

THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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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



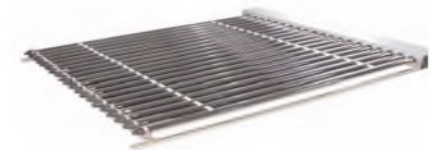
2kW WIND TURBINE KIT

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
www.slips.co.uk

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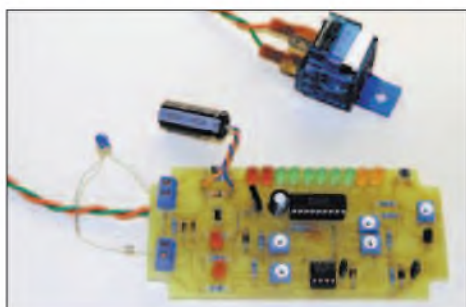
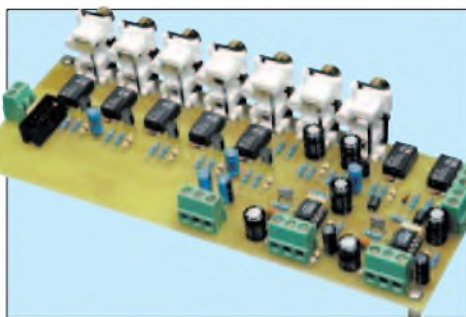
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EPE EVERYDAY PRACTICAL ELECTRONICS

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Our March 2008 issue will be published on Thursday,
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PIC & ATMEL Programmers

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

Programmer Accessories:

40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU010) £18.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.

Kit Order Code: 3149KT - **£39.95**

Assembled Order Code: AS3149 - **£49.95**

NEW! USB 'All-Flash' PIC Programmer

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

Assembled Order Code: AS3128 - **£44.95**

Assembled with ZIF socket Order Code: AS3128ZIF - **£59.95**

'PICALL' ISP PIC Programmer

Will program virtually all 8 to 40 pin *serial-mode* AND *parallel-mode* (PIC15C family) PIC microcontrollers. Free Windows software. Blank chip auto detect for super fast bulk programming. Optional ZIF socket. Assembled Order Code: AS3117 - **£24.95**
 Assembled with ZIF socket Order Code: AS3117ZIF - **£39.95**

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.

Kit Order Code: 3123KT - **£24.95**

Assembled Order Code: AS3123 - **£34.95**

Introduction to PIC Programming

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

Kit Order Code: 3081KT - **£16.95**

Assembled Order Code: AS3081 - **£24.95**

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 DS18B20 sensor. Kit Order Code: 3145KT - **£17.95**
 Assembled Order Code: AS3145 - **£24.95**
 Additional DS18B20 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**



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

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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500-in-1 Electronic Project Lab

Top of the range. Complete self-contained electronics course. Takes you from beginner to 'A' Level standard and beyond! Contains all the hardware and manuals to assemble 500 projects. You get 3 comprehensive course books (total 368 pages) - *Hardware Entry Course*, *Hardware Advanced Course* and a microprocessor based *Software Programming Course*. Each book has individual circuit explanations, schematic and connection diagrams. Suitable for age 12+.

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**

Now on sale at just £21.95!

See website for more super deals!



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Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

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 tinted PCBs and have clear English instructions. Watch this space for future featured kits.

Tempmaster Kit

KC-5413 £11.75 + post & packing

This project turns a regular fridge or freezer into a wine cooler by accurately controlling the temperature between 2.5 - 33° making it suitable for wine storage. Kit supplied with PCB, panel mount Aussie mains socket, mains lead, machined case with screen printed lid and all electronic components.

Requires UK mains socket or PP-4019 adaptor @ £2.25



45 Second Voice Recorder Module

KC-5454 £11.75 + post & packing

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

Supplied with silk screened and solder masked PCB and all electronic components.



Screecher Car Alarm MKII

KA-1813 £9.95 + post & packing

The Screecher MK II is very effective and produces an ear-piercing scream that will scare the pants off any would be thief. This project is easy to construct and features entry delay with a soft warning tone, exit delay and high intensity deterrent LED. Kit includes PCB, siren, all electronic components and two adhesive warning stickers.



Automotive Headlight Reminder Kit

KC-5317 £7.75 + post & packing

Nothing is more frustrating than getting into your car to discover that you had left your headlights on and the car's battery is flat. This kit will warn you if the lights are still on when the ignition has been switched off. Features optional door switch detection, time-out alarm and a short delay before the alarm sounds. Supplied with PCB and electronic components.



PC Link for Automatic Control

KV-3590 £18.95 + post & packing

Automate your house, switch on garden lighting, turn on sprinklers or even control your household heating with this terrific kit. Each SPDT relay can handle 10 amps and has an LED to show whether it is on or off. Software is provided on a 3.5 disk. Kit includes PCB, relays, software, and all electronic components. 8 - 12V DC power required.



Digital Multimeter Kit

KG-9250 £6.00 + post & packing

Learn everything there is to know about component recognition and basic electronics with this comprehensive kit.

From test leads to solder, everything you need for the construction of this meter is included. All you'll need is a soldering iron!
• Meter dimensions: 67(W) x 123(H) x 25(D)mm



Engine Immobiliser MK II

KC-5255 £9.75 + post & packing

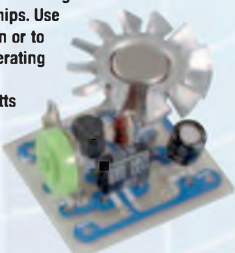
This immobiliser repeatedly stalls the engine when a thief tries to start your car. The circuit allows the engine to start, but will stall after about two seconds, giving the thief the impression that there is an intermittent problem. Kit supplied with PCB, plastic enclosure and all specified electronic components..



Fog Horn

KG-9092 £3.85 + post & packing

This kit generates a deep sounding noise similar to fog horns on ships. Use as a unique warning siren or to improve a child's toy. Operating voltage is 4.5 - 12V DC. Output power up to 5 watts depending on the input voltage used. Requires an 8ohm speaker.



SHORT CIRCUITS

Short Circuits is a learning system that was developed by Jaycar to introduce young readers to the exciting world of electronics. The system is implemented across a series of three books and takes the reader from novice to experienced constructor. Volume one even includes the parts required to construct all the projects described in the book.

Short Circuits Book I Including Parts

BJ-8502 £11.95 + post & packing

This full colour 96 page book has over 100 drawings and diagrams. The projects are fun to build and relevant to the electronics scene in the new millennium. Included with the book, you get the baseboard, plenty of spring terminals and ALL the components required to build every project in the book, INCLUDING the bonus projects. Book measures 205mm x 275mm



Short Circuits Book - Volume II

BJ-8504 £4.00 + post & packing

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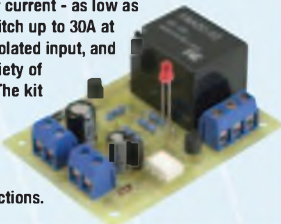
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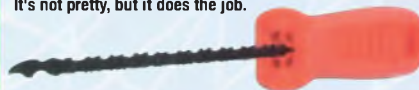
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0-1A	60mΩ	
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The pace of technology

Last month's *News* item on Nokia phones shows just how far technology has come from humble beginnings at the start of the last century. A phone that takes a photo when a text message is sent to it, then uploads the photo to a website; or a phone that uses optical character recognition to translate images it takes of text; or even one that sends you to relevant websites when it takes a photo of a product; or gives you a plan of a shopping mall; or works as a credit card. Some of these will be available very soon.

Back in the early 40s, when war was raging, the push for developments in electronics was massive and the first ever electronic programmable computer was born to quickly crack the encrypted codes the Germans were using. Although the world-at-large knew nothing of *Colossus* until at least 30 years later, it was instrumental in shortening the war and was right at the cutting edge of technology at the time – even though the valves used were not considered by most engineers of the time to be very reliable.

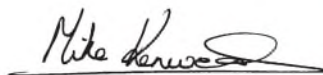
Colossus was so fast that it is only very recently that modern computers have been able to beat it in translating the encrypted code – our feature on *Colossus And Pico* this month shows how a Pico PC-based scope is being used with *Colossus* to demonstrate the operation of the codebreaker to the visiting public; a modern PC to show how the first computer worked.

I guess none of the highly inventive engineers who designed *Colossus* would ever have dreamed how far the digital technology employed would develop and allow such products as Nokia's phones just 60 odd years later.

New Editor

After exactly 30 years as Editor, and nearly 40 years working for the magazine, I am moving towards retirement and passing the editorial baton into the safe hands of Matt Pulzer. Matt has worked for the company on a freelance basis for many years, originally as Editor of *The Modern Electronics Manual*, more recently he has been responsible for many of the technical diagrams in *EPE* and for proof-reading all the pages.

While I will continue working as Publisher (on a part-time basis), Matt will be responsible for the editorial content of *EPE*. My thanks to all the contributors, advertisers and readers who have supported *EPE* over the years – long may it continue.



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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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New Musical Instrument

Barry Fox reports on novel music creation with lights

YAMAHA is test launching a completely new kind of electronic musical instrument in the UK, 'because the DJ dance music club scene is so popular in Britain'.

The Tenori-on was designed by Toshio Iwai, who describes himself as a 'media artist' and is built by Yamaha in Japan. A 20cm flat square tablet has a matrix of 16 × 16 pushbuttons on the surface, each with its own white LED. The vertical buttons represent a music pitch scale, and the horizontal buttons represent timing between notes. Pushing buttons creates a rhythmic pattern of up to 16 musical notes, which the keyboard memorises as a loop and plays *ad infinitum*.

A musician will know which buttons to press to compose a tune; non musicians can press buttons at random to build rhythmic patterns based on notes

pre-programmed by Yamaha's musical engineers. So the effect still sounds quite musical.

Up to 16 different loops can be stored and played at the same time to 'paint' a multilayer picture of repetitive, pulsating sound. Master control buttons shift the overall pitch of any loop in octaves and transpose the music to another key.

The overall effect is similar to the electronic soundtrack for an alien-invader computer game. The constant loop repetition makes the sound strangely mesmerising.

The buttons flash in time with the music to create a visual display which also appears on a matching set of LEDs on the underside of the keypad. So the instrument creates its own light show. Everything played can be stored in memory for replay later.

At the London launch, designer Iwai admitted 'I am not a musician'. His first computer experience was with the ill-fated MSX system, which was launched as Japan's attempt at challenging the first home computers from the USA, and quickly flopped. Iwai then progressed to playing mechanical music box recordings backwards and discovering that Happy Birthday played in reverse sounds 'unhappy'. He then moved on to using Nintendo games to create music and visual effects.

Yamaha is initially shipping just 50 hand-built samples of Tenori-on to ten record stores in the UK, for sale at £600 each. Yamaha expects DJs to buy them for use at clubs. Some may be sold to children with well-heeled parents who are brave enough to risk being driven to distraction by the sound of bedroom experimentation.

EMAIL ALERTS

Lascar have announced they can now offer environmental email alerts in realtime through their EL-USB-RT module. This is a USB-enabled temperature and humidity sensor designed to send email alerts of temperature or humidity readings that exceed acceptable conditions.

The device is connected to a PC via its USB port and is supplied with dedicated software that provides a realtime indication of ambient temperatures between -10°C and +60°C, and a humidity between 0 and 100% RH. These, together with a calculated dew point, can be viewed as either a constantly updated graph, or a numerical indication of the last reading taken.

Users can assign high and low alarms for both temperature and humidity, and the software can be configured to send email alerts as these levels are exceeded.

The EL-USB-RT costs £29.50 at one-off. For more information, browse www.lascar-electronics.com or call the sales team on +44 (0)1794 884567.



Barbed DVR Monitoring

When digital video recorders and personal video recorders like TiVo first went on sale, pundits warned that they would kill off advertising revenue. With a hard disc recording, viewers can all too easily skip or fast forward through recorded commercial breaks. So companies will no longer pay high prices to advertise at peak times.

NDS, the company which sells the Electronic Programme Guide and DVR control software used by DirecTV in

the US and Sky in the UK, claims that new audience measuring techniques show this is not the case. The electronics used by BARB, the Broadcasters Audience Research Board, was initially fooled when viewers watched a recorded programme. The measuring system just registered that the viewer had accessed the EPG menu as a first step towards selecting and viewing a recording. So BARB was logging an hour of EPG viewing instead of an hour of watching a recorded programme.

Now, according to David Whittaker of NDS, in a speech given to the

2007 European TV Symposium in Barcelona in early November, BARB can track the programmes recorded and viewed. Based on these figures Whittaker concludes that 12.2% of what viewers watch is now time shifted, which gives an extra 20 minutes of viewing per day, with 'overall viewing of commercials' increased by 1% or 2%.

BARB's monitoring can also distinguish between fast forward advert skipping and normal speed viewing, he assures.

Barry Fox

Tales of Putrefaction

With global attention still focussed on the energy crisis, we return to the theme of alternative energy sources. This time, the emphasis is on some creative means of electricity generation from natural waste products. Join Mark Nelson for a pretty wee-volting journey of discovery.

'Money for nothing and your chicks for free' is one of my favourite song lyrics and let's face it, anything you can purloin for nothing has to be a good deal. So what's free and can it make electricity? Try compost, sewage, waste food and chicken droppings for starters.

Taking the ****?

If you think I'm taking the micky, just do a Google search for the word NoPoPo. NoPoPo stands for no-pollution power and the NoPoPo Aqua battery is a reusable AAA or AA-size cell that is activated with beer, apple juice or human urine. You use a pipette to fill it and it gives you 500mAH of power (on a par with standard supermarket or corner shop dry cells). Any drawbacks?

Yes – they can be recharged only a limited number of times and right now they are available only in Japan. On the other hand, they are claimed to be less harmful for the environment than existing batteries as they contain no noxious mercury or cadmium to pollute water supplies after disposal.

Oh yes, is 'taking the micky' a jibe at the Irish? Not at all; it's just a more polite way of discussing micturation (which I'll leave you to check out in the dictionary).

Fowl power

If you're looking for greater power output, then speak to the University of Manchester, whose researchers are aiming to produce 200 kilowatts of electricity from chicken droppings. They reckon the average chicken farm will generate more power than it can use itself by disposing of chicken litter in a gasifier that converts biomass into combustible gas that is fed into a gas turbine. The Carbon Trust and gasification technology company Keld Energy are supporting this research, which promises anticipated power efficiency a third higher than existing techniques at 30 per cent.

Other waste-to-watts projects are based on anaerobic digesters, which make biogas by breaking down (composting) food waste, sewage, cardboard and other substances in an oxygen-free environment. The gas produced is used to generate electricity and small self-contained plants are fully economic.

In Denmark, farm cooperatives supply electricity made in this way to surrounding villages, while in New Zealand use of the technique goes back to the 1970s. In Ireland, Celtic Composting Systems Ltd is one of the leaders in its field, but several others are jumping on this bandwagon

on now. And with large retailers like Marks & Spencer exploring this technology as part of its commitment to halve food waste and use 50 per cent renewable energy by 2012, there's no doubt that electricity from biomass will soon be mainstream. If our annual 5.5 million tonnes of food waste went to anaerobic digesters, the energy produced could provide enough electricity to power 164,000 homes, according to Friends Of The Earth.

Eco-friendly

Of course, electronics hobbyists knew all about recycling long before the Green movement took off. As a student back in the 1960s, my chums and I couldn't afford the cost of new components for our ambitious projects so we frequented surplus shops for electronic junk that we could recycle. Maybe you too remember wielding a huge soldering iron to remove ICs from old computer boards, sometimes also transistors and electrolytics as well, if they had leads long enough for re-use.

Many towns had districts with 'treasure trove' shops like this; London had Lisle Street and the Edgware Road, Birmingham had Hurst Street and Manchester had Shude Hill and the London Road. There were also outdoor scrapyards in Chelmsford, Cheslyn Hay, Haywards Heath and Milton (south of Banbury) where you could wrestle with seriously 'heavy metal' assemblies.

Normally you paid for this plunder by the lump, but a shop in Reading had a more inventive policy. The establishment went by the name of Chiltmead and was located in a backstreet off the London Road near a technical college as I recall. The way they priced electronic junk was by weight, on the basis that the heavier something was, the more 'technical' it must be.

You clambered up stairs and sorted through all manner of assemblies housed in diecast boxes, rack shelves and cases, then hoiked them downstairs for weighing and payment. All around were notices threatening dire consequences to anyone smuggling in screwdrivers or any other tools, as there was an obvious temptation to break up the gear into subassemblies and leave behind the empty casings.

Surplus shops like Chiltmead are now but a memory (unless you know otherwise) but stripping old components is coming back into fashion, at least in Japan. Hokuto System, reports trade newspaper *Mobile News*, is extracting the colour displays, processors and memory

chips from discarded cellphones to build into retail point-of-sale units. The company assembles these parts onto a new PCB of its own design and makes more creative use of the phones than the more basic methods of recycling.

Tunnelling

Let's change the subject once more. When I first drew circuit diagrams, the norm was to draw semi-circular bridges (or tunnels, if you think about it) where one wire crossed another without touching. These are frowned on now and they've always been taboo when laying out tracks on a PCB. With two exceptions, that is.

Back in 1980, the American hobby magazine *Creative Computing* had a hilarious spoof April Fools issue in which loops and tunnels were most definitely allowed and employed in their construction projects. And now there's a 'microwire' PCB process that enables not only wires but also semiconductors to be buried below the surface of the board.

Hiding dies

This is not simply the same thing as multi-layer boards because you need only one layer, explains Andreas Ostmann of the Technical University of Berlin. He is one of the players in HID-ING DIES, a clever acronym that stands for **H**igh **D**ensity **I**ntegration of **D**ies into **E**lectronics **S**ubstrates, a research project funded by the European Commission.

On the EC's Cordis website he states: "Packaged chips, the things that look like black plastic beetles on a circuit board, are an obstacle to further miniaturisation of devices such as mobile phones and PDAs. Because the chips can be placed side by side inside the polymer of the board, the interconnects are much shorter and their radio frequency properties are greatly enhanced."

The microchips are around 50 microns thick, roughly the same width as a human hair, while the smallest module produced with the Hiding Dies technology is around 100 microns. That compares with the minimum of 500 microns for current chip packages. Their small size allows them to be stacked to pack more performance into devices without taking up more space, a form of 3D integration that is virtually impossible with packaged chips, while their close proximity to each other does away with long interconnects. Austrian PCB maker AT&S intends to offer PCBs with buried ICs in the next two years, and it's an even bet that other firms will follow.

ELECTROSMOG SNIFFER

By Thomas Scarborough

Cellphones – Computers – Microwave Ovens – Fluorescent Lighting – Electrical Power Lines all can produce an 'Electro-smog' or Electromagnetic Field (EMF)



This easy-build project will give a meaningful reading of most EMFs you are likely to be exposed to in the home or workplace

'ELECTROSMOG' has received a great deal of attention in the press. This is more seriously known as EMF, or electromagnetic field(s) – *not* to be confused with electromotive force. It has a great many sources, including computers, cellphones, microwave ovens, fluorescent lighting, electrical power lines, and industrial plants. It may also cover a wide frequency range, from ELF (extremely low frequency) all the way up to microwaves (thousands of MHz) and even higher.

The Electrosmog Sniffer described here will detect EMF from a few Hertz up to about 7MHz, and has the potential to do so up to about 50MHz (see below). This means that while it is not as capable as some commercial units, it will be far more useful than a simple electrician's milligauss meter.

The debate

With regard to the risks of exposure to EMFs, the author turned up some balmy findings in the published research: 'cardiac arrhythmias in frogs ... disturbed carbohydrate metabolism in rabbits ... altered genetic structure in *E.coli* ... premature ageing of pine needles ... increase in melatonin in cows ...' and so on. If anything, such results are enough to make one sit up and pay attention.

The effects of EMF on human health, however, are much disputed. While a large number of studies have shown that small amounts of 'electrosmog' may increase the risks to one's health, a good many studies have turned up no evidence at all. It depends, of course, what a given study was looking for, and how it was carried out – it is a puzzling situation nonetheless.

Experts' statements seem equally confusing. One claims: "It seems clear that EMF causes many kinds of adverse health conditions," while another claims: "The current body of scientific evidence does not show that exposure to EMF presents a human health hazard."

Conjecture

The author will take a few guesses as to how such a situation might have come about:

1. The observed risk factors or 'odds ratios' (OR) are usually fairly small. An OR of one indicates that there is no evidence that there is a health risk, while an OR of less than three is generally considered 'weak'. Most epidemiological studies relating to the risks of EMFs have turned up an OR of less than three. While some are convinced that this is a 'non-chance' situation, others would consider it to be altogether doubtful.

2. A great deal depends, of course, on what one considers to be a risk to human health. Studies frequently focus on 'epidemiological' data – that is, clearly quantifiable health risks, such as brain tumours, leukaemia, or miscarriage. Others, however, would rather speak in terms of the extent to which 'optimum wellness' might be compromised – which sets the bar far higher. Yet this is a way of doing science which tends to be far more vague and debatable.

3. Finally, while it would seem too easy to speak of vested interests, there seems little doubt that opinions on the potential hazards of EMF have fallen to either side of such interests. Here is a real example (source: www.mercola.com):

"In a draft report issued in March 1990, the EPA [the U.S. Environmental Protection Agency] recommended that EMFs be classified as a Class B carcinogen – a probable human carcinogen ...

"After the EPA draft report was released, utility, military and computer lobbyists came down hard on the EPA. The EPA's final revision did NOT classify EMFs as a Class B carcinogen."

The reason the EPA gave for this retreat was that: "at this time ... the basic nature of the interaction between EMFs and biological processes leading to cancer is not understood". That is, without understanding the biological mechanism, it could not safely make such a claim. This would not seem to be too comforting a 'retraction'.

When all has been said, what is not in any doubt is that several governments have decided to set the 'safe' limit of exposure at 1 or 2 milligauss (mG) – which represents a fairly small amount. In fact, one is quite likely to be exposed to much more than this during the course of a normal day. Here are some typical EMFs that one might encounter at about 30cm (1 foot) from a device. Note, however, that *actual* EMFs may vary a great deal from these figures:

Microwave oven 120mG

Fluorescent light 30mG

Ceiling fan 25mG

Colour TV 10mG

Computer CRT10mG

Fridge7mG

Of course, at typical 'working distances', these figures are usually much less. At twice the distance, the mG reading would typically be about 4.5 times less. Thus the microwave oven, at 60cm (2 feet) would likely register about 27mG.

Concept

The first and most obvious design problem that the author needed to consider was the extreme range of intensity of EMFs. The Electromog Sniffer should be able to detect the statutory 1 or 2mG – yet hundreds of mG may not be too unusual in places in the home or office. This seemed a range far too wide to be easily accommodated in one device. The author therefore decided on a readout of 0 to 10mG, with overload protection for higher readings. This range can, however, be multiplied or divided roughly by ten (see below).

