the phone. Our 2-channel model uses an SMS (password protected) or a 'missed call' by up to 250 users whose numbers are on the phone of the controller to activate/deactivate the output (pulse or latch). Users could be added on, or deleted from, the controller phone on (a) the phone keypad or (b) an SMS from any cell phone using a password – very convenient for large number of users using an electric gate at townhouses where people move in and out every month.

When the 3V to 12V DC input is triggered, the controller will send an SMS to the user or the unit could call up to three users, repeated five times in sequence, until the call is acknowledged by any of those three users.

Jan Henning, Janca Electronics, South Africa

Thanks Jan, I'm sure interested readers will Google on your company for more information.

What Energy Saving?

Dear EPE,

In comment to the *Readout* letter regarding low energy lamps in the December issue:

The energy saving is in the transmission and distribution through the electrical supply. A typical low energy lamp only requires around one fifth the energy required by a standard lamp. The individual savings are nominal, but consider the theoretical savings of 1000s of megawatts that need not be generated if we all replaced a few lamps.

The question really is, are these savings greater than the energy required to produce and distribute low energy lamps? (Do not forget to take into account the energy required to produce and distribute standard lamps.)

Elemer Nyiry, via email

Indeed Elemer, 'balancing the books' in this type of situation is very complex.

ADE7756AN Chip

The following thread recently came about on our *Chat Zone* (access via www.epemag.co.uk):

electron: Many thanks to John Becker for publishing my email offer in the December issue. I have already received enquiries for this device from readers. The effort I put in to obtain these devices is now paying off!

john_becker: That's great Electron. I'm pleased to help.

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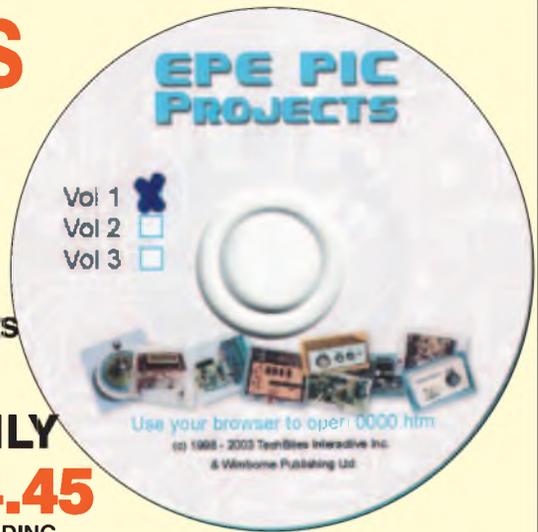
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Net Work



Alan Winstanley

A fine mashup

Shopping online has become second nature for many of us, and the preceding Christmas period showed that many shopping sites had geared up successfully to take advantage of e-commerce, ensuring they did not over-sell and had adequate stock to deliver on the appointed day. Buyers showed more faith in Internet shopping than before and were more confident ordering perilously close to the Christmas shut-off.

Naturally, some buyers were disappointed that their item failed to arrive in time, but these were very small in number compared to the huge turnover of business – Amazon UK reportedly handled nearly 5.5 million orders on a single business day in December 2007. The effective use of CRM (customer relationship management) systems, and the use of timely and focussed email shots, meant that many Internet suppliers indulged in a bumper online shopping spree, unlike traditional retail stores, whose sales continued to fall: this was evident in December in some empty-looking stores whose staff often outnumbered shoppers.

Not all is sweetness and light online though. An example of how not to do it was shown by one online store who replied to my enquiry about an error on their website and stock availability with a terse 'currently out of stock'. With everyone under pressure to churn out email responses, first impressions count for everything and extra care is needed with courtesy and good 'netiquette' to ensure that customers feel their business is valued.

Keeping tabs

Of course, one of the main benefits that the Internet brings is the simplicity of comparing websites. Using Internet Explorer 7 or Firefox, you can navigate to a new website by opening a new tab (press CTRL + T) and typing a new URL. Then switch tabs to travel between multiple websites and home in on the best deal.