Another obvious design decision concerned the *frequencies* which the Sniffer would be able to detect. It was clear that the unit would first need to detect, then amplify the EMFs 'out there'. However, most preamplifier ICs will not run faster than a few MHz. Further, with Third World readers in mind, the author did not

Parts List – Electromog Sniffer



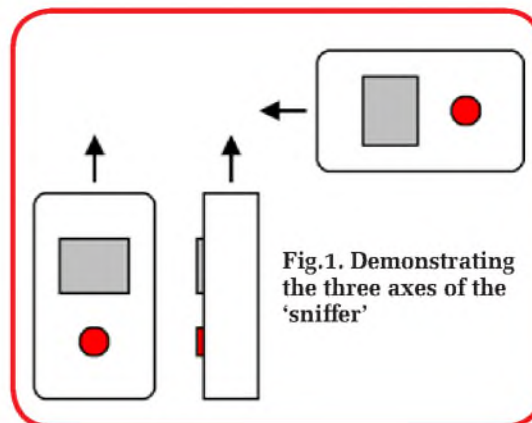
1 PC board, code 660, available from the <i>EPE PCB Service</i>, size 92mm x 31mm 1 1mA moving coil meter (ME1 – see text) 1 14-pin DIL socket 1 8-pin DIL socket 1 6mm x 25mm bolt with nut 2 32mm diameter washers to fit 6mm bolt 100 metres of 0.315mm (30swg/22awg) enamelled copper wire (for L1) 1 SPST push-to-make push-button switch (S1) 1 9V or 12V battery pack 1 battery clip - Suitable case (see text); cable ties; 6 solder pins; connecting wire; solder etc	Semiconductors 4 1N4148 signal diodes (D1-D4) 1 4069UB CMOS hex inverter (IC1) 1 LM741CN op amp (IC2) 1 LM7805 positive voltage regulator (IC3) Capacitors 1 10nF polyester or ceramic (C1) 1 1nF polyester or ceramic (C2) 1 100µF 16V radial elect. (C3) Resistors (0.25W 5% carbon film) 1 220kΩ (R1) 1 10MΩ (R2) 1 470Ω (R3) Potentiometers 1 50kΩ multiturn preset (VR1) 1 1kΩ multiturn preset (VR2)
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want to choose obscure components. A CMOS unbuffered inverter seemed a good solution, offering up to 7MHz in practice – or even as high as 50MHz (see below).

At first, the author chose the secondary winding of a 230V to 6V step-down transformer for the sensor. This worked well, but it was clear that it would not serve the best interests of a 'repeatable' design. Various transformers gave markedly different results. The author therefore decided on a simple custom-wound pick-up coil – called a 'single axis coil'. More expensive milligauss meters will employ a triple axis coil, which measures the combined field strength along three axes – however, if the Electromog Sniffer is turned through all three axes (see Fig. 1), the *highest* reading will give a good indication of EMF strength.

Big question

The last big question was what to use for the readout. A moving coil meter seemed to be the simplest and most 'user-friendly' option – thus the Sniffer was designed specifically for use with a 1mA meter. However, such meters can be pricey, so details are given as to how a VU meter may be pressed into service, or a multimeter, or even a humble LED.



ELECTROSMOG SNIFFER

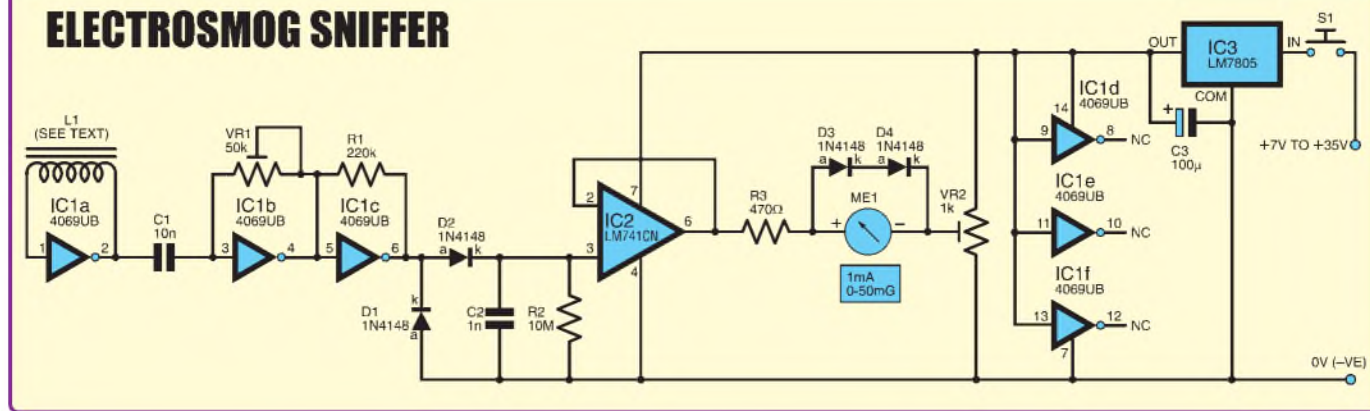


Fig.2. Complete circuit diagram for the Electromog Sniffer

One option was not entertained. Some milligauss meters employ 'frequency weighting', which might be described as 'a kind of RIAA', whereby different frequencies are weighted differently according to the biological effects they might have. This was not considered, for the reason that it would have considerably complicated the circuit and its development.

While the overall result is not a 'precision' device, and does not reach into the higher frequencies, it should nonetheless give a meaningful impression of most of the EMFs to which we are exposed to in the home or workplace – at a far lower price than is typical in the marketplace.

Circuit details

The gauss (a milligauss is one-thousandth of a gauss) is a unit of measurement of magnetic field strength. A milligauss meter (which is what the Electromog Sniffer is) measures the strength of magnetic fields. Inside a milligauss meter there is a coil of thin wire, typically with hundreds of turns (L1 in this design – see Fig. 2). As a *changing* magnetic field radiates through the coil, it induces a current, which is amplified by the circuitry inside the milligauss meter.

Sniffer coil

To ensure that all constructors would be 'on the same page', a custom-wound coil was decided on for this project. Coil L1 is 1,200 turns of 0.315mm diameter (30swg/22awg) enamelled copper wire on a 6mm diameter, 25mm long, bolt. Two 32mm diameter washers serve as the 'end-stops'. A nut is turned onto the end of the bolt (see photo), and the washers and the nut

are set with some dabs of glue. Coil L1 leaves a lot of room for error, so that a hundred missed turns, or a 10% different wire gauge will not impair the circuit. If one is feeling lucky, one might not even count the turns – just fill the coil as shown in the photo.

Coil L1 feeds the output of inverter IC1a back to its input, thereby stabilising the output to about half of the supply voltage. However, any EMFs detected by the coil will 'send ripples' through the IC1a circuit. These are amplified about 50 times at its output. These 'ripples' are then sent via DC-blocking capacitor C1 to IC1b.

IC1b essentially serves as a gain control, with VR1 to a greater or lesser extent 'short circuiting' any ripples that pass through it. Preset VR1 also serves to stabilise the output at about half the supply voltage.

IC1c and resistor R1, on the other hand, serve mainly to provide a linear output to meter ME1, with R1 providing suitable negative feedback. If R1 is omitted, meter ME1 tends to swing wildly as coil L1 approaches a source of EMF (although this would greatly increase the sensitivity of the circuit).

All pumped up

Diodes D1, D2, capacitor C2, and resistor R2 represent a standard diode pump, or charge pump, which effectively converts AC (at IC1c pin 6) to DC (across C2). Resistor R2 serves to provide a discharge path for C2.



Construction of the sensor coil L1. Approximately 1,200 turns of 30swg/22awg enamelled copper wire are wound on a 6mm x 25mm long bolt

While R2 could be dispensed with, a discharge path makes a circuit more predictable and manageable.

IC2 is a voltage-follower or buffer. Since the charge on capacitor C2 is very 'weak', it needs a little encouragement before it is fed to something as power-hungry as a meter. IC2 therefore 'bolsters' the voltage that is found across C2.

Resistor R3 serves to protect components IC2, ME1, and VR2. It ensures that a maximum of 10.6mA (5V/470Ω) will flow through any of these components. As an example, without R3, preset VR2 could be adjusted so that the output of IC2 would flow to 0V with minimal resistance – a perfect recipe for disaster. Circuit design is often, as in this instance, about predicting what *could* go wrong, and preventing it.

Preset potentiometer VR2 serves to balance meter ME1. This is usually

called a 'zero adjust' potentiometer, since it adjusts meter ME1 to zero. In fact, a moving coil meter will usually have a zero adjust screw on its front panel. This should be used to adjust the meter to zero *before* VR2 is adjusted, but *not after*.

As already mentioned, it is quite likely that the circuit will pick up EMFs in excess of 10mG in the home or workplace, so that meter ME1 could suffer overload. To prevent *serious* overload, diodes D3 and D4 are employed, to drop any voltage exceeding about 1.2V. This means that, in a worst case, only 2mA would pass through the meter, and this would be very unlikely to cause it any damage.

Power source

Last, the circuit uses a positive 5V voltage regulator, IC3. Since the Electromog Sniffer is a sensitive circuit, which is carefully calibrated, it should best be provided with a steady supply voltage. Voltage regulator IC3 may be fed with any DC voltage between 7V and 35V – so a 9V PP3 battery or a 12V AA battery pack are the most obvious choices to power the circuit.

Note, incidentally, that some component values shown in the photographs of the prototype have been changed in the circuit diagram and components list, so that the circuit diagram and components list show the values which were finally selected.

Modifications

With the component values shown in Fig. 2, the circuit has been balanced to give full-scale deflection (FSD) of ME1 when 10mG is detected. However, the circuit may be considerably modified and adjusted.

First, its sensitivity may be *reduced*, by turning back preset VR1, or even by reducing the values of VR1 and R1. This is recommended if a more sensitive meter is used (eg a 130µA or 250µA VU meter). It is recommended that, if a VU meter is used, a value of 10kΩ be used for VR1, and 100kΩ for R1. The adjustment of a VU meter in this circuit may be a little more critical or delicate than that of a 1mA meter, although by no means too awkward to achieve.

On the other hand, sensitivity of the circuit may be *increased*, possibly as much as tenfold (ie to a range of 0 to 1mG). This would be accomplished

by increasing the values of VR1 and R1 – or by replacing VR1 with a 10M resistor, and removing R1 from circuit. In this case, IC1 may be replaced with an HCU device, which has a smaller gain, yet will detect up to about 50 MHz. The 74HCU04 IC was tried successfully in this circuit, although output linearity seemed lost (that is, the meter tended to swing wildly on approaching sources of EMF).

Seeing red

A red LED may also be used in place of a meter, and this would represent a large cost saving. This should be a normal (not ultrabright) red LED. However, sensitivity is reduced by a factor of 10 (assuming that the circuit has been adjusted for 0 to 10mG and a 1mA meter).

The LED will just begin to illuminate when the Electromog Sniffer detects about 10mG – unless, of course, one increases the sensitivity of the circuit as described. From this, one may divide by 4.5 for every doubling of distance to estimate the strength of EMFs at greater distances from the source.

A final option is a multimeter, switched to its 1mA or 2mA range, and clipped to the solder pins reserved for moving coil meter ME1. A 1mA reading will indicate 10mG, while eg a 0.3mA reading will indicate 3mG.

Construction

The printed circuit board (PCB) measures 92mm × 31mm (3.6 × 1.2inches). Since IC1 is a sensitive CMOS device, anti-static precautions are advised. In particular, discharge your body to earth before handling this IC.

It needs to be noted that IC1 is used here as a sensitive HF preamplifier, therefore even slightly unsound joints may disrupt its operation far more easily than would normally be the case. Any trouble-shooting should put this possibility high on the list.

Referring to Fig. 3, begin by soldering the link wire, the six solder pins, and the two DIL sockets – observing the correct orientation of the sockets. Continue with VR1 and VR2, then the resistors and capacitors – noting the polarity of electrolytic capacitor C3. Solder D1 to D4 (again noting polarity), and IC3. IC3's tab should be safely clear of the adjacent solder pins.

Solder the battery clip to the appropriate solder pins as shown in Fig. 3, inserting a push-to-make pushbutton switch in the positive lead. Be sure to attach the battery clip the right way round – a mistake here could destroy the circuit. Solder pickup coil L1 to the solder pins as shown (this may be soldered any way round).

Finally, attach moving coil meter ME1 via suitable leads, noting the

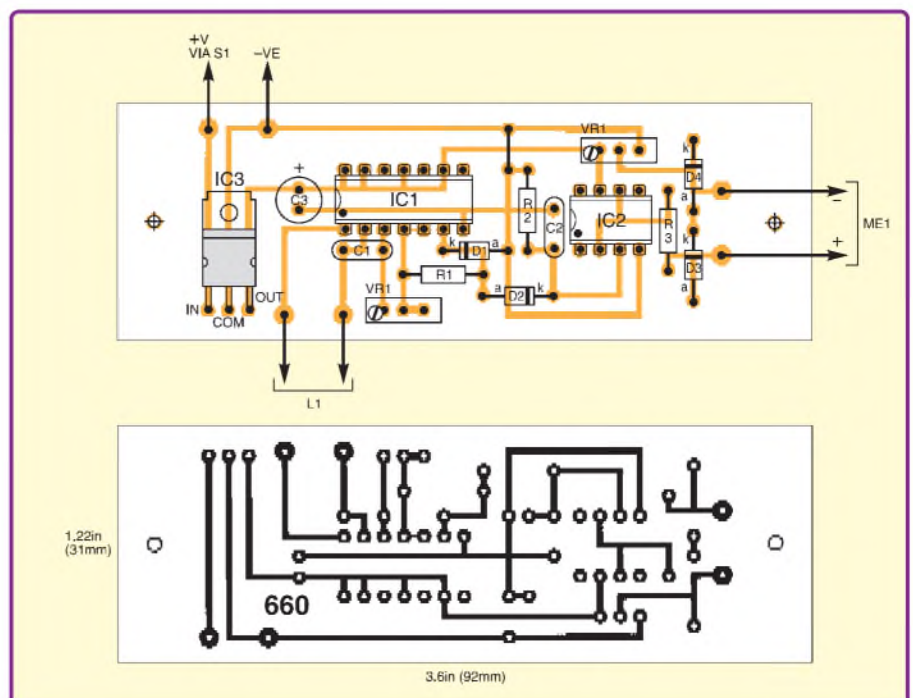


Fig.3. Sniffer printed circuit board component layout and full-size copper master

polarity of the leads. If a VU meter is used instead, this is wired up the same way, again noting the polarity. If an LED is used instead, it may be treated as a meter, with its anode being regarded as the positive terminal. Note, if an LED is used instead of a meter, D3 and D4 need to be omitted from the PCB, or they will effectively short-circuit the LED.

Boxing up

The author used a plastic pencil box to hold the parts. This cost a mere one-tenth of the ABS boxes on offer at the local electronics store. Although this created a somewhat *avant garde* look, at least it was roomy and functional. The author held coil L1 and the PCB in place with cable ties, and snapped ME1 and S1 into suitable holes cut into the plastic.

Note that meter ME1 should *not* be mounted immediately on top of coil L1. There needs to be a few centimetres' space between these two components to prevent magnetic feedback (feedback might be noticed by a wavering needle).

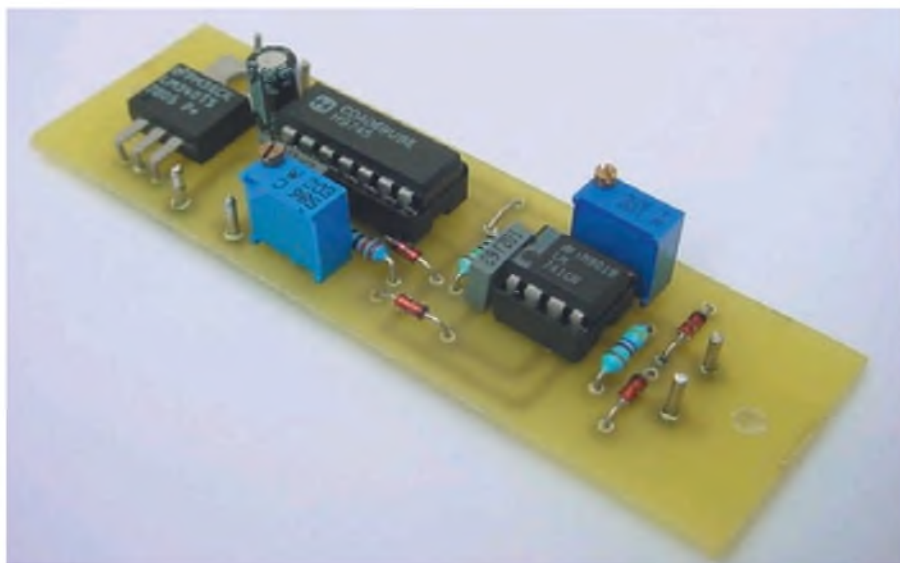
Calibration

If there is a zero adjust screw on the front panel of the moving coil meter, use this to adjust the meter to zero with the unit turned off. Usually a preset potentiometer has already been turned to its mid-position when it is purchased. Leave VR2 in its mid-position, but turn VR1 right back (anti-clockwise).

Attach a battery or battery pack to the battery clip (9V or 12V would be ideal), stand clear of any obvious sources of EMF, and press pushbutton S1 to turn on the circuit. ME1 is likely at first to swing too high or too low. Use preset VR2 to turn the needle back (anti-clockwise) or forwards (clockwise), until it is adjusted to zero precisely. You might need to return to VR2 as you adjust VR1 (see below).

Potentiometer VR1 is used to *calibrate* the Electrosnog Sniffer. But how to calibrate? Ideally, one would have a calibrated Sniffer to calibrate the Sniffer! It is a chicken and egg situation.

The perfect solution would be a professional milligauss meter to compare. Most constructors, however, are unlikely to have access to such a device – in fact, it might be for this very reason that they are building the Sniffer!



Layout of components on the completed Sniffer circuit board

With this in mind, the author sought some kind of EMF 'standard' that might be common to all. Ultimately, he felt that the best he could come up with was a computer CRT (cathode ray tube). Although such monitors tend to cast EMF forwards, backwards, upwards, or downwards as the case may be, it was found that several monitors all gave approximately the same maximum readings at the side. They typically emitted 1.5mG at 30cm (one foot) to the side of the back section of the monitor.

This may not always be the case, but it is quite likely that, by using this EMF, one will gain a roughly correct adjustment. One can always check it against another monitor for reassurance.

Hold the Electrosnog Sniffer's coil L1 30cm (one foot) away from the side of the back section of a CRT. Turn the Sniffer through all three of its axes to find the highest reading. One might read nothing at all at first. Turn preset VR1 clockwise, and keep turning it clockwise, until the needle stands at 1.5mG maximum on meter ME1. Now move away from all obvious sources of EMF. Does the meter needle still fall back to zero? If not, readjust VR2. Then readjust VR1 as described. The circuit is now set up.

In use

Always turn the Electrosnog Sniffer through all three axes when checking a source of EMF. Full scale deflection of the meter (1mA) indicates 10mG, while 0.2mA indicates 2mG. Although the Sniffer will detect the EMF (at least in part) of a PDA or a microwave oven, note that its effectiveness will seriously drop off when measuring frequencies above about 7MHz. Up to a point, this may be compensated for by increasing the circuit's sensitivity as described above, or by employing an HCU IC.

Note that one's hands should not get in the way of sensor coil L1 when taking measurements. Place a hand between L1 and the source of the EMF, and most of the EMF will 'disappear'. Where has it all gone? And what is it doing there?

A particularly useful introduction to EMFs (though not the potential health hazards) may be found at <http://www.niehs.nih.gov/emfrapid/booklet>. *EPE*



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Static LCDs and PICs

LCDs are a very popular form of user display in embedded projects, and are often the reason why we add a microcontroller to a design in the first place. An LCD can provide a wealth of information that cannot be articulated by a few LEDs or a moving coil meter.

In the small microcontroller projects that we tend to be familiar with the most common choice of LCD display is the 2-line, 16 character intelligent module. These modules are equipped with integrated driver circuits that provide a simple, parallel interface to control the display, relieving us of the need to understand how the LCD actually works.

The drawback with these displays is that they consume a reasonably large amount of current – a few tens of milliamps – which can make some battery-operated projects impractical. A typical AA battery has a capacity of around 1000mA/hour, which means it could power an LCD module for only a few continuous days.

An example where this would indeed be a problem is a bedside digital clock. Ideally, one would like such a device to be able to display the time continuously, and only require the batteries to be replaced once or twice a year.

Static LCD structure

With that kind of design requirement in mind, one has to look elsewhere for a display technology that can solve the problem. And this is where a different kind of LCD module, the *static* LCD display panel, comes into play.

Static LCD display panels differ from the more usual LCD modules in several ways. The most striking is that they have no additional electronic components – they are just glass, and a large number of pins to connect to your circuit. With no driver electronics to simplify our interface, we have to do more work in the microcontroller and possess a more detailed understanding of how they work. Fortunately, this is not too complicated, and it is possible to explain the important, relevant factors in a single article.

Let's start with the basic construction of an LCD panel. It consists mainly of two sheets of glass, glued together with a small gap between them. Inside this sandwich is a special liquid – imaginatively called a 'liquid crystal fluid'. This fluid is an organic material composed of 'rod' shaped molecules. The rod shape plays a crucial role in the display, as we shall see shortly.

On the underside of the top sheet of glass is an extremely thin electrode, which

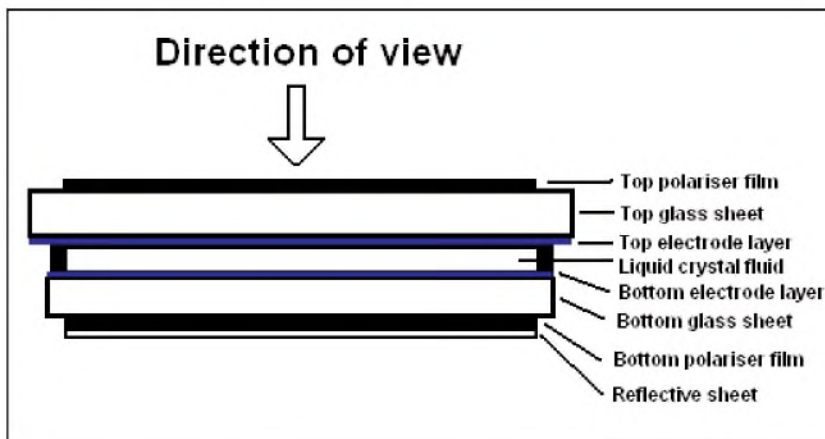


Fig.1. Construction of an LCD Panel

traces out the pattern of the LCD's digits and connects each one to a pin at the edge of the glass. The electrode layer is almost invisible, but if you look closely at the glass in bright light you should be able to see the tracking. On the top surface of the lower glass sheet is a single electrode that covers the entire surface of the sheet and connects to a single 'Common' pin on the edge of the glass. Sometimes two or more common connections are provided, to help provide a better signal.

Polarising

On the upper side of the top glass sheet is a thin plastic polariser film. Polariser films (used in some sun glasses) are like small scale gratings that only allow light which is orientated parallel to the direction of the grating to pass through. 'Light waves' from normal sources such as the sun or artificial lighting arrive at the

surface of the LCD in many different polarisations, so the front polariser absorbs much of the light, and only allows some of it through. The light passes through the liquid crystal fluid, out of the lower glass sheet and then through a further polariser sheet. Behind that sheet is a mirror reflector which bounces the light back through the glass and out towards the viewer (assuming you are looking at the glass!). The various components of the panel are shown on Fig.1.

While that description of the construction is a simplification, we have left out a couple of important factors, which are best described with the assistance of another diagram, Fig.2.

The top polariser filters light in one direction, but the lower polariser filters light in a perpendicular direction – so the light that filtered through the first filter should be absorbed by the second one. One

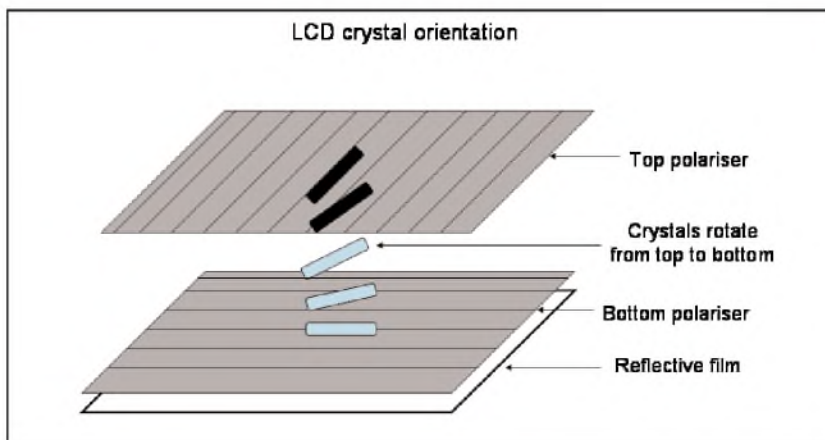


Fig.2. LCD crystal orientation when no power applied

would think that the display would simply appear completely dark, but this isn't the case. So what is going on? This is where the LCD fluid comes into play, as can be seen from Fig.2.

The fluid consists of tiny rod-like molecules that line up with the polarisation lines on the top and bottom of the glass. Between the two layers of glass the rods 'rotate' in a spiral. This has the effect of twisting the light coming in, changing its direction of polarisation.

When the light reaches the bottom plate it is now aligned with the lower polarisation plate and can pass through, be reflected by the reflective film and sent back up through the LCD fluid and out of the top glass sheet. This gives the 'light' appearance of the LCD panel when it is not powered. In summary, ambient light entering the glass is reflected back out to the viewer.

When power is applied between a segment on the top sheet and the common on the lower sheet an electric field forms between the two. This causes the rods between the two conductors to align up in a straight line. Now, the light passing through is not twisted and is simply absorbed by the lower polariser film, making the area below the segment appear dark.

That, in a nutshell, is the physics and chemistry of how LCDs work.

Voltage control

There is one important complication with LCDs which affects how we use them. The LCD fluid will become damaged if a constant DC voltage is applied between the segment and common signals. To get round this problem we use an AC signal, which simply inverts the signal frequently (the LCD fluid does not care about the polarity of the signal.)

The typical voltage signals on two example segments and the common signal are shown in Fig.3. The signals are simple square waves, alternating at a frequency of about 30Hz. An 'on' segment is out-of-phase with the common signal, resulting in a constant voltage of 6V. The 'off' segment is in-phase with the common signal, resulting in a net voltage of zero. Switching delays will, of course, generate a small net DC voltage but this will be small enough not to damage the LCD.

An LCD panel provides one or two common signals (to provide a good return path for the segment signals) and one segment signal for each independent digit on the display. Fig.4 shows a typical LCD panel, as used in the example design we will discuss shortly.

LCD panels come in many different standard designs for common applications; the design in Fig.4 can be used for digital multimeters or clocks and is widely available. Custom LCD panels are very easy to make and are quite cheap for commercial applications, costing only a few hundred pounds in some cases with a minimum order quantity of 1000 parts. Oddly enough, for the hobbyist these simple glass panels are slightly more expensive than the more complicated 2×16 character LCD

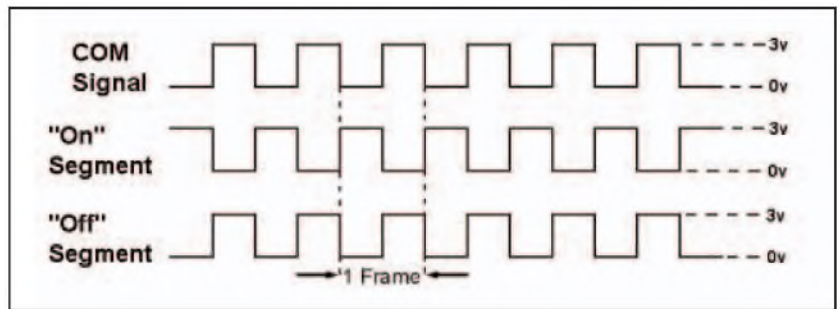


Fig.3. LCD signals

modules; this is simply due to the high demand for alphanumeric displays.

So why would we want to use a simple, 4-digit display instead of a cheaper, alphanumeric module? The main reason is *power*. LCD panels draw *extremely* low current, just a few microamps compared to the 10 to 50 milliamps required by an LCD module. That's more than a thousand times less power consumption, enabling designs to be powered from tiny batteries for very long periods. The rest of the circuit must be low power too of course, but in the case of the digital clock example that we will show in this article that is easily achievable.

Powering an LCD panel is simple – most LCD panels are designed to run at between 3V to 6V, and do not really require a regulated power supply. As the voltage drops, the display becomes progressively dimmer, which can act as a 'battery low' warning. Or you can just fit a regulator. For many hobby applications the former method is quite acceptable.

Parameter choice

When choosing an LCD panel there are three main parameters you need to consider. As panels come with a variety of different digit layouts, you obviously need to find one that matches your needs. Then, you need to check that the working voltage suits your circuit's power supply. The panel we have chosen operates at up to 6V. Remember that we are alternating the polarity of the signal between the segment and the common signals, so a 3V circuit supply voltage will give a 6V 'swing' across the display.

Our circuit can run at 3V, which is fine. On investigation it was found that the circuit will run quite happily down to 2.6V, and so will run off two AA cell batteries without regulation. It requires some experimentation to check that the contrast is acceptable, as the display will dim at lower voltages.

Finally, you need to check the switching speed of the panel. Panels typically operate at around 30 to 100Hz, so you need to check that your microcontroller will support that switching speed (more on this later.) Our panel runs best at 32Hz, a speed supported by our microcontroller of choice, the PIC16F917, when running of a 32kHz clock. The clock speed is not an exact requirement – remember, there are no electronics on the panel. The clock speed is determined by the chemistry of the LCD fluid, and is related to the 'viscosity' of the fluid, how quickly the rods can change direction when the voltage changes polarity.

Now we know how to drive an LCD panel, it's time to decide on a processor to drive it. It's worth mentioning briefly that while Microchip supply processors that are intended to drive LCDs, it is quite reasonable for you to drive an LCD with just standard PIC I/O port pins. Having a set of segment outputs and a single common output changing polarity 32 times a second is a trivial programming problem. Microchip make things simple by providing processors that have many output pins which can be configured to 'toggle' state periodically without software activity, and while running in ultra low power.

Digital clock example

Fig.5 shows the example circuit for a digital clock based on the PIC16F917 processor. We have chosen this part for a number of reasons. It's a low voltage device, capable of running down to 2V; it has LCD drive capability built in; it has enough LCD segment pins to drive our chosen LCD, and it is the device fitted to the PICKit2 debug board, making development easy.

Before coming up with the circuit we had some design decisions to make, based on how we want the circuit to work: it should be a simple, working design and it should draw low enough power to run for more than six months off two AA batteries.

Driving the LCD is simplicity itself. Connect the two common signals on the LCD panel to the COM pin on the processor, and connect up pins SEG0 to SEG23 to the segment pins on the panel. The order in which you connect the segment signals up is not critical; at some point in your code you will have to produce a routine that 'maps' numbers to be displayed into a particular set of register settings.

The VLCD3 pin needs to be connected to the V_{dd} pin to provide the LCD supply voltage. And that is it. Although there are a large number of pins to wire, the setup is quite straightforward.



Fig.4. Four-digit static LCD Panel

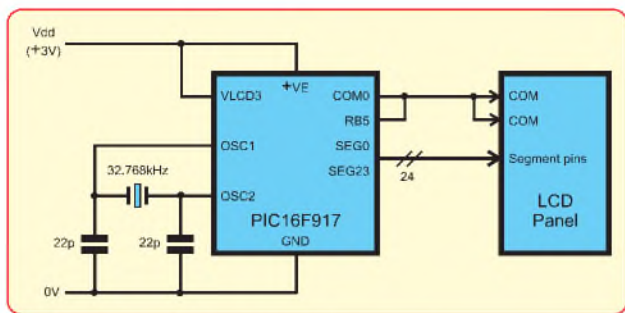


Fig.5. LCD clock circuit

PIC pin use

To keep the overall circuit simple, we have opted to wire the MCLR pin internally, via a config bit setting. That saves a pin. The only remaining components are a 32.768kHz watch crystal and two 22pF capacitors. You may well need to tinker with these values to get an accurate 32.768kHz signal from the oscillator. In most cases, however, this should be close enough.

To enable the circuit to draw the absolute minimum of power, we will clock

course, far too inaccurate to operate as the timebase for a real clock; instead, we wire the COM0 pin to an interrupt input on RB5 to provide an accurate interrupt 64 times a second. The processor is held in SLEEP mode, and on the 64th interrupt the real time clock is updated, and the digits on the display changed to reflect the new time. Amazingly, this circuit draws less than 10µA.

Setting up the LCD peripheral is similar to setting up an I/O port. First, define the clock rate and source by writing to LCDPS

the LCD peripheral from the Timer 1 oscillator, which confusingly is wired to the main oscillator pins. The CPU itself is clocked from an on-chip RC oscillator by setting the config bits to the INOSCIO setting. The RC oscillator is, of

and LCDCON. Next, enable the segment pins that you want to use by writing a '1' bit in the appropriate position in the LCDSE0-2 registers. We want to enable all 24, so we write 0xFF to all three registers. Enable the display by setting the VLCDEN and LCDEN bits in the LCDCON register.

Now, to display a digit on the LCD, simply write a '1' bit into the appropriate position in the LCDDATA0-2 registers.

The full sequence of code, including the configuration of the Timer 1 oscillator can be found in the *PicNmix* section of the *EPE* website's Download area (via www.epemag.co.uk). All the code is located in a single source file, *lplcd.asm*. The remaining files contain the MPLAB project settings, so you can easily modify and build the program in MPLAB.

The sample circuit draws so little current that it can be powered by a simple home-made battery. We found that a lemon, zinc plated nail and a short length of copper wire had no problem powering the clock!

References

4-Digit Static LCD datasheet, Farnell part number 253-558

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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
SP24	4 x CMOS 4001	SP160	10 x 2N3904 transistors
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 1N914 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'd colours
SP47	5 x Min. PB switches	SP182	20 x 4.7/63V radial elect. caps
SP49	4 x 5 metres stranded-core wire	SP183	20 x BC547B transistors
SP102	20 x 8-pin DIL sockets	SP186	8 x 1M horizontal trim pots
SP103	15 x 14-pin DIL sockets	SP189	4 x 5 metres solid-core wire
SP104	15 x 16-pin DIL sockets	SP192	3 x CMOS 4066
SP109	15 x BC557B transistors	SP195	3 x 10mm Yellow LEDs
SP112	4 x CMOS 4093	SP197	6 x 20-pin DIL sockets
SP115	3 x 10mm Red LEDs	SP198	5 x 24-pin DIL sockets
SP116	3 x 10mm Green LEDs	SP199	5 x 2.5mm mono jack plugs
SP118	2 x CMOS 4047	SP200	5 x 2.5mm mono jack sockets
SP124	20 x Assorted ceramic disc caps		
SP126	6 x Battery clips - 3 ea. PP3 + PP9		
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SP133	20 x 1N4004 diodes		
SP134	15 x 1N4007 diodes		

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By PETER SMITH

Studio Series – Stereo Preamplifier

A Superb Preamplifier For The Audio Enthusiast!

This easy-to-build hi-fi preamp features high-performance audio op amps for ultra-low noise and distortion. Its modular design incorporates five switched RCA phono inputs and support for a headphone amplifier.

THESE DAYS, audio power amplifiers that produce low noise and distortion and cost only a few hundred pounds are relatively easy to find. In fact, they're built into many of the latest multi-channel home theatre systems. Much of this gear is based around hybrid amplifier modules, which typically produce distortion levels in the 0.02% realm.

However, those serious about their audio will demand a much higher level

of performance than can be found in these mass-produced units, which explains why the discrete power amplifier projects described in *EPE* are so popular.

Having built one of our high-performance amplifiers, many readers have also asked us for a matching preamplifier design. And so our design brief was simple: a minimalist approach, focused on achieving ultra-low noise and distortion, but with

enough gain (with the 'wick' wound right up) to overdrive any of our audio power amplifiers, including the big 350W and 500W units. So, what were our options?

Discrete versus integrated

Initially, we were aiming for a discrete class-A amplifier design, speculating that this would be the best way to achieve the ultra-low distortion figures that were required. Another option was to use 'boutique' op amps specified for hi-fi audio use, such as those manufactured by Analog Devices and Texas Instruments.

High linearity and the lack of cross-over distortion are the major reasons for the use of class-A mode in audio applications. However, when compared to an equivalent op amp design, a discrete class-A amplifier would

Features and Performance

Main Features

- High performance design – very low THD+N
- Five on-board RCA phono inputs
- Passive-switched inputs maintain signal integrity
- Switched headphone amplifier output

Measured Performance

Frequency response...	flat from 10Hz to 20kHz, –1dB @ 82kHz (see Fig.5)
Maximum input signal.....	2.9V RMS (9.5V RMS output)
Input impedance.....	~90k Ω
Output impedance.....	100 Ω
Harmonic distortion	typically <0.0005% (see Fig.7)
Signal-to-noise ratio	–102dB unweighted
Channel crosstalk.....	–96dB @ 1kHz, –73dB @ 10kHz
Source crosstalk.....	–110dB @ 1kHz, –93dB @ 10kHz

Note: all measurements were performed at the maximum volume setting with the output driving a 50k Ω load. Input signal amplitude was 600mV RMS (2V RMS output). For crosstalk measurements, non-driven inputs were back-terminated into 600 Ω .

have consumed a large amount of PC board space, making the completed module physically large and more prone to radiated noise. It would also be considerably more difficult to build, containing many more components than an equivalent op amp design.

We then looked at the current audio op amp offerings and their implementation. In many of our past designs, we've used the industry-standard NE-5534 and LM833 devices. These are relatively cheap and easy to obtain, and both typically produce about 0.002% total harmonic distortion (THD) at 1kHz when driving a 2k Ω load. Don't get us wrong – this is a very good figure – but it just wasn't good enough for our new preamp! Our intention was (and is) to produce a preamp which causes virtually no signal degradation when teamed with our benchmark class-A 15W amplifier.

From the limited selection of audio-specific op amps available, most were deemed either too expensive or too hard to obtain. However, the Burr-Brown (Texas Instruments) OPA134 series is not expensive and easy to obtain, and it produces an extremely low 0.00008% harmonic distortion at 1kHz! This is more than an order of magnitude (25 times better!) below the figures for the op amps mentioned earlier and with all things considered, would give superior performance compared to a discrete class-A design.

Incidentally, the output stages of these op amps do not run in class-A mode, despite their excellent linearity. The manufacturer's datasheets do not reveal how they have achieved these impressive results.

Extra features

We've stuck to our minimalist brief and added just two features to the basic preamp. The first of these addresses a common problem faced during preamp construction: how to switch the various signal inputs through to the preamp input while maintaining low noise and crosstalk.

Typically, multiple inputs are handled by fitting a bunch of RCA phono sockets to the rear panel and laboriously wiring these to a rotary switch on the front panel with shielded cable. Alternatively, the RCAs are mounted on a PC board at the rear along with the switch, which is then piped through to the front panel with a long extension shaft. While these methods work, they

have their disadvantages. What's more, they don't allow for remote control selection!

We've opted for an electro-mechanical solution, using passive (relay) switching for minimum impact on the audio signal. Each stereo input has its own miniature relay, positioned right next to the RCA phono socket. This gives absolute minimal source crosstalk and less induced noise, even when compared to some cabling schemes.

The second feature is closely related to requests we've had for a high-quality headphone amplifier that runs off the preamp (rather than power amp) stage. In support of this idea, we've included a relay circuit that can route the preamp's output to an RCA socket at the rear or a terminal block on the inside, where it would connect to a separate headphone amplifier board.

In summary, to operate as a fully functioning unit, the Studio Series Preamplifier module requires only a volume potentiometer, source selection switch and low-noise power supply, all of which are described in detail in this article.

In the pipeline

Next month, we expect to describe a high-quality headphone amplifier module to suit. And the following

month a companion control board, which will feature an infrared remote control (motorised) volume pot and remote source selection.

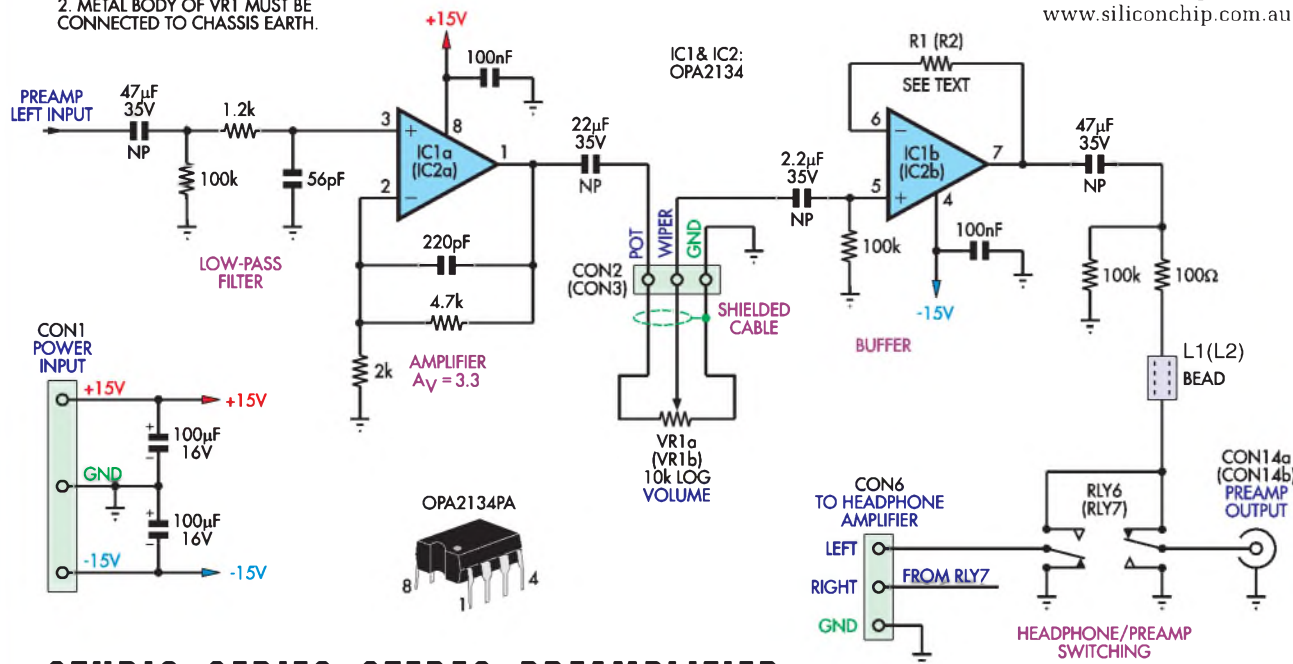
In the final article, we'll show you how to put all of these modules together in a slim rack-mount case.

How it works

The preamp consists of two identical signal paths from input to output, catering for the left and right stereo channels. Therefore, to avoid duplication and reduce clutter, our circuits show only the left channel. We've also divided the preamplifier circuit diagram into two sections, corresponding to the input signal switching (Fig.1) and preamplifier functions (Fig.2).

Referring first to the signal inputs (Fig.1), no less than five RCA sockets (CON8-CON12) are provided for connection to various audio sources. We've used labels such as 'CD', 'DVD' and 'TAPE', but of course, these inputs will accept any audio signal classed as 'line-level'. The sixth socket (CON13) simply loops the selected input pair back out, duplicating the 'tape loop' function found in some preamps and control units.

Each input pair is connected to the normally-open contacts of a relay, with the poles of all relays connected



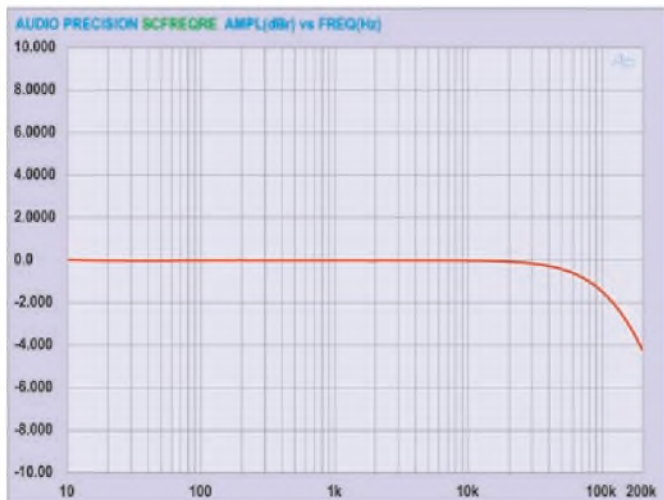


Fig.5: a plot of the frequency response for both channels shows a ruler-flat response over the entire audio spectrum, after which the curve gently rolls off, with a -3dB point at 154kHz.

Like many op amps, the OPA2134 shows an increase in distortion in non-inverting applications if the impedance seen by its positive and negative inputs is not matched. Unfortunately, the input impedance that the negative input of IC1b 'sees' varies with the wiper of the pot.

Despite this shortcoming, the distortion levels of the OPA2134 are very low even at the worst case wiper position, where noise far outweighs distortion anyway. Nevertheless, we've provided positions on the PC board for two impedance-matching resistors (R1 and R2).

If desired, you can install equal value resistors (instead of wire links) in these two locations that approximate the wiper-to-ground resistance of the volume pot at your typical listening levels. This extra little feature allows you to obtain the very best performance from your preamplifier module!

Of course, the said wiper resistance can only be determined after you've used the preamp with your complete stereo system and favourite music for awhile, so wire links are installed in these locations during construction. We suspect that most constructors won't bother to replace the wire links!

Output switching

Finally, provision has been made to allow the preamp output to be switched between the RCA socket pair at the rear (CON14) and a terminal block (CON6). The latter connector is intended for use with the internal

high-quality headphone amplifier to be described next month.

Two relays (RLY6 and RLY7) are used to allow the non-driven input to be grounded. Relay operation is dictated by the insertion and removal of the headphone jack, which operates a switch inside the jack socket.

The jack switch is wired to CON7 (Fig.1), where it controls transistor Q6 to drive the two relay coils. With a jack in the socket, the switch is open and the base of Q6 is pulled high via diode D6 and the two 1.5kΩ resistors. This turns Q6 on and energises both relay coils, directing the output signal to CON6 and the headphone amplifier.

When the jack is unplugged, the socket switch closes, grounding the 'SWITCH' input on CON7 and stealing Q6's base current. After a short delay, the transistor (and the relays) switch off, redirecting the output

Fig.7: all our audio tests were performed on an Audio Precision System One. This graph shows total harmonic distortion and noise versus frequency. The reading is mostly below 0.0005%. However, this figure is barely above the noise floor of the test instrument, so the real value is probably much lower!



Fig.6: crosstalk between channels is also very respectable. Increasing crosstalk at the higher end of the scale indicates electrostatic coupling, due to the physical proximity of the channels and the long PC board tracks connecting the relays.

signal to CON14 and the power amplifier.