This is fine if you know where to shop. One of Google's increasing infuriations is that when searching for a specific product or service, the search engine will latch onto certain keywords and then display page after monotonous page of shopping directory website links, where you have to start the search all over again. The same is true for hotel, insurance or holiday searches: Google has a policy of focussing intensively on price comparison directories such as Kelkoo, Bizrate, Price Runner or Dealtime and, of course, it manages to drill into eBay's items too. Understandably, price comparison sites (called 'mashup' sites, because they combine data from several sources), such as [Pricecomparison.co.uk](http://www.Pricecomparison.co.uk) are becoming more influential on a consumer's choice.

If you are anything like the writer, your eyes soon blur after seeing endless pages of meaningless directory results. Usually I sample two or three sites to get a feel for price and then choose a preferred supplier. It is becoming impossible to cope with the sheer volume of online choices, and one of the more perverse aspects of online shopping – security issues apart – is that it can soon become very time consuming and onerous trying to find the best online deal (let alone whether they have the stock, and whether they can deliver). Remember that in the UK, the Consumer Protection (Distance Selling Regulations) 2000 gives all consumers a seven working day cooling off period for the majority of goods, but the onus is on you to return goods in as new, original condition. More details are at <http://tinyurl.com/yr7c7k>

For some people, shopping will always be a social thing of wandering around stores and meeting people: in that case, the web enables you to swot up on specifications and compare different products beforehand. The best buyers (which stores hate!) are always in possession of the facts, so use the price comparison sites, read reviews and check specifications before visiting a store.

During the coming year it will be interesting to see how major retail stores respond to the increasing trend of knowledgeable web shoppers, like *Net Work* readers, checking out physical goods instore before buying online from a cheaper source: expect more pressure from hungry retail staff and more incentives to buy on the spot.

I'll vouch for that

Consumers face increasing information overload, and you can bet that marketers will use ever more ingenious and insistent methods to get their message across. Perhaps 2007 should have been dubbed the 'Year of the Voucher'. A highly effective guerrilla marketing technique, money off vouchers circulate almost unseen on the Internet, where they are pounced on by shoppers hoping to bag a bargain. Typically, vouchers offer some form of cash discount or some other incentive, and a new genre of websites has sprung up designed (most importantly) to attract visitors and exchange the latest vouchers.

Anything from domain names to dishwashers can be the subject of a corresponding voucher, so all you have to do is hunt them down. These are usually in the form of a discount code that is entered in the shopping cart checkout phase. Simply Google for 'discount vouchers' – perhaps include your favourite retail's name – and links to many specialist sites will be revealed. Popular sites include www.vouchercodes.com and <http://www.vouchercodes.co.uk>. Shop till your line drops!

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Details building and programming instructions provided, including numerous step-by-step photographs.

288 pages – large format Order code BP901 £14.99

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision Command System

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using Lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'water service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

288 pages Order code BP902 £14.99

ANDROIDS, ROBOTS AND ANIMATRONS – Second Edition – John Iovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots, Robotic Locomotion, Motors and Power Controllers, All Types of Sensors, Tilt, Bump, Road and Wall Detection, Light, Speech and Sound Recognition, Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC, Robotic Intelligence (Neural Type) Using Simple Neural Networks (Insect Intelligence), Making a Lifelike Android Hand, A Computer-Controlled Robotic Insect Programmed in BASIC, Telepresence Robots With Actual Arcade and Virtual Reality Applications, A Computer-Controlled Robotic Arm, Animated Robots and Androids, Real-World Robotic Applications.

224 pages Order code MGH1 £16.99

DIRECT BOOK SERVICE

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The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order to your door. Full ordering details are given on the last book

For a further selection of books see the next two issues of *EPE*.

Radio

BASIC RADIO PRINCIPLES AND TECHNOLOGY

Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation, Receivers, Transmitters, Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages Order code NE30 £20.00

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.

R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets;

A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and SSB audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/CW tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages Order code BP304 £4.45

AN INTRODUCTION TO AMATEUR RADIO

I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages Order code BP257 £5.49

Computers and Computing

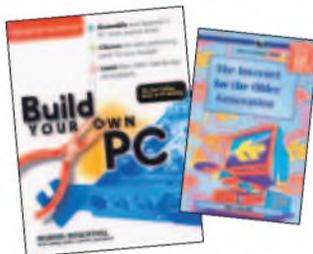
THE INTERNET FOR THE OLDER GENERATION

Jim Gatenby

Especially written for the over 50s. Uses only clear and easy-to-understand language. Larger type size for easy reading. Provides basic knowledge to give you confidence to join the local computer class.