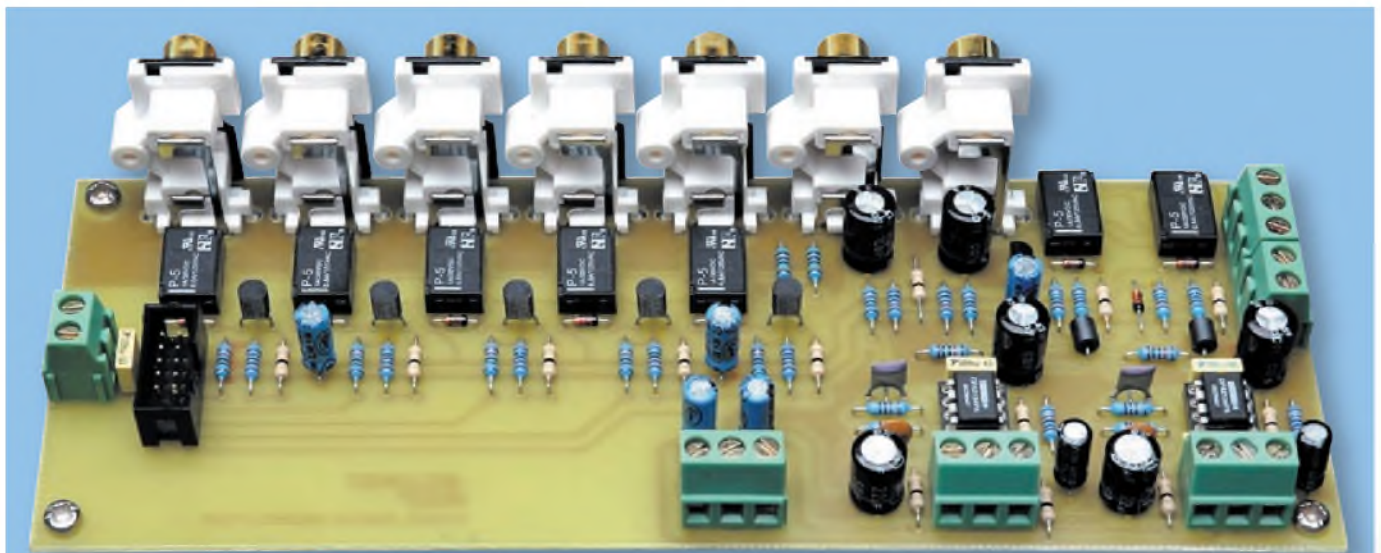
The diode, capacitor and resistors are included in the base circuit of Q6 to slow the circuit's response to changes at the switch input. This helps to minimise relay chatter during jack insertion and removal.

Power supply

To ensure the best possible performance, we've designed a separate, low-noise power supply for the preamp module. It provides regulated $\pm 15V$ and +5V outputs for the preamp and any future add-ons.

The power supply board accepts a 30V AC centre-tapped transformer input, typically formed by joining two 15V AC secondary windings of a toroidal transformer – see Fig.4. Four diodes (D1-D4) and two 2200μF capacitors rectify and filter the input to create $\pm 21V$ DC (nominal) rails.





This prototype preamp board varies slightly from the final version shown in Fig.8. The miniature relays switch the selected source to the preamp stages and switch the preamp output between the external power amplifier and an optional internal headphone amplifier (to be described next month).

Zero ohm 'resistors' can be used in place of wire links in the remaining 11 positions, if desired. These are shaped just like conventional 0.25W resistors and are identified by their brown body and single black band. Although they impart a neater appearance to the finished work, they have no electrical benefits over ordinary copper wire! For the time being, you should also install wire links in place of resistors R1 and R2.

Note that the two 100Ω resistors require special treatment. Slip a 5mm ferrite bead over one lead before bending and inserting each resistor into its PC board holes – see photo, above right.

The relays (RLY1 to RLY7) can go in next, taking care to insert them the right way around. The white line on the top of the package must match the corresponding marking on the overlay diagram. Remember that RLY6 and RLY7 can be left out if headphone amplifier switching isn't needed, as explained earlier. However, you must fit two wire links in place of the relays, as shown in Fig.8.

Install the two 8-pin IC sockets and the 10-way header (CON4) next. Note that one side of the header housing is keyed and this must be oriented towards the centre of the board. Likewise, the notched (pin 1) end of the IC sockets must be correctly oriented.

Follow with the screw terminal blocks, all of the capacitors and the transistors. Five of the electrolytic capacitors (100μF and 10μF values)

are polarised and must be installed with their positive leads aligned as shown. The remaining electrolytics are non-polarised (marked 'NP' or 'BP') and can go in either way.

The RCA phono connectors (CON8 to CON14) go in last of all. Be sure to push each connector all the way home and check that it's sitting perpendicular to the board surface before soldering.

Power supply assembly

The power supply PC board is a relatively simple design and should not present any particular assembly problems. Apart from the mains transformer and wiring, all components mount on a single-sided PC board measuring 54.6 × 80mm, including the bridge rectifier, filters and voltage regulators.

As before, install all of the low-profile components first, starting with the single wire link, resistors and diodes (see Fig.10). To aid heat dissipation, the two 5W resistors should be mounted about 2mm proud of the board surface.

Take care with the orientation of the electrolytic capacitors, as all on this board are polarised. Also, be sure not to interchange the two adjustable regulators (REG1 and REG2) and note that they face in opposite directions!

Unlike REG1 and REG2, regulator REG3 mounts horizontally. Bend its leads at 90° about 5mm from its body and trial fit it in position to verify that the hole in the tab lines up with its hole

in the board. Adjust as necessary, then slide a TO-220 heatsink between the regulator and the PC board after applying a thin smear of heatsink compound to the mating surfaces.

Secure the assembly to the board with an M3 × 10mm screw, flat washer and nut. Don't solder the regulator's leads until after the screw has been tightened, otherwise the PC board or regulator package could be damaged.

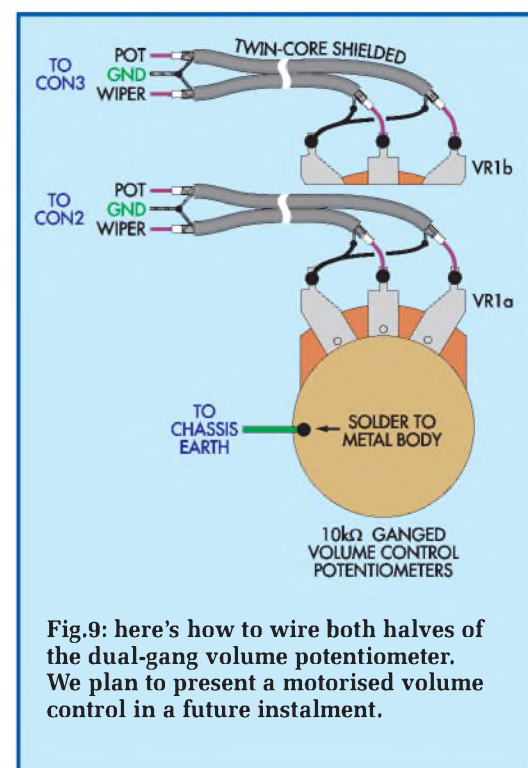
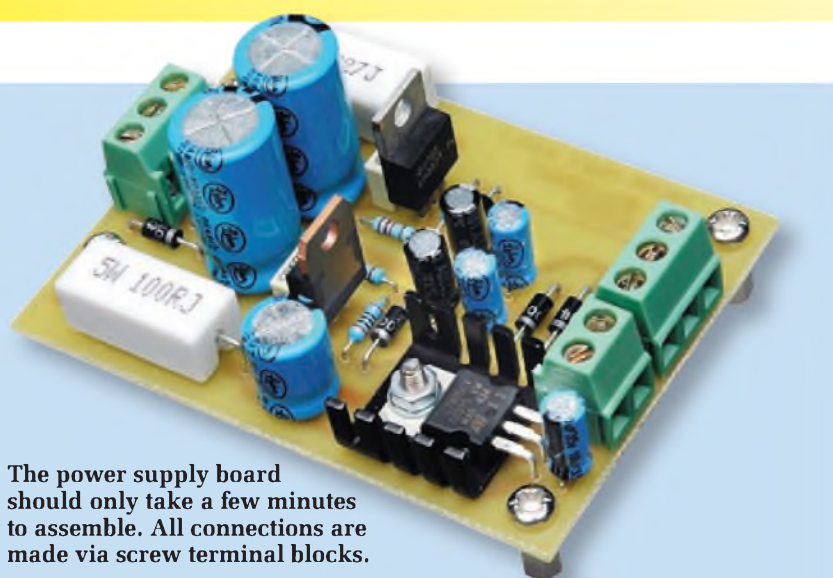


Fig.9: here's how to wire both halves of the dual-gang volume potentiometer. We plan to present a motorised volume control in a future instalment.



The power supply board should only take a few minutes to assemble. All connections are made via screw terminal blocks.

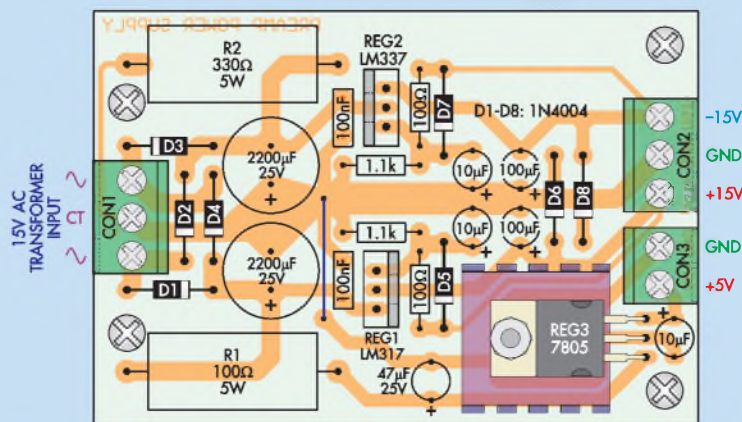


Fig.10: follow this diagram to assemble the power supply board. Take care not to get the 3-terminal regulators mixed up.

Before moving on to the wiring, attach four threaded standoffs to each board in the holes provided using M3 × 6mm screws.

Mains wiring

It's very important that the power

supply is checked thoroughly before it's connected to the preamplifier module. To do this, first assemble the transformer into your metal project case.

For best results, the mains transformer should be located as far away from the preamp board as possible to

minimise induced noise. A toroidal model is recommended for its low radiated field and low physical profile.

Important: a full metal case is recommended for this project. Plastic will not provide the necessary electrical screening!

Connect the mains (primary) side of the transformer, using the basic diagram in Fig.4 as a guide. Be sure to adhere to any instructions provided with the transformer, particularly with regard to mounting, fuse ratings and wire colour coding.

All work must be carried out professionally and in accordance with mains wiring practices. In particular, ensure that all live connections are properly insulated, which includes the use of rubber boots (or equivalent) over the rear of all switches and mains sockets.

The mains wiring is not complete until the mains earth is secured to the metal chassis using the scheme shown in Fig.11. That done, use your multimeter to verify that a good electrical connection exists between the earth pin of the mains plug and all panels of the metal chassis.

Power supply test

The power supply test is uncomplicated and involves simply measuring the unloaded output voltage of the three supply rails. To do this, first connect the two secondary (15V AC) windings to the transformer input (CON1) of the board.

Apply power and use your multimeter to measure the three rails at the supply outputs (CON2 and CON3). Assuming all is well, the +15V, -15V and +5V rails should all be within ±5% of the rated values.

Electrolytic vs Polypropylene Capacitors

HIGH-CAPACITANCE non-polarised electrolytics are used for signal coupling throughout this design. The results are excellent, as reflected in the various performance measurements. However, some hi-fi proponents will be unhappy with this choice, instead insisting that polypropylene capacitors somehow 'sound' better than electrolytics when used in the audio signal chain.

To explain, polypropylene capacitors have a much lower dissipation factor (DF) and lower dielectric absorption

(DA) than electrolytics; a major reason for their use in sample-and-hold circuits, high-frequency filter networks and speaker crossovers, for example. However, their benefits in low-level audio frequency circuits are much harder to quantify, especially considering their proportionally larger size, higher cost and limited availability in appropriately large values.

Those with a personal preference for polypropylene capacitors can, of course, substitute these for the specified non-polarised electrolytics, given

sufficient board space and part availability. Smaller capacitance values will need to be used for polypropylene substitutes due to the sheer size and cost differences. To minimise impact on bass response, a minimum of 2.2µF should be substituted for the 47µF and 2.2µF electrolytics and a 4.7µF value for the 22µF electrolytic. It would also be preferable to use a 20kΩ log pot for VR1.

Note that the use of physically larger coupling capacitors is likely to increase noise and crosstalk.

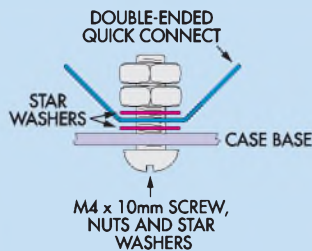


Fig.11: the mains earth terminal is secured to the case as shown here. The top nut serves as a lock-nut, so that the assembly cannot possibly come loose.

Low-voltage wiring

Once you're satisfied that the power supply is working properly, disconnect input power and wire up the $\pm 15\text{V}$ and 5V outputs to the preamp supply inputs. Note that these supplies must be cabled separately, meaning that two wires are required for the 5V supply ($+5\text{V}$ and GND) and three for the $\pm 15\text{V}$ supply ($+15\text{V}$, -15V and GND).

Use medium-duty, multistrand hook-up wire for the job and twist the wires tightly together to reduce noise and improve appearance. Again, run the cable for the 5V supply separately; do not twist it together with the $\pm 15\text{V}$ wiring.

For most installations, the preamp's common (GND) rail should be connected to chassis earth. This is achieved by running a wire from the pad marked 'EARTH' on the preamp board to the main chassis earth point. Do not connect any other part of the preamp circuit or power supply to chassis earth (except the volume pot, see below).

The volume pot must be a dual-gang logarithmic type, preferably $10\text{k}\Omega$ in value. If using a motorised pot, a $20\text{k}\Omega$ value may have to suffice. Don't use a larger value, as this will affect the preamp's noise performance. Do use twin-core shielded cable for each section of the pot, wired as shown in Fig.9.

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 plating on the pot, so remove a small area of the plating

Parts List		Additional items
1 PC board, code 658, available from the <i>EPE PCB Service</i>, size $73\text{mm} \times 192\text{mm}$ 7 DPDT 5V DIL relays (RLY1 to RLY7 – see text) 7 PC-mount gold-plated dual RCA phono sockets (CON8 to CON14) 1 10-way 2.54mm PC mount shrouded header (CON4) 4 3-way $5\text{mm}/5.08\text{mm}$ terminal blocks (CON1 to CON3, CON6) 2 2-way $5\text{mm}/5.08\text{mm}$ terminal blocks (CON5, CON7) 2 5mm ferrite beads (L1, L2) 2 8-pin gold-plated IC sockets 4 M3 x 10mm tapped spacers 4 M3 x 6mm pan head screws 7 self-tapping screws (for RCA phono sockets) Semiconductors 2 OPA2134PA dual FET-input op amps (IC1, IC2) 5 BC327 PNP transistors (Q1-Q5) 1 PN100 NPN transistor (Q6) 8 1N4148 signal diodes (D1-D8) Capacitors 3 $100\mu\text{F}$ 16V PC electrolytic 2 $10\mu\text{F}$ 16V PC electrolytic 4 $47\mu\text{F}$ $35\text{V}/50\text{V}$ non-polarised PC electrolytic (max. 8mm diameter) 2 $22\mu\text{F}$ $35\text{V}/50\text{V}$ non-polarised PC electrolytic (max. 8mm diameter) 2 $2.2\mu\text{F}$ $35\text{V}/50\text{V}$ non-polarised PC electrolytic (max. 5mm diameter) 5 100nF 50V metallised polyester (MKT) 2 220pF 50V ceramic disc 2 56pF 50V ceramic disc Resistors (0.25W 1%) 2 $1\text{M}\Omega$ 2 $2\text{k}\Omega$ 6 $100\text{k}\Omega$ 2 $1.5\text{k}\Omega$ 6 $10\text{k}\Omega$ 2 $1.2\text{k}\Omega$ 2 $4.7\text{k}\Omega$ 2 100Ω 5 $3.3\text{k}\Omega$ 13 0Ω (for links) R1, R2 – see text		1 dual-gang $10\text{k}\Omega$ log potentiometer 1 single-pole 5-way rotary switch 1 10-way IDC cable-mount socket 10-way IDC ribbon cable 2-core shielded audio cable for volume pot connections Medium-duty hook-up wire for low-voltage wiring Power Supply 1 PC board, code 659, available from the <i>EPE PCB Service</i>, size $54.6 \times 80\text{mm}$ 1 Micro-U $19^\circ\text{C}/\text{W}$ TO-220 heatsink 2 3-way $5\text{mm}/5.08\text{mm}$ terminal block (CON1, CON2) 1 2-way $5\text{mm}/5.08\text{mm}$ terminal block (CON3) 4 M3 x 10mm tapped spacers 5 M3 x 6mm pan head screws 1 M3 nut and flat washer Semiconductors 1 LM317T adjustable positive regulator (REG1) 1 LM337T adjustable negative regulator (REG2) 1 7805 $+5\text{V}$ regulator (REG3) 8 1N4004 diodes (D1-D8) Resistors 2 $1.1\text{k}\Omega$ 0.25W 1% 2 100Ω 0.25W 1% 1 330Ω 5W 5% (R2) 1 100Ω 5W 5% (R1) Capacitors 2 $2200\mu\text{F}$ 25V PC electrolytic 2 $100\mu\text{F}$ 16V PC electrolytic 1 $47\mu\text{F}$ 25V PC electrolytic 3 $10\mu\text{F}$ 16V PC electrolytic 2 100nF 50V metallised polyester (MKT) Additional items: 1 $15\text{V}+15\text{V}$ 30VA toroidal transformer 1 Mains switch and connection hardware, including a 500mA fuse and a $1\mu\text{F}$ 250V AC class X2 capacitor

with an ink rubber or scouring pad prior to tinning.

If you've installed the headphone amplifier switching circuitry (RLY6,

RLY7 etc) and have a suitable amplifier board, then connect the headphone audio output (CON6) to the input of your headphone amplifier

OPA134 Series High-Performance Audio Op Amps

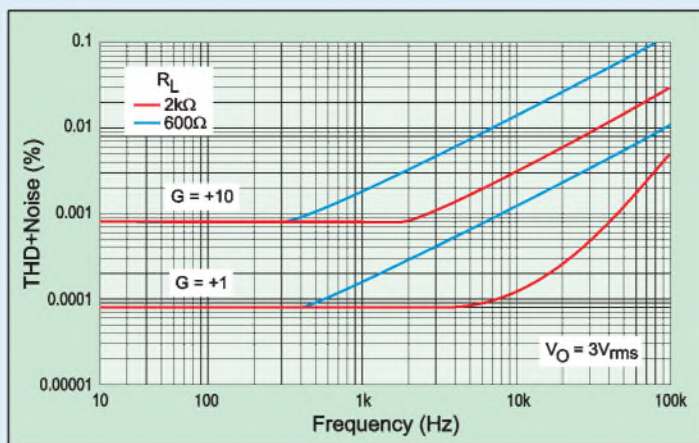


Fig.12: at unity gain, the THD+N performance for these op amps is almost invisible and certainly inaudible! This graph is reproduced from the device's datasheet, which can be obtained from the Texas Instruments website at www.ti.com.

THE OPA134 series op amps include single (OPA134), dual (OPA2134) and quad (OPA4134) versions. The series is fully specified for audio applications, boasting ultra-low distortion and low noise. They include true FET input stages to provide superior sound quality and speed for exceptional audio performance.

This, in combination with high output drive capability and excellent DC performance, allows use in a wide variety of demanding applications. In addition, the OPA134's wide output swing, to within 1V of the supply rails, allows increased headroom, making it ideal for use in any audio circuit.

OPA134 op amps are easy to use and free from the phase inversion and overload problems often found in common FET-input op amps. They can be operated from $\pm 2.5\text{V}$ to $\pm 18\text{V}$ power supplies. Input cascode circuitry provides excellent common-mode rejection and maintains low input bias current over its wide input voltage range, minimising distortion.

These op amps are unity-gain stable and provide excellent dynamic behaviour over a wide range of load

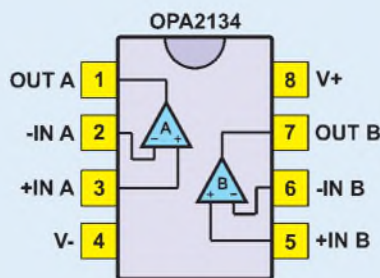


Fig.13: our preamp uses the OPA2134 (dual) version, which follows the industry-standard package configuration.

conditions, including high load capacitance. The dual and quad versions feature completely independent circuitry for lowest crosstalk and freedom from interaction, even when overdriven or overloaded.

Another strong characteristic of this series is its extremely low signal distortion. Total harmonic distortion plus noise (THD+N) is below 0.0004% throughout the audio frequency spectrum (20Hz to 20kHz) with a 2k Ω load. In fact, the THD+N produced by these op amps is below the normal measurement limit of all known commercially available test instruments!

certain earth loop in your system!

Important: if the headphone jack switch isn't connected to the preamp board, then you must insert a shorting link between the two terminals of CON7; otherwise, you'll get no signal from output CON14.

Source selection

As mentioned earlier, each RCA input pair is individually selectable via one control line on the 10-way header (CON4). To select a particular input, simply connect the associated control line to ground (GND).

While we intend to describe a means of remotely controlling the preamplifier's source switching (and volume) in a future issue of *EPE*, a far cheaper and simpler method is to use a mechanical switch. All that's required is a single-pole 5-way rotary switch, a 10-way IDC cable-mount socket and a length of IDC cable.

As the cable doesn't carry low-level audio signals, it can be routed anywhere you like within your case without regard to length. The equivalent electrical circuit for the switch wiring is given in Fig.3.

Final checks

Before connecting inputs and outputs, power up, and with your negative meter probe touching a handy ground point, measure the voltage on the power supply pins of the two op amps. Obviously, pin 8 should measure +15V and pin 4 should measure -15V. In addition, the outputs (pins 1 and 7) of both op amps should be within a few mV of ground.

Finally, if you've connected a source selection switch, you should be able to hear the relays clicking when you rotate the knob.

OK, that's it – you should now have a working hifi preamp! Happy listening!



Prototype Headphone Amplifier. The final version includes a second headphone socket and has a few other minor changes

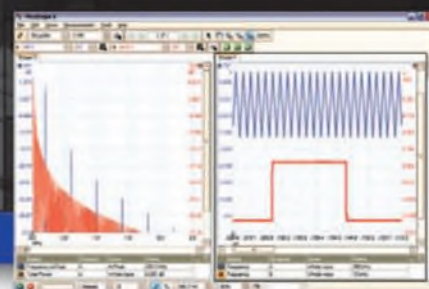
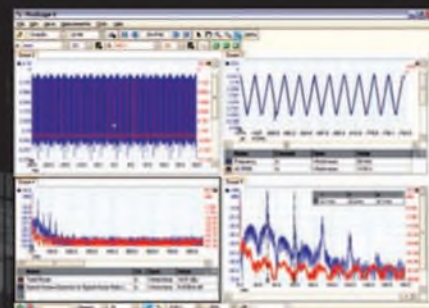
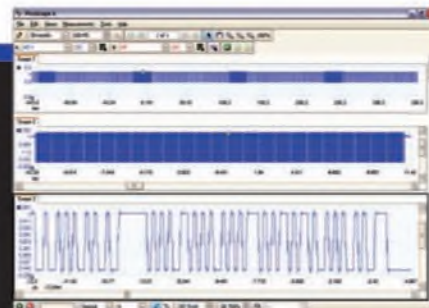
using twin-core shielded cable.

In addition, the switch contacts of the headphone jack socket must be wired to CON7. Many jack sockets have isolated switches built in, so all you need to do is connect across the normally-closed terminals of one of the switches.

However, the switch contacts in

some sockets share a ground connection with the audio signal. If you have this type of socket, then find the contact that is disconnected from ground when the jack is inserted and connect this back to the 'SWITCH' input of CON7, leaving the 'GND' input disconnected. This avoids creating a

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Circuit Surgery

Ian Bell

Concluding our discussion of SPICE simulation

This month we conclude our short series of articles on analogue circuit simulators (SPICE simulation) by taking a quick look at some of the aspects of how SPICE works. Although it is not necessary to have a detailed understanding of the mathematics and algorithms employed by SPICE to make use of it, some understanding is helpful.

Typically, new SPICE users will at some point encounter a circuit which does not simulate correctly, crashes, or runs excessively slowly. Looking through the simulator's menus may reveal a lot of settings which could be tweaked, but without some knowledge of what the simulator is doing it may not be easy to choose which setting to change.

The default values for the various simulator options are chosen by the software developers to give reasonable performance from the simulator for a wide range of circuits. However, as we saw last month, when we looked at simulating an astable multivibrator not all circuits will simulate correctly (or in reasonable time) with the default settings. There are many options and settings which are common to most SPICE simulators, but individual simulators may have unique settings for which you will need to consult their individual user guides.

Equations

For simulation we need to solve circuit equations; we might have $y = f(x)$, which means 'y is a function of x'. The function f for example y might be the current in the circuit and x might be the voltage. We need to know the value of x for which y takes a certain value, typically this might be $y = 0$. This is the case if we are trying to solve Kirchhoff's current law (KCL) which states that the sum of currents flowing into a junction in the circuit is zero. In this case y is the 'sum of currents' and $f(x)$ is a formula obtained from the current-to-voltage relationships for each component connected to the node of interest.

The development of the mathematics behind SPICE simulation of analogue circuits goes back to Isaac Newton (1642-1727), who is often credited as having made the first steps towards modern calculus. One of the methods used by simulators to solve circuit equations is called **Newton's Method** or the **Newton-Raphson Method**. However, Newton's

original papers are somewhat different from our current approach to calculus. Key developments in the technique were made

by Joseph Raphson (in 1690) and Thomas Simpson (in 1740), who finally developed the modern iterative form.

During simulation the circuit equations cannot usually be solved by direct algebraic means, so a numerical approach is used. Fig.1 shows a possible function $y = f(x)$ represented by the blue curve (this could be the voltage/current characteristic of a component). We want to find the value of x for which y is zero (the point at which the curve crosses the x axis). To do this using Newton's method we start with a guess (Fig.1a). We then find the tangent to the curve at this point – this is the straight line with the same slope as the curve at that point (in green on the diagram). We follow the line to the axis to get our next guess (Fig.1b). We can repeat this process a number of times (Fig.1c). This process of repeated calculation is called *iteration*.

If all goes well, we get closer to the correct answer with each new guess – this is known as *convergence*. For any guess we can work out the actual value of $f(x)$ – by using the guess value in the formula – to see how close we are to the desired value. We can repeat the process indefinitely, but in practice we choose some tolerance criterion – once we get sufficiently close the iterations are stopped. SPICE has various settings that might affect this tolerance value.

Convergence

Newton's method is not perfect – it does not always find the answer. This is

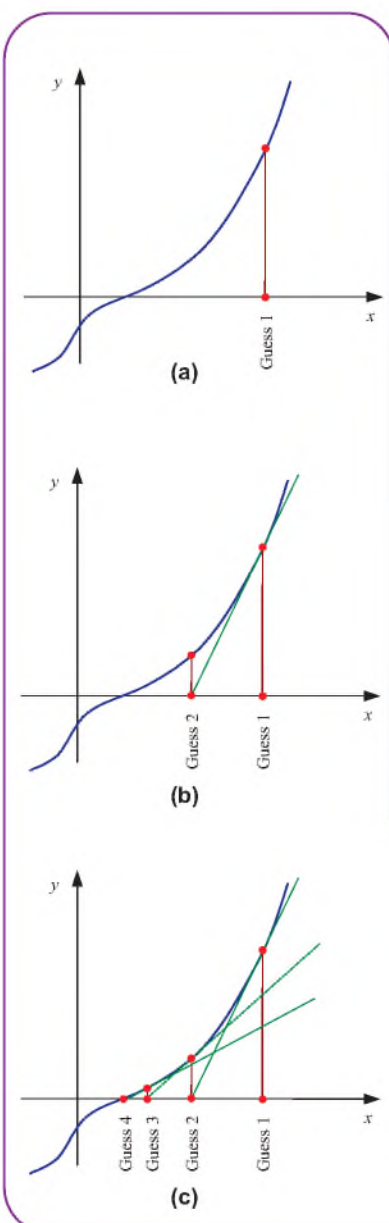


Fig.1. Illustration of Newton's method

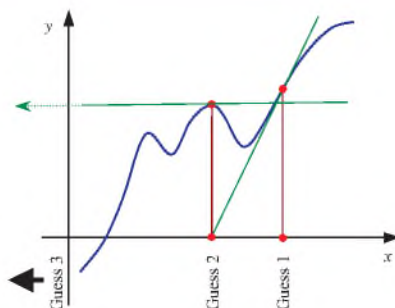


Fig.2. Simple example of Newton's method failing to converge.

illustrated by Fig.2. Here the guesses go off to infinity. In other situations the guesses may jump between two values, rather than converge. In many cases a better initial guess would result in convergence – this is the case with the situation in Fig.2.

Convergence is a key issue for circuit simulators. There is often a trade-off between accuracy and convergence in the various SPICE options. For example, setting SPICE's voltage tolerance value, *vntol*, to very small values in order to increase accuracy may cause convergence to fail. Modern circuit simulators use various strategies to detect and avoid convergence problems, but they do not always succeed, in which case you get a 'convergence failure' error message.

Convergence is measured in two ways – the difference between iterations to find the voltage at a node and the degree to which Kirchhoff's current law has been met. These are called the *update criterion* and *residue criterion* respectively.

The examples we have looked at concern a single equation, but the circuit simulator has to solve a large number of interrelated equations (Kirchhoff's current law applied at each node in the circuit). The Newton-Raphson method is extended to deal with multiple equations using matrix mathematics. Matrices are arrays of numbers and/or interrelated equations.

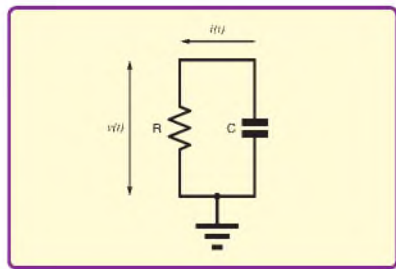


Fig.3. Example circuit (see text)

Transient analysis

SPICE transient analysis computes the response of a circuit as a function of time. From a mathematical point of view this involves the solution of non-linear differential equations. Such equations are generally impossible to solve algebraically. Instead, we can use a step-by-step approach – time is treated as a series of small time steps – and we find the solution to the equation at the next time step based on the current situation and an approximation of the equation at that point. The fact that we use a small time step means that the difference between the true and approximate versions of the equation can be acceptably small.

We can illustrate this with an example. For the RC circuit shown in Fig.3, using Ohms Law, we can write for the resistor:

$$i(t) = \frac{v(t)}{R}$$

and for the capacitor we have:

$$i(t) = -C \frac{dv(t)}{dt}$$

Note that we write $i(t)$ and $v(t)$ rather than just i and v for the current and voltage to indicate they are functions of time (we are doing transient simulation). If you are not familiar with calculus, all you need to know here is that $dv(t)/dt$ means the 'instantaneous rate of change of voltage' (at time t). This is the slope of the curve on the graph (waveform) at each point in time (the slope of the tangent line).

Current flow

There is no power supply in the circuit in Fig.3. We are assuming that the capacitor starts with some charge already on it. It will then discharge through the resistor.

Kirchoff's current law tells us the current in the resistor and capacitor must be equal, so we can combine the two equations (eliminating i):

$$\frac{v(t)}{R} = -C \frac{dv(t)}{dt}$$

To find the solution at each point from 'time zero' to some later time (i.e. the duration of the simulation) we have to start by knowing $v(0)$ – the voltage at time zero. This is called the *initial condition*. The simulator does a DC analysis (using Newton-Raphson), or uses initial conditions set by the user, to start a transient simulation. In general, we cannot solve the circuit equations directly, we have to use some form of approximation to work out 'what happens next' – that is, how do voltages and currents change as time progresses?

There are a number of approaches to this (which go under the general title *integration methods*) and most SPICE simulators provide more than one integration method that can be selected by the user. All these methods use time steps, rather than the 'continuous time' of reality. The simplest integration method is called *Euler's method* (or more strictly the *Forward Euler method*). Leonhard Euler (1707-1783) was a Swiss mathematician who made a major contribution to the development of mathematics. In fact, he is probably one of the greatest mathematicians of all time.

We can rearrange the previous equation for our RC circuit like this:

$$\frac{dv(t)}{dt} = -\frac{v(t)}{RC}$$

Recall that $dv(t)/dt$ is the slope of the line. So at time $t = 0$ the slope is $dv(0)/dt$ and we can draw a tangent to the curve at this point as shown in Fig.4a (magenta line) (the tangent has the same slope as the curve at the point where they touch). By moving a small amount of time, h , forward along the tangent line we can find an estimate for $v(t)$ at a new time (call this time t_1), this is also shown in Fig.4a. The change in $v(t)$ along the tangent line is the slope multiplied by the time step h , so the estimate for $v(t_1)$ is:

$$v(t_1) = v(0) + h \times (\text{slope}) =$$

$$v(0) + h \left(\frac{dv(0)}{dt} \right) = v(0) - h \left(\frac{v(0)}{RC} \right)$$

we repeat this process starting at t_1 to find a value of v at a time h later (time t_2). And so on, as shown in Fig.4b. We can write the equation above in a more general form applicable to any time step:

$$v(t_{\text{new}}) = v(t_{\text{old}}) \left(1 - \frac{h}{RC} \right)$$

Although we have used a specific example here, it is straightforward to develop a general 'next step' Euler method equation for any function. As can be seen from Fig.4b, the Euler method curve deviates from the true curve and the error gets worse as time progresses. We can reduce the error by using smaller time steps or using a better integration method.

Different integration methods produce different approximate equations for estimating $v(t_{\text{new}})$. These estimation equations are more complex than those obtained using Euler's method and will often be non-linear. They can be solved using techniques such as the Newton-Raphson method we described above.

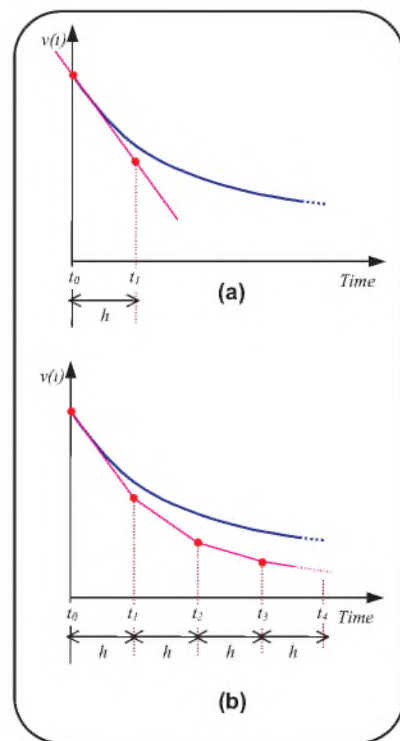


Fig.4. Euler's Method

The fact that approximate methods are used in transient simulators results in errors (as seen in Fig.4). The *Local Truncation Error* (LTE) is the error made at a given time step assuming previous steps were all accurate, and *Global Truncation Error* (GTE) is the maximum accumulated truncation error. Accumulated error is serious because it gets worse as the simulation progresses. Different circuits have widely varying sensitivity to simulation error (tendency to accumulate errors). Circuits with long time constants and oscillators tend to be sensitive to errors; ordinary logic circuits tend to be very insensitive.

SPICE options

SPICE simulation options can be set using the SPICE tab of the Control Panel Window in LTspice (see Fig.5). Other options may require use of the **.OPTIONS** SPICE directive, or be available via other setup windows. There are around 50 different things you can set with the **.OPTIONS**. For more information look up **.OPTIONS** in the LTspice help system. Other SPICE simulators will have many of the same options and a few different ones.

In the following paragraphs we will describe most of the options in the LTspice control panel.

Default Integration Method: SPICE simulators are basically solving sets of non-linear differential equations. Such equations cannot be solved directly so circuit simulators use a variety of approximate techniques, LTspice provides three: *trapezoidal*, *modified trapezoidal* and *Gear*. Other simulators may provide other methods.

Solver: This switches between different systems for solving the simulation equations (using Newton-Raphson or similar). This option is specific to LTspice. It can only be in the Control Panel (not in a **.OPTIONS** statement). The alternative solver will simulate more slowly, but with much greater internal accuracy.

Ttol (Transient Error Tolerance): Spice controls the error (Local Truncation Error) in transient simulation by adjusting the time step. *Ttol* is one of the parameters used in ensuring that the time step is small enough (a very complex criterion). The usual default for *Ttol* in other SPICE simulators is 7, but LTspice uses 1 so that simulations using switch mode power supplies perform better. For transistor-level simulations, a value larger than 1 is usually better and may produce a noticeable speed increase without adversely affecting simulation accuracy.

Gmin: The simulator adds small conductances (large resistors) across non-linear devices (diodes and transistors) to prevent nodes in the circuit from becoming disconnected if the device is fully turned off. In some circuits these added conductances may change the behaviour of the circuit too much. On the other hand, if you make *Gmin* too small the simulator may not be able to solve the circuit equations (no convergence).

Gmin Stepping: This is used in DC analysis (e.g. to find the initial conditions in the circuit for transient simulation). The simulator adds small resistors across non-linear devices (diodes and transistors) so that they dominate the behaviour of the circuit. It solves the circuit and then increases the added resistance value. This process is repeated until the resistors are so large they have no effect on the circuit. The option *gminsteps* can be set to zero to prevent *Gmin* stepping (the box on the control panel ticked).

Noopiter: If this is set to *true* then the simulator skips the usual operating point calculation and goes straight to *Gmin* stepping.

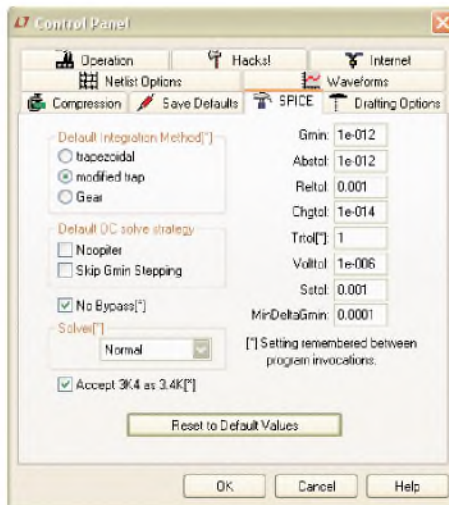


Fig.5. SPICE settings in the control panel

abtol (Absolute current tolerance): For small currents *abtol* is used for checking convergence (residue criterion) and setting time steps. In general, it should be set to about 1 million to 100 million times smaller than the largest circuit current.

reltol (Relative convergence tolerance): This is used to decide when to stop the Newton-Raphson solver iterations; *reltol* is multiplied by the maximum voltage on the node and if the change in approximate solution is less than this, convergence has occurred. This is useful for relatively high voltages, but for very small voltages or currents *reltol* becomes too small and *vntol* or *abtol* determines convergence.

vntol (Absolute voltage tolerance): For small voltages, *vntol* is used to decide on convergence of the Newton-Raphson solver (update criterion) and setting time steps. If the difference between successive solutions is less than this value then the solution has converged. For larger voltages, *reltol* is more important. In general, it should be set to about one million to 100 million times smaller than the largest circuit voltage.



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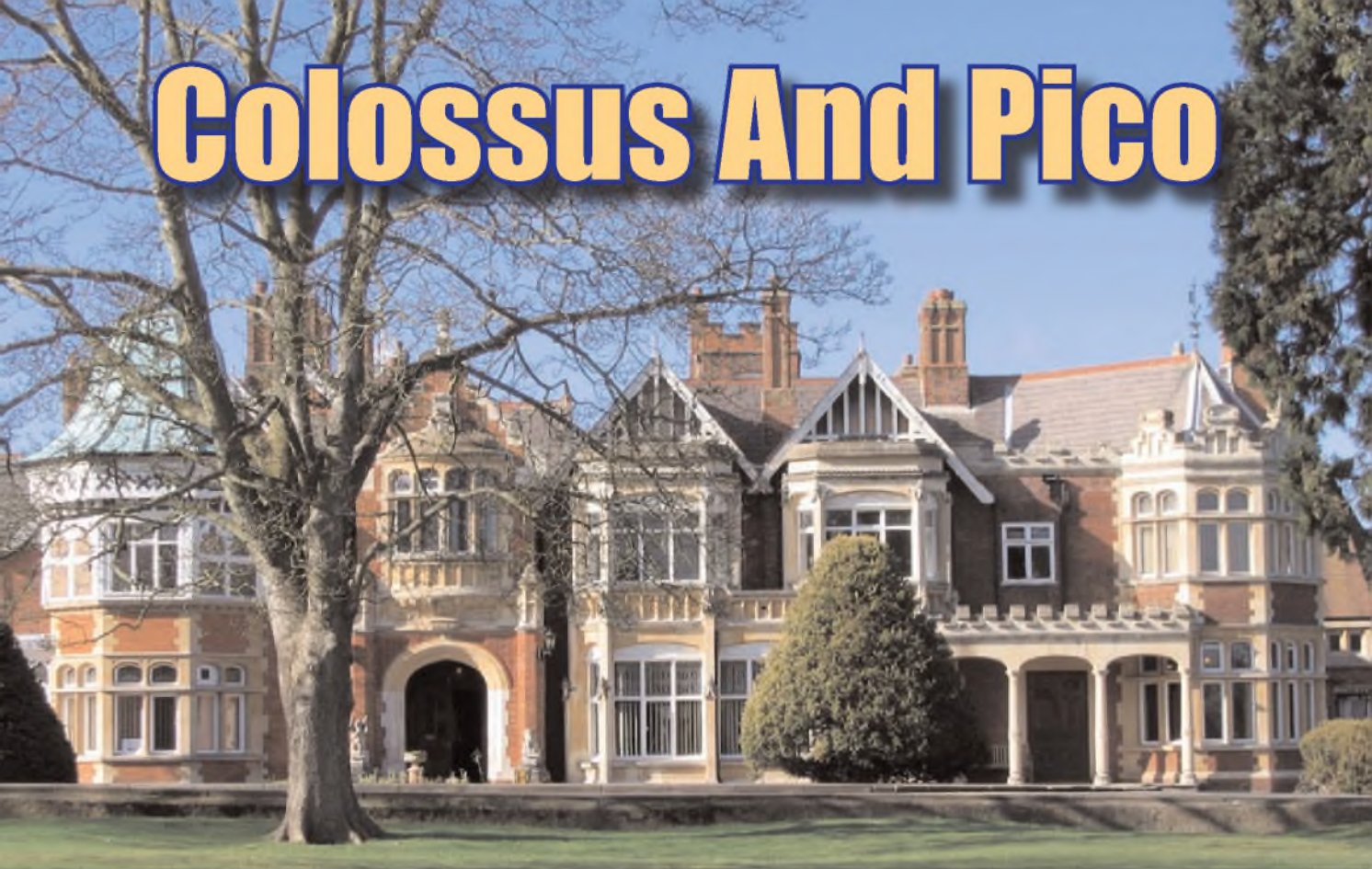
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Colossus And Pico



The world's first programmable electronic computer is linked to a Pico PC-based oscilloscope

SITUATED about 50 miles to the north west of London at Bletchley Park (shown above) is the former WW2 code-breaking centre (also known as Station X). It was here that a dedicated team of talented mathematicians (including Alan Turing) worked to break the German Enigma codes and also the more complex codes used by Hitler and his high command.

Britain's best kept secret

The number of people working at Bletchley Park grew throughout the war to a point where there were literally thousands of people working around the clock decoding and analysing messages. Despite the number of people involved, the German high command had no idea that their security had been compromised and believed that their codes were unbreakable.

The success of the code breakers was one of the key factors in the Allied victory, many historians believing that it shortened the war by up to two years, saving thousands of lives.

After the war, all trace of what occurred at the park was burned or destroyed. Such was the culture of secrecy at Bletchley Park that no word of what happened began to emerge until the mid 1970s. To this day,

many people who worked there are still reluctant to talk about it.

During the war, many ingenious aids and machines were developed at Bletchley Park to aid the breaking of codes. One of these was *Colossus* — the world's first programmable electronic computer. (For many years the honour of being the world's first electronic computer was given to the American ENIAC. In recent years, however, both the UK and US governments have declassified and released papers giving more information about *Colossus*. In the light of this, historians have been forced to reconsider and most now agree that *Colossus* was in fact the world's first programmable electronic computer.)

German codes

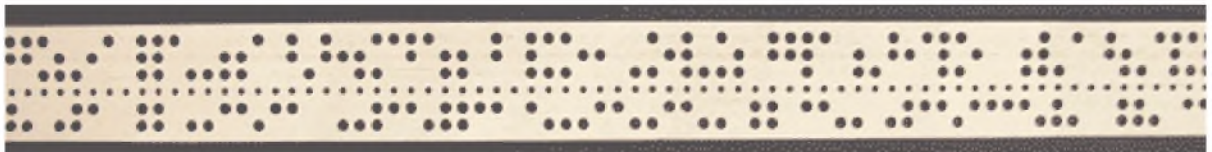
During WW2, the Germans relied mostly on the Enigma machine to encode messages. Enigma traffic was first broken before the war in Poland, and continued to be broken throughout much of the war at Bletchley. (A film based on the Robert Harris book *Enigma*, financed by Mick Jagger and starring Kate Winslet, was released in 2001.) The German Army High Command, however, did not rely on

Enigma, but on a more complex system based on encoded teleprinter traffic using a machine developed by the Lorenz company.

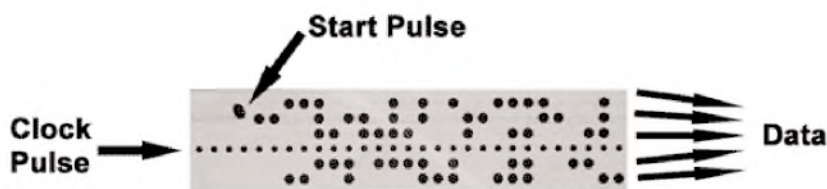
The Lorenz machine worked with teleprinter punched hole paper tape, shown below (32 symbol baudot code). The message was encoded by combining the original with a sequence of obscuring characters using modulo two addition (exclusive NOR in boolean terms). At the receiving end the message was decoded by once again adding the same sequence of obscuring characters.

Had the sequence of obscuring characters been truly random it would have been impossible to break the code, but luckily for the code breakers, the sequence was generated by rotating mechanical wheels and was a repeating pseudorandom sequence — if this sequence could be unravelled then the code could be broken.

Working at Bletchley, Brigadier John Tiltman and Cambridge graduate Bill Tutte exploited mistakes made by German radio operators and began to reconstruct the pseudorandom sequence and discover how the Lorenz encoding machine worked. This was completed in 1942 and the Post Office Research Labs at Dollis Hill were asked to



The teleprinter punched hole paper used by the Lorenz machine



Data and clock pulses on the punched tape



The reconstructed Robinson (above) and Tunny with its keyboard (right)

build a machine to replicate the operation of a Lorenz machine (at this time they had not even seen a picture of a Lorenz machine). With this machine (known as *Tunny*) the code began to be broken. The problem was the time taken to work out the correct settings. This was a manual and laborious task that often took weeks, or even months, for a single message, so long in fact that by the time it was decoded the information was useless.

Brief history of Colossus

Max Newman, the famous mathematician, devised an automated way to find the Lorenz machines' settings. This involved having two loops of paper tape. The first contained the message to be decoded and the second contained the repeating pseudo-random sequence. The idea was that each time the loop of tape containing the

message was fed through the machine, the second tape was moved on by one position. In this way each possible setting was tested and a score recorded for each. The setting with the highest score was hopefully the one required for the *Tunny* machine to decode the message.