This book explains how to use your PC on the Internet and covers amongst other things: Choosing and setting up your computer for the Internet. Getting connected to the Internet. Sending and receiving emails, photographs, etc., so that you can keep in touch with family and friends all over the world. Searching for and saving information on any subject. On-line shopping and home banking. Setting up your own simple web site.

228 pages Order code BP600 £8.99



BUILD YOUR OWN PC –

Fourth Edition

Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a state-of-the-art computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering what first-time builders need to know. How to select and purchase parts. How to assemble the PC. How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are eagerly looking for.

224 pages – large format Order code MGH2 £16.99

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION

John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages Order code NE36 £18.50

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C

– Learning to Fly the PIC24 Lucio Di Jasio

(Application Segments Manager, Microchip, USA) A Microchip insider tells all on the newest, most powerful PICs ever! Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compiler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

Until recently, PICs didn't have the speed and memory necessary for use in designs such as video- and audio-enabled devices. All that has changed with the introduction of the first-ever 16-bit PIC family, the PIC24. This new guide teaches readers everything they need to know about the architecture of these new chips, how to program them, how to test them and how to debug them. Lucio's common-sense, practical, hands-on approach starts out with basic functions and guides the reader step-by-step through even the most sophisticated programming scenarios.

Experienced PIC users and newcomers alike will benefit from the text's many thorough examples, which demonstrate how to nimbly side-step common obstacles and take full advantage of all the new features.

496 pages + CD-ROM Order code NE45 £32.50

FREE CD-ROM

Theory and Reference

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS

Third Edition
Mike Tooley

A comprehensive reference text and practical electronics handbook in one volume – at an affordable price! New chapter on PIC microcontrollers – the most popular chip family for use in project work by hobbyists and in colleges and universities.

New companion website: spreadsheet design tools to simplify circuit calculations, circuit models and templates to enable virtual simulation, a bank of on-line questions for lecturers to set as assignments, and on-line self-test multiple choice questions for each chapter with automatic marking, to enable students to continually monitor their progress and understanding.

The book's content is matched to the latest pre-degree level courses, making this an invaluable reference for all study levels, and its broad coverage is combined with practical case studies, based in real-world engineering contexts throughout the text.

The unique combination of a comprehensive reference text, incorporating a primary focus on practical applications, ensures this text will prove a vital guide for students and also for industry-based engineers, who are either new to the field of electronics, or who wish to refresh their knowledge.

400 pages

Order code NE43

£24.95

BEBOP TO THE BOOLEAN BOOGIE

Second Edition
Clive (Max) Maxfield

BOOK PLUS
CD-ROM

This book gives the "big picture" of digital electronics. This in-depth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. Comes with a free CD-ROM which contains an eBook version with full text search plus bonus chapter – An Illustrated History of Electronics and Computing.

Contents: Fundamental concepts, Analog versus digital, Conductors and insulators, Voltage, current, resistance, capacitance and inductance, Semiconductors, Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps, State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs, Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

500 pages

Order code BEB1

£27.50

BEBOP BYTES BACK (and the Bebop Computer Simulator) CD-ROM

Clive (Max) Maxfield and Alvin Brown

CD-ROM

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop 1" left off, guiding you through the fascinating world of computer design... and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200



megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM

Order code BEB2 CD-ROM

£21.95



GETTING THE MOST FROM YOUR MULTIMETER

R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages

Order code BP289

£5.49

STARTING ELECTRONICS, THIRD EDITION

KEITH BRINDLEY

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but

not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equipped lab.

288 pages

Order code NE42

£11.50

THE AMATEUR SCIENTIST CD-ROM – VERSION 2

CD-ROM

The complete collection of The Amateur Scientist articles from *Scientific American* magazine. Over 1,000 classic science projects from a renowned source of winning projects. All projects are rated for cost, difficulty and possible hazards. Plus over 1,000 pages of helpful science techniques that never appeared in *Scientific American*.