TRE (Telecommunications Research Establishment) at Malvern were approached to develop a machine to implement the idea. This machine was based on mechanical relays and known as *Robinson* (as in Heath Robinson). Although *Robinson* worked, it was unreliable. In particular the mechanical tape reader had problems keeping the two tapes in synchronisation at the operating speed of 1000 characters per second.

Tommy Flowers

Newman, looking to solve the problems with *Robinson*, was put in touch with Tommy Flowers, a talented electronics engineer working for the Post Office at Dollis Hill.

Tommy Flowers' design solved the problems of *Robinson* in an innovative way. Rather than using paper tape to store the pseudorandom sequence, Flowers replicated it electronically using a huge array of valves. This saved using two tapes and solved the synchronisation problems. The use of valves for digital switching was also a groundbreaking step which offered a huge increase in operating speed over mechanical relays (valves at the time were regarded by most as unreliable components, used for amplifying analogue signals.)

The design of *Colossus* started in March 1943 and the first unit was operational at Bletchley Park in January 1944. *Colossus* was immediately successful, and the *Colossus-Tunny* combination allowed 'high grade' German codes to be decoded in hours. This proved immensely useful during the D-Day landings. The parallel design of *Colossus* made it incredibly fast, even by today's standards.





Two views of the rebuilt Colossus, the tape reader can be seen on the right in the photo above



A total of ten *Colossi* were built, the design being improved and upgraded throughout the rest of the war. These machines were used to decode tens of thousands of intercepted messages and made a huge contribution to the Allied victory.

At the end of the war, to keep their existence secret, the ten *Colossi* were dismantled and all the technical drawings and diagrams were burned. Their existence was to remain a secret for nearly 30 years.

Colossus rebuild

As already mentioned, information about what happened at Bletchley began to leak out in the 1970s. In the early 1990s a campaign was started to save what remained of the park from demolition (for housing). One of the campaigners was Tony Sale, who went on to become the first curator of the Bletchley Park Museum. (Tony Sale worked for many years with MI5, including a period as technical assistant to Peter Wright, of *Spycatcher* fame)

In 1993, Tony Sale collected all the information available on Colossus, which amounted to a few wartime photos, some fragments of circuit diagrams and interviews with some of the

surviving design engineers. Armed with this information he decided to rebuild a *Colossus*.

The rebuild project started in 1994 at Bletchley Park, on the site of the original *Colossus* number nine computer. By June 1996 Tony Sale and his team were ready to switch on (albeit only working at a two bit level rather than the full five bits). The switch-on was performed by HRH the Duke of Kent on the 6 June 1996. Present also was Dr Tommy Flowers, the original designer.

Full working

In November 2007 *Colossus* was returned to full working order and deciphered a teleprinter message transmitted by radio from Paderborn in Germany, where it had been encrypted by one of the original Lorenz cipher machines. The rebuild can be seen during the museum open days (see links at the end). For readers wanting more information on the rebuild, Tony Sale has a excellent website.

PicoScope

One of the problems with *Robinson*, the forerunner of *Colossus*, was the tape reader. This read the tape containing the coded message in the 'conventional' manner, which involved mechanically driving the tape through the reader using the centre row of punched holes. This limited the speed to 1000 characters per second, as above this the tape would rip apart.

An optical tape reader was designed for *Colossus* in 1942 by Dr Arnold Lynch, and could read at 5000 characters per second. This used an optical system to read not just the five bits of data, but also the row of holes that normally were used to mechanically drive the tape. The signals from this row were used as the clock pulse to synchronise the whole computer (in the same way as a modern computer is synchronised to a master clock). The benefit of this system is that the tape could be run on low- friction wheels and the speed of operation was not critical.

The photocells and optical mask (below) The black tape on the top of the photocells is a modern addition to prevent pickup of the fluorescent lights



In the photograph of the *Colossus* rebuild, the tape reader can be seen on the right. A bright light is shone through the tape and focused onto hard vacuum photocells, one for each bit of data and one for the clock pulse. The photocells used in the rebuild are original *Colossus* parts.

Before the light hits the photocells, it is 'shaped' by passing through an optical mask (supported by the wooden frame on the left in the photo). This helps ensure the signals produced by the valves are of a uniform square shape. The black tape on the top of the photocells is a modern addition to prevent pickup of the overhead fluorescent lights!

The *Colossus* rebuild at Bletchley is housed in a room with windows at one end for public viewing. Unfortunately, this makes the photocells difficult to see as they are at the far end of the room. To improve visitors' understanding of what is happening at the tape reader, it was decided to capture the signals from the photocells and display them on a PC-based oscilloscope. A PC-based oscilloscope was chosen as the large colour display from the monitor makes it ideal when several people want to see the data at the same time.

Simple task

When the technical team at Pico Technology volunteered to help display the signals, they thought the task would be a simple one. After all, they are used to connecting oscilloscopes to computers with clock speeds thousands of times faster than *Colossus* – of course, the task proved a bit more involved than expected.

The original idea was to place a PC and a PicoScope ADC-212 PC-based oscilloscope in the public viewing area and run the analogue signal from the valves down a long cable to the scope's inputs. The problem was that the extra capacitance from the leads prevented the valves from operating correctly. To solve this problem one of the Pico technicians (David Sabine) built a high input impedance, low-capacitance buffer amplifier.

The buffer amplifier takes signals from the photodiodes and transmits them along about 30 feet of cable to the PC-based scope. Power is also fed back up the cable to power the buffer amplifier.

In the photo, above right, the buffer amplifier can be seen in place next to the optical tape reader. The cables are taken up through the roof void, across and down to the computer with the PC-based scope. Once connected up, the system worked first time. The top trace (blue) shows the clock pulse (from the narrow holes on the tape) and the bottom trace (red) shows one of the data streams from the tape. Below the scope display is one of PicoScope's automated measurements to display the frequency of the clock signal. As you can see, this is very close to the 5000 characters per second the tape reader was designed to run at.

More information

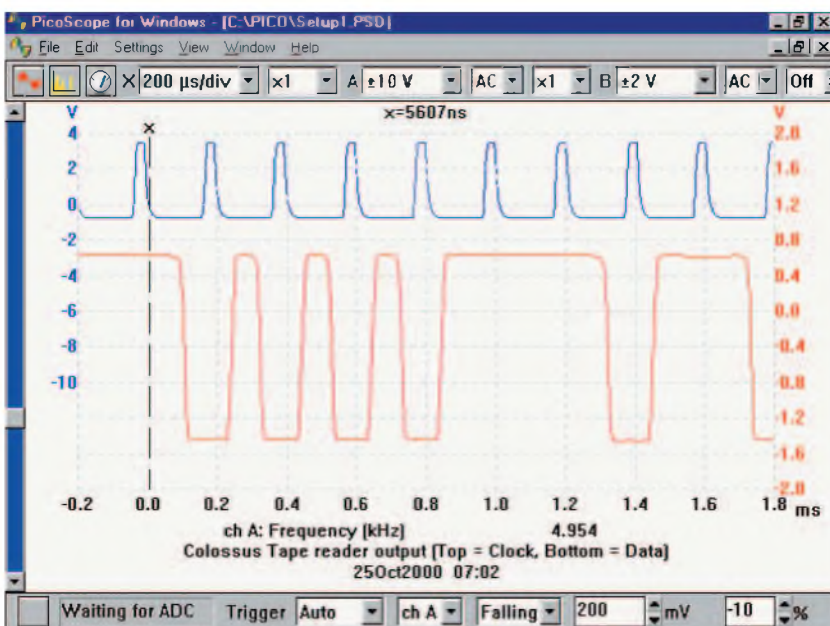
For more information on the *Colossus* rebuild project, visit Tony Sale's website at www.codesandciphers.org.uk.

If you are interested in visiting Bletchley Park (a good day out) visit www.bletchleypark.org.uk

Pico Technology www.picotech.com



The Pico buffer amplifier and the tape reader (above). The PicoScope display is shown below



The Lorenz machine being taken to the Heinz Nixdorf museum in Germany by the army. Dr Tony Sale looks on. (Photographs: Bletchley Park Trust and Pico Technology)



The tiny droplet size resulting from the use of the 'espresso' pump and a Spraying Systems nozzle can be seen here. In this case, the nozzle is aimed forwards and the car drives into the cloud of water droplets. These very effectively cool a front-mounted intercooler and as a bonus also help cool the other radiators!

By JULIAN EDGAR

Low-Cost Intercooler Water Spray Controller

A cheap but sophisticated way of controlling a turbo car intercooler water spray

MOST TURBOCHARGED petrol and diesel car engines use intercoolers – radiators that cool the air after it has been compressed by the turbo. An intercooler has the twin benefits of providing more power (the intake charge is cooler and therefore denser) and, in the case of petrol engines, reducing the chance of detonation.

In many cases though, the intercooler is too small for best performance – especially on hot days. This can be greatly improved by adding a water spray – the small droplets evaporate on the core, lowering its temperature.

How do you trigger the spray? Many people use a boost pressure switch – but this wastes lots of water because the spray operates even when the intercooler is cool. Another

approach is to use a temperature switch, but this also wastes a huge amount of water because it doesn't take into account heat-soak (eg, when the car is stopped for a long time in traffic), where a simple temperature switch can continue to run the spray until the tank is emptied. Also, both types of switch cannot easily be adjusted for their switch-on points.

Possibly the best way to trigger the water spray is on the basis of measured intercooler temperature and engine load; when both are high, the spray is switched on. This wastes very little water because the spray operates only when it is really needed.

So now we know what we want – but how to get it? The answer is that the *Smart Mixture Display* project

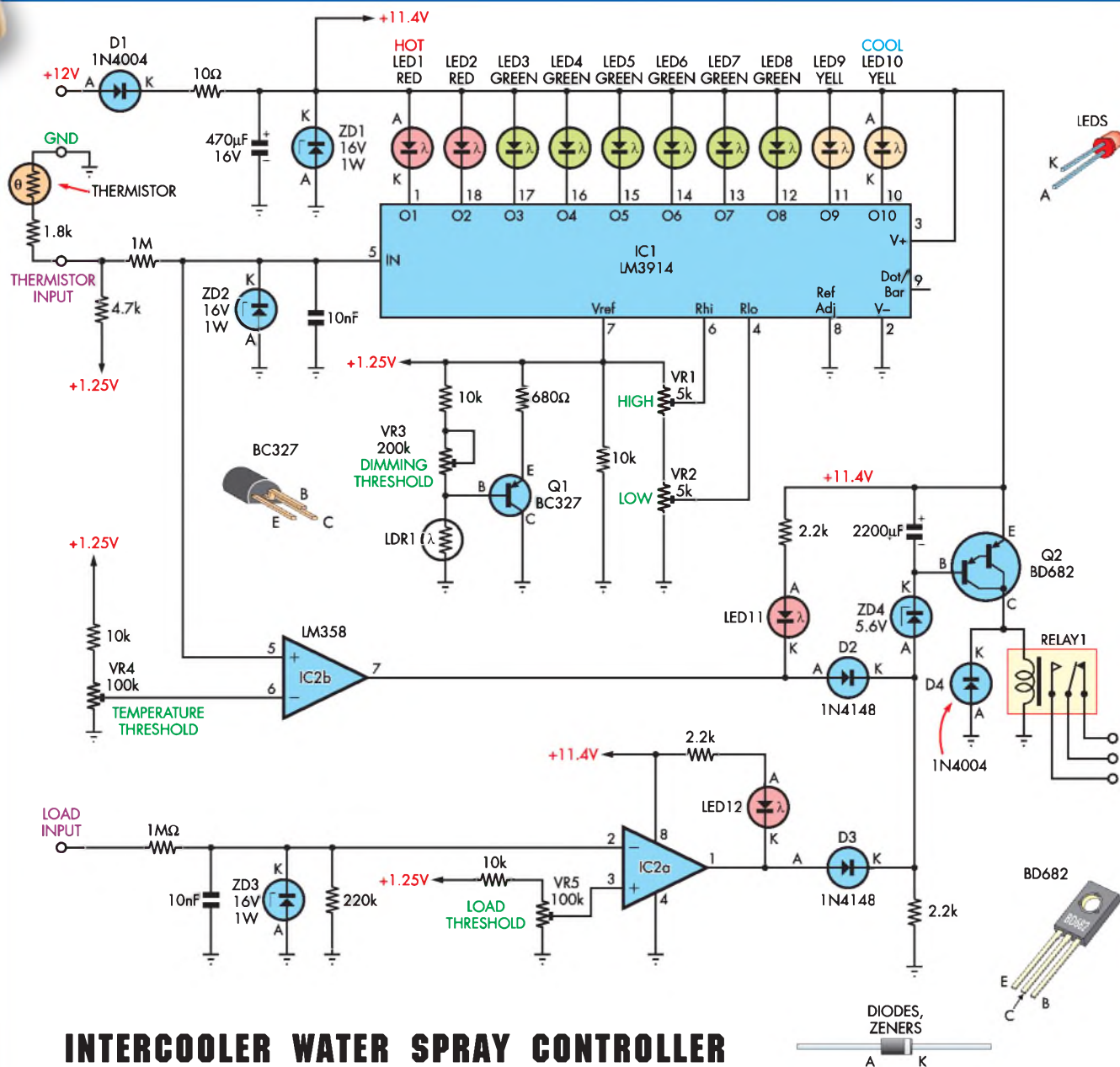
(described in the September 2006 issue of *EPE*) provides nearly all that we need. In fact, it provides even more features, with a colour LED bargraph that can be used to show intercooler temperature!

To transform it into its new function we need add only a handful of components and make some simple changes to the PC board, none of which require cutting tracks.

That makes it one very cheap and easy-to-build Intercooler Water Spray Controller!

Smart mixture meter

The *Smart Mixture Display* was designed to monitor the output of the oxygen sensor, which indicates the rich/lean status of the air/fuel ratio.



INTERCOOLER WATER SPRAY CONTROLLER

Fig.1: the circuit is virtually identical to the *Smart Mixture Display*, described in the September 2006 issue of *EPE*. An LM3914 IC drives the display LEDs, while op amp IC2b, transistor Q2 and Relay 1 control the water spray.

Two inputs were provided – one from the oxygen sensor (with its output shown on an LED bargraph) and the other from a load sensor, such as the airflow meter. When the load was above a set threshold and the output of the oxygen sensor showed that the fuel mixture was lean, a piezo alarm sounded, to give a 'lean-out' warning.

We have adapted the *Smart Mixture Display* to control a water spray controller. It needs a load input with an adjustable switching threshold, while the oxygen sensor input is connected to a thermistor, with its output

configured to drop with increasing temperature.

Therefore, with very little change to the existing project, the piezo alarm will sound when the intercooler temperature and engine load are both high. But instead of operating a piezo buzzer, the circuit now operates a heavy-duty automotive relay, to switch a spray pump.

Finally, so that the intercooler water spray won't turn off during gear-changes or when the load is fluctuating rapidly, we add a one-second switch-on delay and a two-second switch-off delay.

New Parts Required

- 1 PC board, code 584, available from the *EPE PCB Service*, size 121mm x 59mm
- 1 BD682 PNP Darlington transistor (Q2)
- 1 1N4004 silicon diode (D4)
- 1 single-pole single-throw (SPST) 30A automotive relay
- 1 2200μF 16V electrolytic capacitor
- 1 4.7kΩ 0.25W resistor
- 1 1.8kΩ 0.25W resistor
- 1 4.7kΩ thermistor

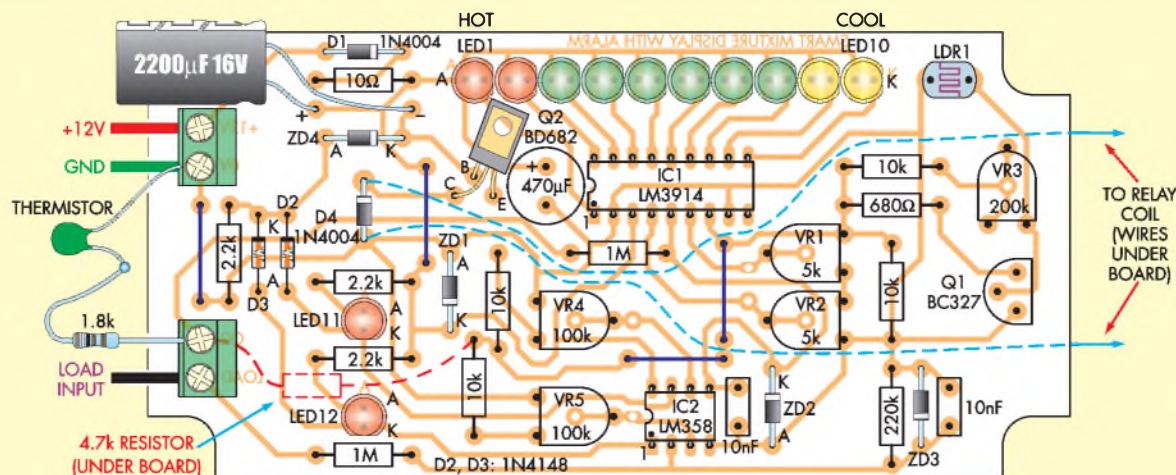


Fig.2: this is the modified PC board layout for the Intercooler Water Spray Controller. Alternatively, you can build the *Smart Mixture Display* exactly as detailed in the Sept '06 article instructions, verify that it is all working correctly and then modify it by following the step-by-step instructions in the article. Don't forget the 4.7kΩ resistor that's fitted on the copper side of the board (shown in red) – it should be insulated from the tracks using heatshrink sleeving – see text.

Changing the mixture meter

The Intercooler Water Spray Controller can be built in two ways. The first way – best if you're a beginner – is to build the *Smart Mixture Display* exactly as per the original instructions. That way, you can test the final result and be sure that the device is working before undertaking the modifications that turn it into the Intercooler Water Spray Controller.

The other way is to build the project from scratch as the Intercooler Water Spray Controller, incorporating the modifications as you proceed. Here are the modifications:

THERMISTOR INPUT: as indicated earlier, a thermistor is used to sense intercooler core temperature – the resistance of the thermistor decreases with increasing temperature. So that the voltage signal received from the thermistor never drops to near zero (which

would cause all the bargraph LEDs to be off), a 1.8kΩ resistor is wired in series with it. It's easiest to solder the resistor in-line with the cable going to the thermistor and then cover the lot with heatshrink sleeving.

The thermistor/resistor assembly is then wired between the original Oxygen Sensor input (now the Thermistor Input!) and the ground connection.

In order that it acts as a voltage divider, power needs to be supplied to the thermistor. This is achieved by wiring a 4.7kΩ resistor between pin 7 of IC1 and the thermistor input. The new resistor and its connecting wiring are most easily soldered into place under the PC board, with the additions insulated with heatshrink sleeving.

As with all the PC board changes, Fig.2 shows where this resistor goes.

If you have built the *Smart Mixture Display* and want to test the modifications as you go along, you can now

power up the board and check that when you heat the thermistor, the illuminated LED moves along the scale.

DARLINGTON TRANSISTOR: Q2, the original BC327 transistor, is not up to the task of supplying enough current to run a heavy-duty relay and so needs to be replaced. The selected replacement is a BD682 Darlington transistor. Note that the pinouts of this transistor are



A simple pump/reservoir combination for an intercooler water spray can be cheaply obtained by using a windscreen washer reservoir and pump.

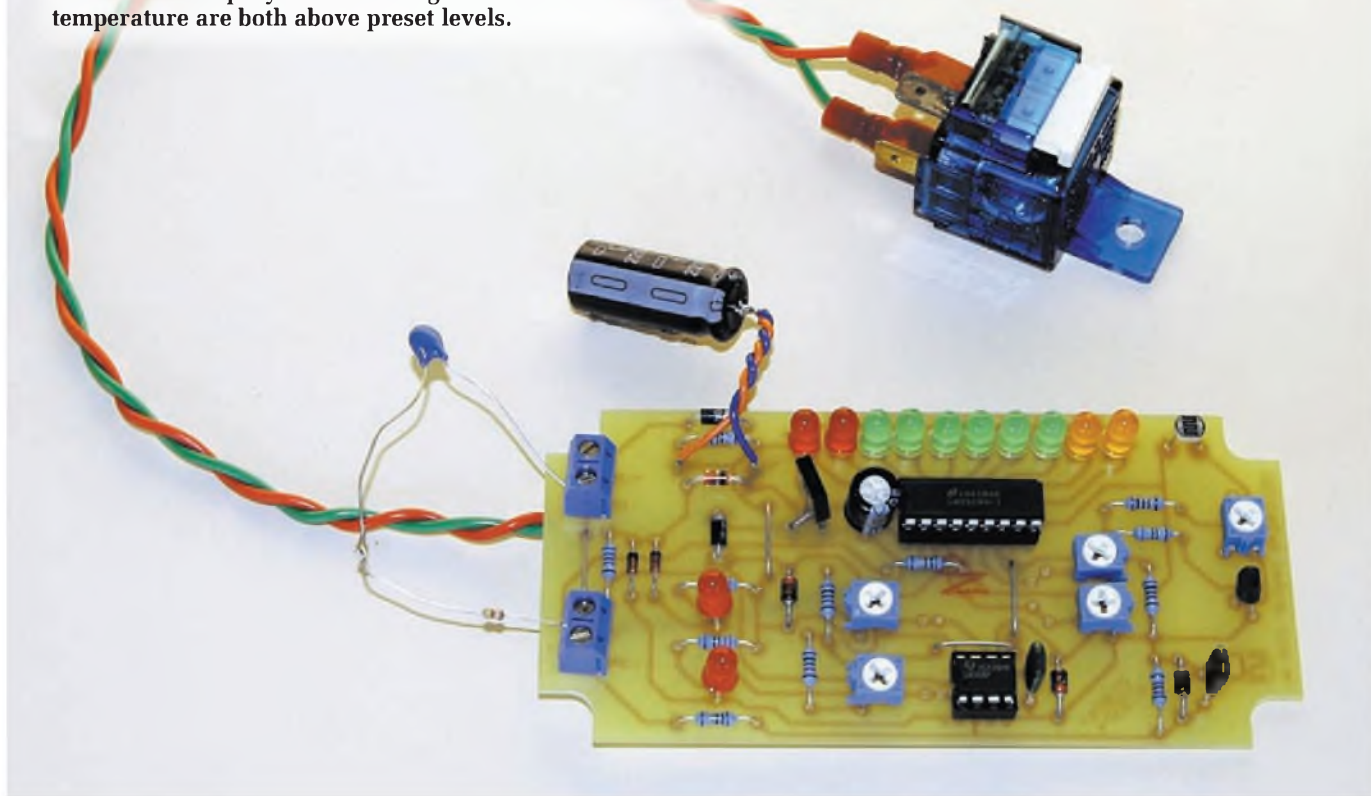
Why Measure Intercooler Temperature?

At first glance it would seem that rather than measuring intercooler core temperature, it would be better to monitor actual intake air temperature. However, this is not so. Intake air temperature can rise substantially when the vehicle is stopped, for example, at traffic lights.

However, if the stop is a short one, the intercooler will remain relatively cool. If intake air temperature was being monitored to trigger the spray, the spray would come on when the car was driven off under high load. But the intercooler would in fact still be cool – so water would have been wasted.

The Intercooler Water Spray Controller is based on the *Smart Mixture Display*, previously published in *EPE*. Seven new components are needed and the modifications are straightforward. The Water Spray Controller operates an intercooler spray whenever engine load and intercooler temperature are both above preset levels.

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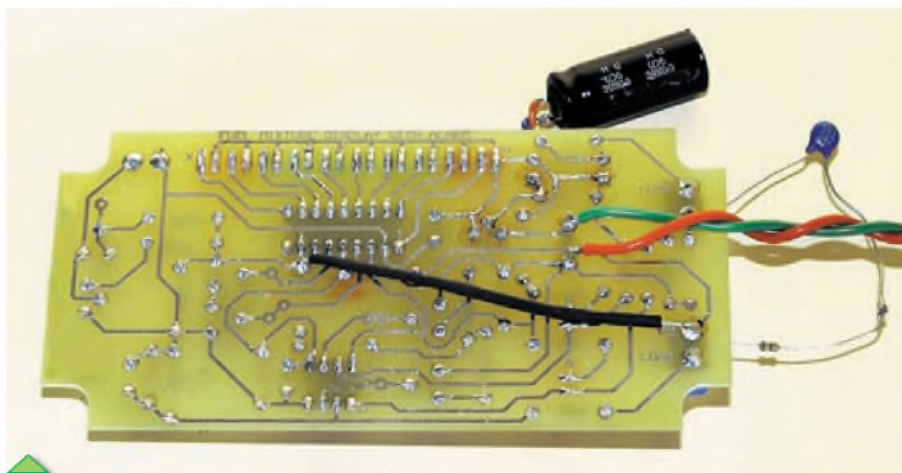


not the same as the original BC327, so care must be taken in following the overlay diagram (Fig.2) and the photographs when installing this device.

At this stage, remove the 680Ω resistor that is positioned on the PC board directly above Zener diode ZD4. Now, with the new transistor in place, the board should work as it did previously. That is, by appropriately setting trimpots VR4 and VR5, LEDs 11 and 12 should be able to be switched on and when they are both illuminated, the piezo buzzer should sound.

DIODE AND RELAY: the relay and the transistor protection diode (D4) replace the piezo buzzer. The 1N4004 diode is placed so that its cathode (the white band) is towards the top of the PC board. Again, check the overlay diagram and photos.

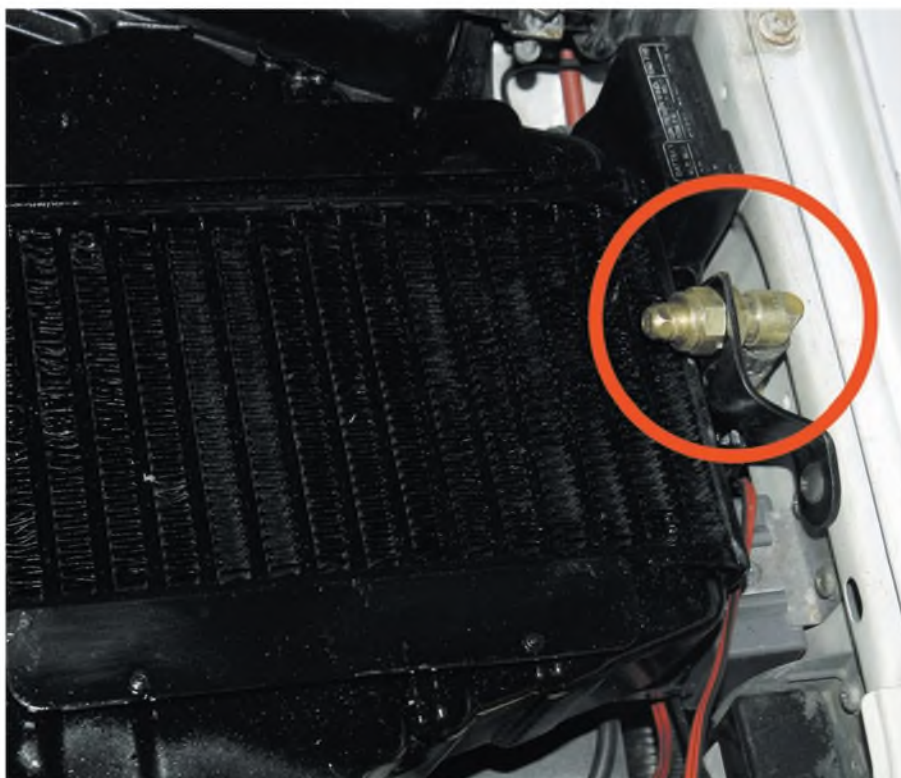
When you have inserted and soldered this diode in place, don't cut the leads off short. Instead, leave enough of each lead protruding through the board to allow flying leads to be easily soldered to them. Connect these flying leads to the relay's coil contacts.



ABOVE: two changes are made on the back of the PC board: (1) a 4.7kΩ resistor is used to link pin 7 of IC1 with the thermistor input (here the resistor is covered in heatshrink); and (2) two flying leads are added, one to each side of the diode that's installed in place of the piezo buzzer. These flying leads connect to the relay coil.

RIGHT: transistor Q2 is now a BD682. Its pinouts are not the same as the original BC327: the new transistor must be installed as shown here.





The nozzle (circled) sprays a fine mist of water over the intercooler to improve performance. A spray is especially beneficial when the intercooler is mounted under the bonnet.

We suggest you use a heavy-duty automotive type relay, in which case these leads will usually connect to terminals 85 and 86 on the relay.

If you're checking things as you go along, power up the board and confirm that the relay pulls in with an audible click whenever LEDs 11 and 12 are both illuminated.

DELAY: the switch-on and switch-off delays are provided by a 2200 μ F

capacitor wired in where the 680 Ω resistor previously resided. This won't fit on the board, so it should be wired in place with insulated flying leads and then glued to the inside of the box or placed horizontally over the new diode. When viewed as shown in the overlay and photos, the capacitor should be wired with its negative lead to the right.

Testing of the finished design should show that when LEDs 11 and 12 are on,

there is a short delay before the relay pulls in. Also, when one or both LEDs switch off, there should be a longer delay before the relay drops out.

If you want to increase the length of these delays, increase the value of the capacitor – say by adding another 2200 μ F 16V capacitor in parallel. If you want to decrease the length of the delays, reduce the value of the capacitor.

Note that because this capacitor provides an anti-chatter function, the lowest value that should be used is 1000 μ F.

OPTIONS: if you wish to, you can alter the position of the LEDs to better indicate the rise in intercooler temperature. For example, you can swap the position of the green and yellow LEDs so that as temperature rises, the illuminated LED alters from green through to yellow and then red. Or you can replace some of the green LEDs with yellow LEDs, etc.

Bench calibration

Now for the calibration. First, set both trimpots VR1 and VR2 to their centre positions. That done, ensure that the thermistor is at room temperature (~20°C), then rotate VR1 until LED9 (yellow) lights. When it does, adjust VR1 a little further anticlockwise until LED10 is just lit.

Warming the thermistor with your hand should then move the illuminated LED from LED10 to LED9.

Now use a heat-gun to further warm the thermistor. When it is just too hot to touch (eg, 55°C), rotate VR2 clockwise until LED1 (the 'hottest' LED) lights. Make sure you don't turn it so far the LED goes out. When the thermistor is again cold, you may need to tweak VR1, as the presets interact with each other to some extent.

When calibrated in this manner, the bargraph display is then configured to show intercooler temperatures over approximately a 20 to 55°C range. Note that because of the thermistor's characteristics, the bargraph isn't linear – it needs a bigger change in temperature to move an LED at the hot end than it does at the cold end.

Installation

For remote installation, the thermistor should be soldered to some twin-core flex and the joins insulated with heatshrink sleeving. The thermistor

Quick Guide To The LEDs & Trimpots

The article on the Smart Mixture Display explains how the circuit works and lists in more detail the function of each LED and pot. But here's a quick reference guide for when the circuit is being used as an Intercooler Water Spray Controller:

- LEDs1-10: show temperature based on thermistor input, LED1 (red) indicating hottest and LED10 (yellow) indicating coldest
- LED11: 'on' indicates the trip point for temperature has been reached
- LED12 'on' indicates the trip point for load has been reached
- VR1 sets the cold end of the scale
- VR2 sets the hot end of the scale
- VR3 sets the night dimmer sensitivity
- VR4 sets the temperature trip point



This Ulka solenoid pump is capable of extremely high pressure, resulting in a very finely atomised intercooler spray. The pump is normally used in espresso coffee machines and requires a small 12V DC to 240V AC inverter to run in car applications.



This Spraying Systems nozzle incorporates a filter. The nozzle gives far better results than the small garden irrigation nozzles that are widely used in intercooler spray applications.

should then be pushed well into the fins of the intercooler, inserting it from the rear of the core. This location will give the best indication of intercooler temperature. The thermistor may need to be held in place with a dab of silicone adhesive.

The load input for the Intercooler Water Spray Controller can be taken from the airflow meter or MAP sensor outputs – or where these are not available, from the throttle position sensor. This can be done at the ECU or the sensor itself. Use the workshop manual wiring diagram to find the load sensor output and then use your multimeter to check that it's correct. The measured voltage on the load sensor output should rise with engine load.

Note, however, that some cars use a frequency output on the airflow meter. In that case, use the throttle position sensor output.

The intercooler water spray pump relay is best located under the bonnet, close to the pump. Test that when trimpots VR4 and VR5 are adjusted so that their adjacent LEDs are on, the pump turns on and the water spray operates.

Driving tests

With an assistant in the car, drive the car and monitor the displayed temperature on the bargraph. The lit LED should move up and down the display with the variation in intercooler temperature. Adjust VR4 until its adjoining LED lights when the intercooler is becoming warm. Then adjust VR5

until its adjoining LED lights when the car is coming onto boost.

Drive the car so that the intercooler gets warm and the car is under load and check that both LED11 (intercooler temperature) and LED12 (load) light. When both have been lit for more than about a second, the water spray will operate. (If you want an on-dash indication that the water spray pump is running, wire a 12V pilot light in parallel with the pump.)

After monitoring the displayed intercooler temperature, you may decide that you want to make further adjustments to the load or temperature trip points. Another important aspect to keep in mind when setting these thresholds is water consumption – check this over a few weeks to make

sure that you haven't got the system tripping too early.

The Intercooler Water Spray Controller can be mounted so that the bargraph LEDs can be seen by the driver or alternatively, the whole device can be located out of sight.

Conclusion

Intercooler water sprays are a very effective and cheap way of upgrading intercooler performance. However, using a 'dumb' system to trigger the spray often results in the need for frequent water top-ups.

Compared with such an approach, the Intercooler Water Spray Controller is likely to reduce water consumption by up to two-thirds, with no loss in cooling efficiency. **EPE**

Water Spray Pumps And Nozzles

The cheapest and simplest pump and nozzle combination is to use a windscreen washer pump and reservoir and a miniature garden irrigation spray nozzle.

A dramatic improvement in spray quality can be gained by using nozzle assemblies from US company, Spraying Systems. These incorporate a mesh filter and provide much smaller droplet size than can be achieved with the garden nozzle, their UK website is **www.spray-uk.com**. These nozzles can be used with windscreen washer pumps.

However, if you want an intercooler spray of almost unbelievable efficiency, use the Spraying Systems nozzle with an Ulka solenoid pump, as used in cappuccino coffee machines. These 240V AC pumps develop extremely high pressures, are designed to flow water, are light and small, and are quiet-running. In car applications, a small 12V DC to 240V AC inverter can be used to power them. Available from BellaBarista: **www.bellabarista.co.uk**.

Teach-In 2008

Part Four – Using alphanumeric LCDs under PIC control

JOHN BECKER



In this fourth part of *Teach In 2008*, we show you how to use an alphanumeric liquid crystal display (LCD) with your PIC projects, and then show a demonstration on a breadboard of the LCD being used as the visual output for an event counter.

Towards the end of this part we shall say a bit more about the use of switches, particularly with regard to a program's selective reaction to them.

A detailed discussion of the fundamental aspects of an LCD's control (but not using a PIC) is available for free download from the *Resources* section of the *EPE* website at www.epemag.co.uk. The article is called *How to use Intelligent LCDs*.

LCD connections

A standard alphanumeric LCD is used, connected to the Control PCB described in Part 1, and for which pin connections were provided on the PCB – those at the right-hand side of the PCB, annotated for LCD use.

Referring to Fig.4.1 and ignoring the switches shown for the moment, wire your LCD to a connector suitable for plugging onto the Control PCB LCD pinouts. If you cannot obtain one, then the LCD connections should be hard-wired and soldered to the pins. Ensure you get the connection order correct.

Note that there is a variety of LCD pinout formats. Two of the most common are shown in Fig.4.2. Load the PIC with program **TEACHIND01.HEX**. Once loaded, the program will go straight into the LCD

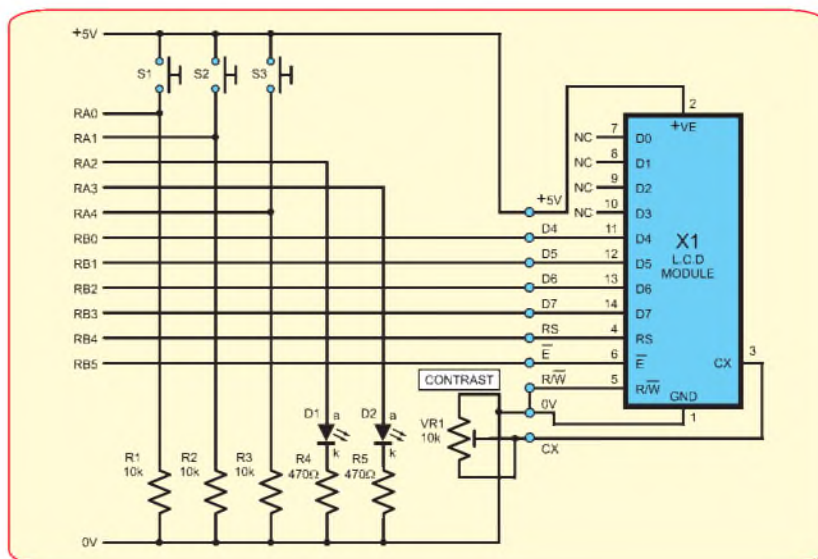


Fig.4.1. Circuit diagram for the examples in Part 4

demonstration routines and show the simple message **READ EPE** on line 1 (top line). If it fails to do so, check your connections. Adjust preset VR1 until the best contrast for the display is shown.

The source code for the program is shown in Listing 4.1

CBLOCK and ENDC instructions

The first five lines of code you have met in previous parts. The sixth line has the indented (column 2) instruction:

CBLOCK h'20'

You have seen similar in the earlier parts, but the use of CBLOCK has not been explained. CBLOCK is a shorthand instruction which allows a simple technique for specifying user register names and allocating them to PIC addresses without using any address value, except for the value following CBLOCK, h'20'.

PICs have one or more areas of memory reserved for user registers. For the PIC16F628, and some other PICs, h'20' (hexadecimal 20) is the earliest address

value which can be used. The area available then extends, for the F628, up to h'7F'.

When CBLOCK is specified, any name that follows (set hard left on the screen/file page, in column 1) is allocated an incremental value according to that specified in the CBLOCK statement. Thus, in Listing 4.1, RSLINE is automatically allocated with the address h'20', STORE is allocated as h'21', and so on.

The allocation continues until the terminating ENDC statement is found (indented – column 2).

Following ENDC, the **_config** statement is encountered as previously. It is followed by the ORG statements previously discussed.

LCD display program routines

We shall not explain in detail how the LCD is actually controlled, simply show how it can be done using a technique which you can follow in your own software.

There are two main sections of code that you need for LCD control, both brought in at different program points using *include* statements. The first is a table

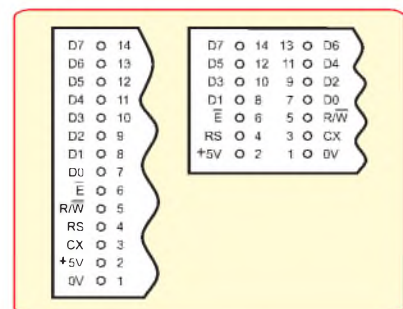


Fig.4.2. Two common arrangements for LCD pinouts

used towards the top of the program, in the same place as the table illustrated last month (we shall explain in a future part more about tables and how many you can use). It is in file **LCDheader.inc**.

This file holds the initialisation commands necessary to set the LCD into 4-bit control mode.

Whereas *include* files containing PIC register details, such as **p16f628.inc**, do not consume PIC memory, other *include* files containing program commands *do* consume PIC memory. It is worth remembering this fact if you are working close to a PIC's memory program limit. Examining a program's **.lst** file shows memory use details.

Next, follows another table, **MESSAG**, holding the data for a message to be shown on the LCD's screen (**READ EPE**). Neither table is accessed by the program until later.

Now follows the instruction to input another *include* file, **LCDroutines.inc**. This holds a number of subroutines associated with LCD control, as described shortly.

Then comes label **STARTIT** and the PICs initialisation commands, as discussed previously. The value then sent to the **OPTION_REG** is different to that previously used. The **PORTB** pullups are turned off by setting bit 7 to 1, as they are not needed.

OPTION_REG's bits 1 and 2 are also shown to be set. The reason is to do with the PIC's internal timer, **TMR0**, being used in this program, and the first three bits (0 to 2) of **OPTION_REG** determine its rate. This is discussed later, suffice to say for now that use of the timer provides several delay periods necessary for the correct initialisation of the LCD, and is of use for other purposes too, used in earlier parts, but not explained then.

The first delay period is called following the **BANK0** statement: **call PAUSIT**. This too will be discussed later. The sub-routine **PAUSIT** is not shown in Listing 4.1.

Now follows **call LCDSET**. This accesses the routine of that name, held in the **LCDroutines.inc** file. This routine performs the LCD initialisation. It is followed by another delay caused by the call to **PAUSIT**. This allows the LCD time to 'settle in' to the configuration given to it.

A call is then made to the routine starting at label **LCDMSG**. This sends data for display on the LCD. First, a counter, **LOOP**, is cleared. Then the command **bsf RSLINE,4** is given. This instructs the LCD, via its RS line connected to **PORTB** pin 4, that the data about to be sent is intended for display, rather than as initialisation commands, for which **RSLINE,4** was cleared as part of that routine.

The value in **LOOP** is now copied into **W** and the table held at **MESSAG** is called. As discussed last month, the table line pointed to by the value in **W** is accessed – **retlw 'R'**.

'R' is the letter required to be shown on the LCD at this moment. The assembly program translates the letter held between the single quotes into its ASCII value. The LCD's internal character generator then displays the ASCII character specified.

The value of **LOOP** is then incremented, a check is made that the value is not greater than required at this time (**btfs LOOP,3**),

Listing 4.1

; TEACHIND01.ASM 25MAY07 - TEACH IN 2008 PT4

```
#DEFINE BANK0 BCF STATUS,5      ; define register bit 5 clear as
                                ; BANK0
#DEFINE BANK1 BSF STATUS,5      ; define register bit 5 set as BANK1

list p=16f628                    ; tell MPASM-type programmer to
                                ; create a list (LST) file

                                ; bring in all standard register values
                                include p16f628.inc

                                CBLOCK h'20'

RSLINE
STORE
LOOP
LOOPA
CLKCNT
ENDC

__config $3F30                  ; internal 4MHz oscillator

ORG 0                            ; reset vector
goto STARTIT
ORG 4                            ; interrupt vector address
goto STARTIT
ORG 5                            ; PIC program memory location at
                                ; which to start
goto STARTIT

                                include LCDheader.inc

MESSAG addwf PCL,F
        retlw 'R'
        retlw 'E'
        retlw 'A'
        retlw 'D'
        retlw ' '
        retlw 'E'
        retlw 'P'
        retlw 'E'

                                include LCDroutines.inc      ; (command could be placed later)

STARTIT clrf PORTA                ; clear PORTA's output if any
        clrf PORTB                ; clear PORTB's output if any
        movlw $07                 ; needed by some PICs,
        movwf CMCON               ; so that PORTA is a digital port

                                BANK1
        movlw b'00000000'         ; all PORTA as output
        movwf TRISA               ; data direction register for PORTA
        movlw b'00000000'         ; PORTB as output
        movwf TRISB               ; data direction register for PORTB
        movlw b'10000110'         ; timer 1:128, pull-ups off (bit 7 = 1)
        movwf OPTION_REG
        BANK0

                                call PAUSIT

MAIN    call LCDSET
        call PAUSIT

                                call LCDMSG

NOMORE goto NOMORE              ; hold here ad infinitum!

LCDMSG clrf LOOP                 ; clear loop
        bsf RSLINE,4              ; set RS for data send
LCDMS2 movf LOOP,W               ; get table address
        call MESSAG               ; get message letter
        call LCDOUT               ; show it
        incf LOOP,F               ; inc loop
        btfs LOOP,3              ; has last LCD letter been sent?
        goto LCDMS2              ; no, so repeat for next one
        return                   ; return to the main program
END
```

and if not, repeats the process by jumping back to LCDMS2, displaying the next table letter called.

In the counter check, it is known that the table is eight commands long. The binary value for eight is $b'00001000$, so it is merely a matter of checking if bit 3 of LOOP is now set, and terminating the loop if it is. There are other techniques available for checking a counter's status.

When loop termination occurs, the program returns to where it came from with the simple command **return**, to label



Fig.4.3 LCD screen for the first example

NOMORE. The action **goto NOMORE** is now repeated indefinitely until the program is reset or the power is switched off. In another program, any other required routine would normally be entered at this point.

LCDroutines.inc content

It is worth highlighting a few other LCD control routines held within the **LCDroutines.inc** file. The routine we have just used is that at **LCDSET**.

There are also several lines of code which specify the LCD character cell at which a display starts, such as:

```
LCD1: movlw b'10000000'
      goto LCDLIN
```

and

```
LCD21: movlw b'11000011'
      goto LCDLIN
```

The first specifies that cell 1 of line 1 should be the starting point. The location values are one higher than the binary values would indicate. This is for human convenience only!

The initial 1 of the binary value is a code value involved in LCD commands. The next 0 specifies the line ($0 + 1 = 1$), and the last three digits specify the cell number, in binary (000 in this instance) ($0 + 1 = 1$).

The second example thus specifies that line 1, cell 4 is the starting point (remember, binary value + 1 in each case).

The call to **LCDLIN** causes the command at that point to set the LCD into the mode for dealing with format commands. The command is then sent to the LCD via the **LCD-OUT** routines, which are common to LCD commands and display data.

There are also two routines which allow all cells on a given line to be cleared to a blank display – **CLRLINE1** and **CLRLINE2**. Simply calling these routines from a program causes the specified clearance to be done.

If there are starting cells other than those already provided for, you may add similar lines for them and resave the file. There is, though, an argument in favour of simply copying/creating cell address lines actually within your program, as they take up program memory, which may be problematic in larger programs running into space shortage.

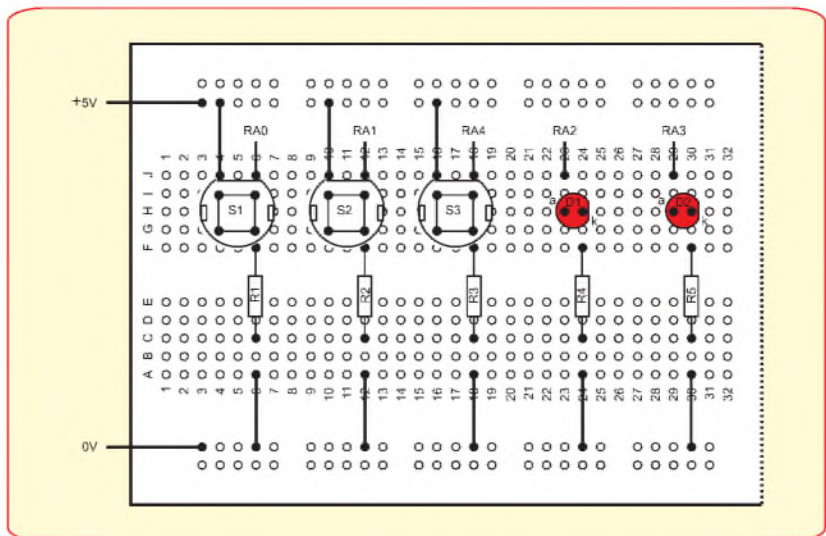


Fig.4.4. Breadboard layout for Fig. 4.1

Note that if you do not specify a starting cell address for any new batch of display data, the LCD will simply follow on with the next location which it thinks is available.