Exciting science projects in: Astronomy, Earth Science, Biology, Physics, Chemistry, Weather... and much more!

The most complete resource ever assembled for hobbyists, and professionals looking for novel solutions to research problems. Includes extensive Science Software Library with even more science tools. Suitable for Mac, Windows, Linux or UNIX. 32MB RAM minimum, Netscape 4.0 or higher or Internet Explorer 4.0 or higher. Over 1,000 projects.

CD-ROM

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eBAY FOR BEGINNERS

Cherry Nixon

There are two kinds of people, those who are trading on eBay and the rest who are missing out. Though eBay has been embraced by entrepreneurs all over the world, it remains the peoples' site and offers the largest market for the smallest fee.

eBay presents an opportunity for everyone, the trick is to master it. This book shows you how to start trading on eBay UK. It also offers advice on getting organised and to put you ahead.

The book has been developed from Cherry's popular hands-on course "Buying and Selling on eBay for Technological Simpletons". In addition to fully explaining eBay and how to trade on it there are sections on PayPal, producing pictures of your sale items, fees and accounts, safety and security, including what to do when things go wrong and what protection is provided.

178 pages

Order code BP551

£8.99



Music, Audio and Video

MAKING MUSIC WITH YOUR COMPUTER

Stephen Bennett

Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.

You'll learn about recording techniques, software and effects, mixing, mastering and CD production.

Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages

Order code PC120

£10.95



QUICK GUIDE TO MP3 AND DIGITAL MUSIC

Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music? All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer, How to use MP3s with handheld MP3 players, Where to find MP3s on the Web, How MP3s work, How to tune into Internet radio stations, How to create your own MP3s, How to record your own CDs from MP3 files, Other digital audio music formats.

Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

60 pages

Order code PC119

£7.45

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an

audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, push-button fader, computer control interface, 12 volt mains power supply.

124 pages

Order code PC115

£10.95 £5.45

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Data and Design

PRACTICAL ELECTRONIC FILTERS

Owen Bishop

This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.

The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rhythm sequencer and a multi-voiced electronic organ.

Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.

88 pages **Order code BP299** £5.49

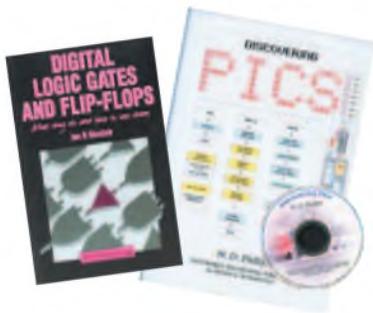
DIGITAL LOGIC GATES AND FLIP-FLOPS

Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters. No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

200 pages **Order code PC106** £9.95



A BEGINNER'S GUIDE TO TTL DIGITAL ICs

R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** £5.45

MICROCONTROLLER COOKBOOK

Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of micro-controllers.

240 pages **Order code NE26** £23.50

RADIO BYGONES

We also carry a selection of books aimed at readers of *EPE's* sister magazine on vintage radio *Radio Bygones*. These books include Jonathan Hill's excellent *Radio Radio*, a comprehensive book with hundreds of photos depicting the development of the British wireless set up to the late 1960s.

The four volumes of our own *Wireless For the Warrior* by Louis Meulstee are also available. These are a technical history of radio communication equipment in the British Army and clandestine equipment from pre-war through to the 1960s.

For details see the shop on our UK web site at www.epemag.co.uk or contact us for a list of *Radio Bygones* books.

Project Building & Testing

ELECTRONIC PROJECT BUILDING FOR BEGINNERS

R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts, resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering, making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping, finishing off, and adding panel labels, getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** £5.49

ELECTRONIC PROJECTS FOR EXPERIMENTERS

R. A. Penfold

Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.

The subjects covered include - Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages **Order code BP371** £5.45

PRACTICAL FIBRE-OPTIC PROJECTS

R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics

enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include - Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** £5.45

DISCOVERING PICS

W.D. Phillips

A good introduction to PIC programming, covering everything you need to know to get you started. No previous knowledge of microcontrollers is required, but some previous experience with electronic circuits is assumed. Covers the basic concept of a microcontroller, fundamentals of a PIC-based circuit and using the MPLAB program. Further chapters introduce binary, PIC architecture, the instruction set, the PIC memory map and special registers plus real world programming. Four simple projects are also fully described: a Wavy Wand, an Electronic Dice, a Games Timer and a Pulse Monitor.

The associated CDROM contains the book in PDF format, MPLAB (plus instruction manuals in PDF format) and all the programs covered in the book as assembler (ASM) files. Those that wish to programme their own PICs will require a PIC programmer.

In addition a p.c.b. based hardware kit is also available that makes up into the Wavy Wand which will spell out a short message via a line of LEDs when waved through the air.

190 pages, A4 spiral bound

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Book + CDROM + Hardware Order code DOC2 £28.50

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PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are NOT plated through hole and will require 'vias' and some components soldering both sides. All prices include VAT and postage and packing. Add £1 per board for *airmail* outside of Europe. Remittances should be sent to The PCB Service, *Everyday Practical Electronics*, Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. Tel: 01202 873872; Fax 01202 874562; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.wimborne.co.uk/shopdoor.htm. Cheques should be crossed and made payable to *Everyday Practical Electronics* (Payment in £ sterling only). NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the *Back Issues* page for details. We do not supply kits or components for our projects.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website. Boards can only be supplied on a payment with order basis.

PROJECT TITLE	Order Code	Cost
Poor Man's Metal Locator	JUN '06	570 £5.71
★ Digital Instrument Display for Cars		
– Micro Board	571	} pair £7.77
– Display Board	572	
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★ Sudoku Unit	JUL '06	575 £6.66
PC Power Monitor	576	£6.50
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Adjustable DC-DC Converter For Cars	578	£6.50
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Quick Brake	NOV '06	590 £6.50
Studio 350 Power Amplifier	591	£9.51
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★ Mind Trainer	598	£6.50
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★ Deep Cycle Battery Charger		
Power Board	604	} set £11.10
Control Board	605	
Display Board	606	
★ PIC Digital Geiger Counter (double sided)	607	£12.53
IR Remote Checker	MAR '07	608 £6.35
★ SMS Controller	609	£7.93
★ Lap Counter For Swimming Pools	610	£7.14
★ PIC Polyphonium – Main Board	611	£8.25
PIC Polyphonium – LED Display Interface	APR '07	612 £7.13
Students' Amp – Amplifier	613	£6.02
– PSU	614	£6.02
Star Power	615	£6.50
Bass Extender	MAY '07	618 £5.87
Caravan Lights Check	619	£6.18
★ Energy Meter – Main Board	JUN '07	616 } pair £9.83
– Display Board	617	
3V to 9V Converter (PCB plus TL499A IC)	620 + chip	£7.53
Bat Sonar	621	£6.03
MiniCal 5V Meter Calibration Standard	JUL '07	622 £6.82
Lead-Acid Battery Zapper	623	£6.50
Video Reading Aid	624	£6.50
Digi-Flash Slave	625	£5.55

PROJECT TITLE	Order Code	Cost
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Printer Port Hardware Simulator	627	£6.66
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APRIL '08 ISSUE ON SALE MARCH 13

ADVERTISERS INDEX

AUDON ELECTRONICS	41
BETA-LAYOUT	41
BRUNNING SOFTWARE	21
BULL GROUP	Cover (ii)
COMPACT CONTROL DESIGN	61
DISPLAY ELECTRONICS	80
ESR ELECTRONIC COMPONENTS6, Cover (iii)
JAYCAR ELECTRONICS	4/5
JPG ELECTRONICS	80
LABCENTER	Cover (iv)
LASER BUSINESS SYSTEMS	59
MAGENTA ELECTRONICS	41
MICROCHIP	69
NURVE NETWORKS LLC	27
PEAK ELECTRONIC DESIGN	40
PICO TECHNOLOGY	11
QUASAR ELECTRONICS	2/3
SHERWOOD ELECTRONICS	41
STEWART OF READING	61
SUMMIT ELECTRONICS	27

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