Value conversions

There is also another *include* file available, containing other useful LCD routines, **LCDconversions.inc**:

```
SHOWHEX (show 4-digit hexadecimal
          value)
SHOWDEC (show 5-digit decimal
          value)
BIN2HEX (convert a binary value to
          hexadecimal)
```

At the head of the file are the register names needed for the routines. Copy them into the **CBLOCK** section of your program and remove the semicolons from in front of them.

The routine at **BIN2HEX** converts a 2-byte binary value (held in **CONVCOUNT1** (MSB) and **CONVCOUNT0** (LSB)) into a 4-digit hexadecimal value held in **CONVDIGIT4** (MSB) to **CONVDIGIT1** (LSB).

SHOWHEX shows the hex value held in **CONVDIGIT4** (MSB) to **CONVDIGIT1** (LSB).

The routine at **SHOWDEC** causes the display of a 5-digit decimal value held in **CONVDIGIT5** to **CONVDIGIT1**.

To use the routines in this file, copy the values you want into the specified registers (study the **.inc** file). Then specify the LCD cell at which you wish the display to commence, e.g. call **LCD1** to start at line 1 cell 1, and then call the conversion routine, e.g. call **BIN2HEX** for binary to hexadecimal conversion display.

Event monitor

We can now move on to showing how an event monitor can be created, outputting the quantity of events to the LCD for display. The quantity is input in response to pressing two switches, one to count up, the other to count down.

Assemble the breadboard as shown in Fig.4.4, with the three switches S1 to S3, the two LEDs D1 and D2, and resistors R1 to R5. The switches are connected to PORTA,

bits 0, 1 and 4, used as inputs. They are biased normally low by the resistors. Pressing a switch applies a high logic level to the associated input. The LED common cathodes are controlled by PORTA bits 2 and 3, with R4 and R5 as their bias resistors.

Load the PIC with **TEACHIND02.asm** and let the program run. Part of its listing is shown in Listing 4.2.

Press switch S1 to count up and LED D1 turns on. Release S1 and the LED turns off. Press switch S2 to count down and LED D2 turns on. Release S2 and the LED turns off.

While either switch is pressed, a hexadecimal value now appears incrementing (S1) or decrementing (S2) on LCD screen line 1, and an equivalent decimal value on line 2.

Note that if S2 is pressed and the total count value is already less than certain values, an excessively large number can appear; some of the registers have been at zero, and are now decremented, rolling over from zero to 255. There are ways around this, which should become obvious.

Much of the program is the same as in Listing 4.1. The first thing to notice in the full listing (not shown) is the inclusion of extra registers within group 2 in the **CBLOCK** section. These are to do with the **BIN2HEX** routine that is called in at the end of the listing via the command **include LCDconversions.inc**. The third group of registers is for the binary to decimal conversion routine called in at the very end as **mathsbin2dec.inc**.

Next, the previous **MESSAG** table has been replaced by another called **OVERTABLE**, with different characters within it.

Switch check

Following label **STARTIT** (Listing 4.2), at **MAIN**, has been placed a routine to check whether switches S1 or S2 have been pressed. If they have not, the check is again made, repeatedly until one or other is pressed.

If S1 has been pressed, the routine at label **MAIN1** is entered. The program then turns on LED D1 to indicate that the switch has been pressed (**bsf PORTA,2**). Register **COUNTA** is incremented, but with a different command to

that previously seen. Instead of **incf**, the command has become **incfsz** (increment file, skip if zero).

This command increments the register as before, but also performs a check to see if it has rolled over to zero. (Remember that a byte can never hold more than a value of 255, and when that byte is being incremented, it can roll over to zero and then continue counting up again, as previously explained.) If it has not become zero, the next command performed is that at MAIN2A.

LCD display

Now the command **call LCD1** is performed, and a routine within the included *LCDroutines* code sets the LCD to start the display from cell 1 on line 1. The hexadecimal value is then shown via the included file for the *LCDroutines* code. The LCD starting address is then changed to cell 1, line 2 with the command **call LCD21**. Following this, a conversion of the binary count to decimal is called within the included **mathsbin2dec** code.

(Some years ago, *EPE* reader Peter Hemsley wrote a suite of maths programs that were published in *EPE*. The routines include such functions as binary to decimal conversion, and several others of use to programmers. The full suite is on the *EPE* Downloads site. The binary to decimal conversion routine has been compiled into the separate **mathsbin2dec.inc** file used here.)

The switch is then checked again to see if it is still pressed. If it is pressed, the counting routine at MAIN2 is repeated.

When COUNTA has rolled over to zero, command **incfsz COUNTB,F** is performed, which does a similar increment and zero check for register COUNTB. If COUNTB has rolled over to zero, COUNTC is incremented. Thus we are building up a 3-byte counter, capable of counting up to 16777215 ($256 \times 256 \times 256 - 1$). If any COUNTER has not yet become zero, again the routine at MAIN2A is actioned.

When COUNTC becomes zero, the command **call OVERFLOW** is performed. At OVERFLOW a routine shows the word OVERFLOW, held in the table OVERTABLE. This table is accessed in the same way as the READ *EPE* message table earlier.

Now the WAITRELEASE routine is entered, at which the release of switch S1 is waited, before the process repeats from label MAIN.

Decrementing

The decrementing routines are similar, but do not include an OVERFLOW check for when the count value becomes too low (effectively negative) to be correctly decremented (ways round this will become



Fig.4.5. LCD screen for the second example

Listing 4.2

```

STARTIT      clrf PORTA          ; clear PORTA's output if any
              clrf PORTB          ; clear PORTB's output if any
              movlw $07           ; needed by some PICs, including
                                   PIC16F628
              movwf CMCON         ; so that PORTA is treated as digital
                                   port

              clrf COUNTA
              clrf COUNTB
              clrf COUNTC
              BANK1
              movlw b'00000011'   ; PORTA 0 & 1 as input
              movwf TRISA         ; data direction register for PORTA
              movlw b'00000000'   ; PORTB as output
              movwf TRISB        ; data direction register for PORTB
              movlw b'10000110'   ; timer 1:128, pull-ups off (bit 7 = 1)
              movwf OPTION_REG
              BANK0

              call FAUSIT

              call LCDSET
              call FAUSIT

MAIN          bcf PORTA,2         ; no, turn off LED D1
              bcf PORTA,3         ; no, turn off LED D2
              btfsc PORTA,0       ; is switch S1 pressed?
              goto MAIN1         ; yes
              btfsc PORTA,1       ; is switch S2 pressed?
              goto DECIT         ; yes

              goto MAIN          ; no

MAIN1         bsf PORTA,2         ; yes, turn on LED D1

MAIN2         ; call FAUSIT
              incfsz COUNTA,F     ; yes, inc COUNTA (LSB), is it =
                                   ; zero?
              goto MAIN2A        ; no, goto MAIN2A
              incfsz COUNTB,F     ; yes, so inc the next counter byte
                                   ; (NSB), is
                                   ; it = zero?
              goto MAIN2A        ; no
              incfsz COUNTC,F     ; yes, inc the next counter byte
                                   ; (MSB), is it = zero?
              goto MAIN2A        ; no
              call OVERFLOW
              goto WAITRELEASE

MAIN2A        call LCD1           ; set LCD for display from line 1 cell 1
              call SHOWHEXVAL
              call LCD21         ; set LCD for display from line 2 cell 1
              call SHOWDECIMAL

MAIN3         btfsc PORTA,0       ; is S1 still pressed?
              goto MAIN2         ; yes, inc COUNTA again
              call FAUSIT        ; allow for switch bounce
              goto MAIN          ; go back and wait next press of S1

OVERFLOW      call LCD1
              clrf LOOP           ; clear loop
              bsf RSLINE,4        ; set RS for data send
              movf LOOP,W         ; get table address
              call OVERTABLE      ; get message letter
              call LCDOUT         ; show it
              incf LOOP,F         ; inc loop
              btfss LOOP,3        ; has last LCD letter been sent?
              goto OFL2          ; no, so repeat for next one
              return             ; return to the main program

OFL2

WAITRELEASE   btfsc PORTA,0       ; is S1 still pressed?
              goto WAITRELEASE   ; yes, wait until released
              call CLRLINE1
              call CLRLINE2
              goto MAIN          ; and start again

```

Continued
next page

apparent later in the series – we don't want to overload *you* with too many commands to take in at one time!!)

Too fast

As will become apparent, the speed of counting can occur faster than you might prefer. The rate can be decreased by inserting a call to PAUSIT at label MAIN2. Delete the semicolon present there to bring that command into play.

Once you understand PAUSIT's timing, you could write a shorter (or longer) delay routine and call that instead. The TMR0 timer and its implications will be discussed in a future part.

Another thing to think about

Until Part 5, keep on thinking as a programmer by considering how you would arrange the door switches and displays for use in an aircraft or train WC. You now have an LCD to help with the displays.

Keep in mind the privacy of an occupant when present, and let others know whether the WC is free or not. Add whatever features you think might be appropriate, such as extractor fan and motorised WC flush controls. Should you allow its use when standing in a station or on the runway?

Questions and answers entirely up to you!

Listing 4.2 (Continued)

```

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

DECIT     bsf PORTA,3           ; inc COUNTA, is it = zero?
          decfsz COUNTA,F       ; no
          goto DEC2            ; dec the next counter byte
          decfsz COUNTB,F       ; (MSB), is it = zero
          goto DEC2            ; no
          decfsz COUNTC,F       ; inc the next counter byte
                                ; (MSB), is it = zero

DEC2      goto MAIN2A

          include LCDroutines.inc

          include LCDconversions.inc

          include mathsbin2dec.inc

          END

```

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INTERFACE

Robert Penfold



SHAPING UP WITH VISUAL BASIC 2008 EXPRESS EDITION

Recent *Interface* articles have covered the lack of any Shape components in modern versions of Visual BASIC. These components make it easy to draw and edit such things as virtual control knobs, switches, and analogue readouts.

Of at least equal importance, they make it very easy to control the onscreen virtual world created from the basic shapes. For example, changing an analogue readout such as the pointer of a virtual panel meter usually requires nothing more than the alteration of two co-ordinates, which can be achieved using a single line of code. Unfortunately, the Shape components have been phased out and are not present in versions later than Visual BASIC 6.

Switch to manual

As pointed out in previous articles, there is a free add-on that can be used to provide modern versions of Visual BASIC with something comparable to the Shape components of Version 6. I incorrectly stated that the PowerPack 2 software would only work with the full version of Visual Studio, and that it would not load into the free Express version of Visual BASIC. I am grateful to a few readers for pointing out that this is not strictly true, and that the PowerPack 2 software can actually be used with Visual BASIC 2005 Express.

However, it is true that installing this software will not result in the new components automatically appearing in the relevant section, as will normally happen with the full version, but they can be loaded manually. I had, in fact, tried to do this, but made a mess of quite a simple process. It is just a matter of going to the Tools menu and choosing Select Toolbox Items. This produces a popup window (Fig.1) where the checkboxes for the three individual Shape components must be ticked.

Make sure that the .NET Framework Components tab is selected, as this is the section where they will be listed. There is no Microsoft prefix to the names, and they cannot be loaded together under the PowerPack 2 name. The components are called 'LineShape', 'OvalShape', and 'RectangleShape'.

Once loaded they can be used in the normal way, and the Visual Express 2005 then makes a good substitute for Visual BASIC 6 for those wishing to produce virtual panel meters, rotary controls, etc. It has the advantage of being free, and more compatible with recent Windows operating systems.

The only real drawback is that its version of the BASIC programming language is a bit different to the one used in Visual BASIC 6, and most other versions of BASIC. This can make it difficult to use at first if you are an experienced user of practically any other BASIC programming language.

The Express versions of the Microsoft programming languages have also been updated, and the free version of Visual BASIC is now Visual BASIC 2008 Express Edition. As far as I can ascertain, all the Express editions remain permanently free and retain the fairly liberal licensing conditions of their predecessors.

Numerous changes have been implemented in the new edition of Visual BASIC Express, but few (if any) of these seem to have any real relevance to the production of simple software for PC hardware add-ons. If nothing else, it should give better compatibility with Windows Vista.

In the past, improvements to Visual

BASIC have actually made it more difficult to produce this type of software. The disappearing Shape components are one example of this. I have not yet had time to fully assess the new Express version, but it does not seem to be fundamentally different to the previous edition. Once 'up and running' (Fig.2), the 2008 edition looks much the same as the 2005 version, with the same screen layout and essentially the same menu system.

It is sufficiently different to its predecessor to preclude simply loading existing programs so that they can be edited in the new version. They have to go through a conversion process first, and as often seems to hap-

pen with this type of thing, the screen layout can become slightly scrambled. This can occur even when converting simple programs. If things go seriously awry it is better to start 'from scratch'.

Positive gains

On the plus side, the Shape components of PowerPack 2 seem to work just as well with the 2008 edition as they did with the previous versions. There are three tabs when the Choose Toolbox Items window appears, but as before, it is the .Net Framework Components tab that must be selected. It is worth looking down the list of available components to see if there are any others that might be of use, but many of them are rather specialised in nature.

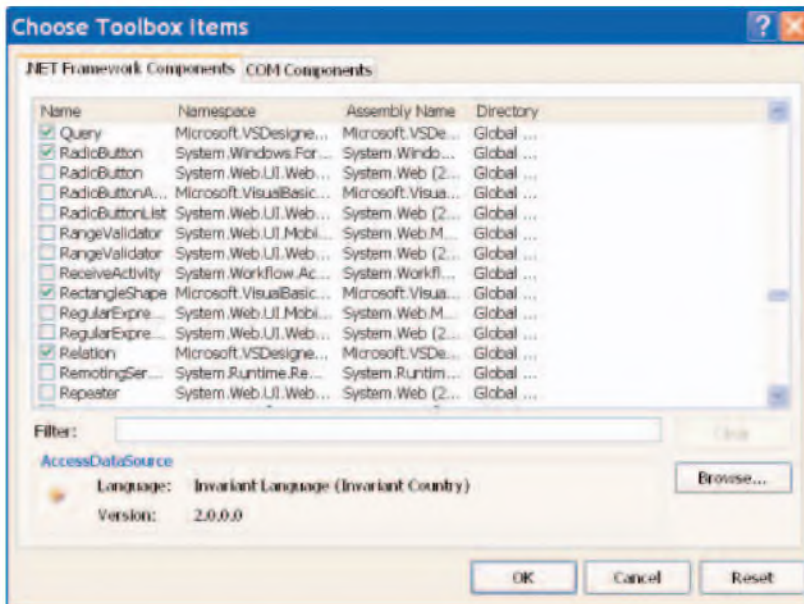


Fig.1. The Shape components will not be loaded automatically when using the Express edition, but they can be loaded manually under their individual names

All change

I suppose that one should eagerly await the arrival of new and improved versions of software, but I doubt if many actually do so these days. Changing to a new version of a program often seems to mean replacing one that works reasonably well with one that offers no real advantages, but does bring some new problems that have to be 'ironed out'.

Somewhat earlier than many had anticipated, Microsoft has launched a new version of Visual Studio in the form of Visual Studio 2008. The full version of Visual BASIC is part of Visual Studio, and therefore becomes a new version called Visual BASIC 2008.

Inpout32.dll seems to work normally with the new edition, but as before, it requires a new module to be installed in order to make Visual BASIC recognise the two additional commands. The module is added by going to the Project menu and selecting the Add Module option.

The pop-up window that appears is then used to provide a name for the new module, or the default can be accepted. You are then taken to the appropriate section of the Code window, where the following code is then entered for the module:

```
Option Strict Off
Option Explicit On
Module inpout
```

```
Public Declare Function Inp Lib
"inpout32.dll" Alias "Inp32" (ByVal
PortAddress As Short) As Short
Public Declare Sub Out Lib
"inpout32.dll" Alias "Out32" (ByVal
PortAddress As Short, ByVal Value As
Short)
End Module
```

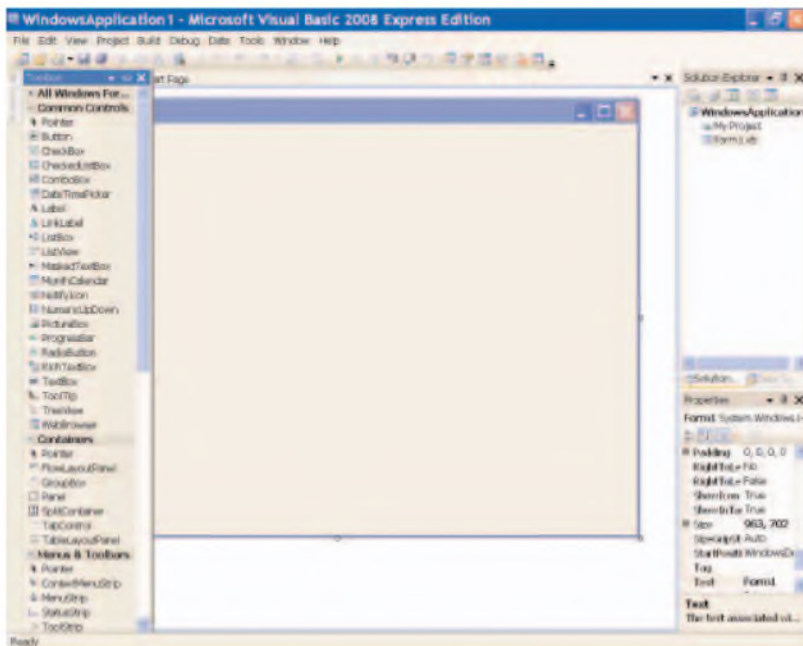


Fig.2. The 2008 version looks much the same as its predecessor, and is used in much the same way. Programs from Visual BASIC 2005 Express must be converted before they can be loaded into the new version

There was an ActiveX control in Visual BASIC 6 that was something of a 'mixed blessing', but it did provide a means of communicating with PC serial ports. A different component (SerialPort) is provided with all versions of Visual BASIC 2005, and this has been retained in Visual BASIC 2008 Express. As pointed out in previous *Interface* articles, the ability to communicate with the serial ports of a PC remains a useful facility, even though there are now relatively few PCs that actually have these ports.

It can be useful because one way of interfacing to a PC is via a virtual serial port. In the past, a virtual serial port was mainly used to communicate with a gadget fitted in one of the computer's PCI expansion slots. These days it is more likely to be a device connected to a USB port, but in either case it is possible to read from and write to the peripheral

device much as if it was connected to a real serial port. It is not normally possible to swap data via a virtual serial port using the direct addressing method, since no conventional serial port hardware is present. However, it should be possible using a component such as the Visual BASIC SerialPort type. Proper communication with the virtual port will be obtained provided the virtual serial port has been correctly installed in Windows using suitable driver software.

As an initial test of Visual BASIC 2008 I tried producing an equivalent to the dummy panel meter featured in the previous *Interface* article. With the aid of the Shape components this proved to be quite easy, and it was also quite straightforward to take things a stage further and make the meter respond to readings from the parallel port (Fig.3). Anyway, the software in future *Interface* articles will be written using Visual BASIC 2008 Express rather than version 6. Visual BASIC 2008 Express can be downloaded from:

<http://www.microsoft.com/express/vb/Default.aspx>

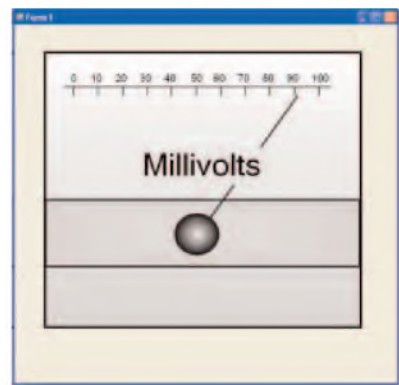


Fig.3. A virtual panel meter reading from a parallel port. This makes use of the add-on Shape components and **Inpout32.dll**, all of which seem to work well with Visual BASIC 2008 Express

These make use of virtual port techniques, and some are quite effective. Unfortunately, others provide only a partial simulation of a serial or parallel port, and will not work with some peripheral devices.

On the face of it, add-on circuits that are controlled using direct addressing of the ports will not work with any form of virtual port. In other words, it would appear that PC projects that utilize **Inpout32.dll**, or any similar utility, will not work with add-on virtual ports. This is not necessarily the case though, and in the past I have used direct addressing successfully with parallel ports implemented via a PCI expansion card.

This was made possible using a utility program provided with the card. The purpose of this program was to intercept read and write operations to the relevant addresses, and then replace them with a routine that contacted the real port hardware in the appropriate fashion. This enabled the virtual port to be used in exactly the same way as the genuine article. Not all add-on ports have this capability, so it is obviously necessary to make sure that you buy the right type.

There is a potential problem with this roundabout way of doing things in that it is likely to be slightly slower than directly addressing a real port. Any lag is likely to be very slow though, and it was certainly not a problem with any of the projects that I used via a virtual parallel port.

USB

With the PC legacy ports gradually disappearing, there are two main choices left for those wishing to interface their own add-ons to a PC. These are the PCI expansion bus and the USB ports. The PCI expansion bus is not really a conventional computer bus of the same type as the now defunct ISA bus. It is really a form of parallel input/output port. The USB ports are a more popular choice for do-it-yourself add-ons, since they are readily accessible, and they are present on all reasonably modern desktop and portable PCs.

A drawback in both cases is that the ports are integrated with the operating system to a much greater degree than the legacy ports. Any add-ons that use these ports have to be installed in Windows just like any other peripheral devices, which clearly complicates matters. There are ways around this problem though, and using USB ports with PC projects will be considered in future *Interface* articles.

The program must be registered in order to go on using it beyond the 30 day trial period, but registration is free.

Old PC projects

The disappearing legacy ports make life difficult for anyone trying to use old projects with a modern PC. Serial ports are now virtually extinct. Parallel ports are actually included on a fair proportion of desktop PCs, but have been conspicuously absent on notebook and laptop PCs for some time. Both types of port will become part of PC history in the not too distant future.

This is not to say that it will be impossible to use old projects that interface via serial and parallel ports unless you keep an old PC in working order. There is a potential way around the problem in the form of add-on ports that either connect to a USB port or are based on a PCI expansion card.

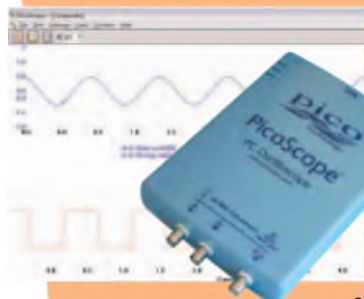
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Infrared Proximity Switch – *Closely Turned On*

A LOW component count, easy to construct and compact circuit of a general-purpose infrared (IR) proximity detector switch is shown in Fig. 1.

The circuit is built around the LM567 phased-locked loop (PLL)/tone decoder (IC1). It is configured to oscillate at a centre frequency of about 5kHz, as set by RC timing components resistor R5 and capacitor C2. Output pulses from IC1 pin 5 modulate the IR LED within sensor module SFH900, IC3, with the help of driver transistor TR1 and associated components.

Resistor R1 sets the operating current of the internal IR LED, and hence the detection range of the circuit.

The circuit is powered by the regulated 5V supply from the output of IC2. Diode D1 is a simple input polarity guard. Capacitors C5 to C8 provide buffering and filtering of the inputs and outputs. In standby mode, the output at IC1 pin 8 is at a high level and the solid-state relay is in the off state.

When infrared light, reflected by any near-by object, is received by the photo transistor inside IC3, it is fed to IC1 input

pin 3 through capacitor C1. If the received signal is within the pass-band, the output at IC1 pin 8 goes low, turning on the relay. Resistor R7 limits the relay's operating current. This condition is maintained as long as the reflected signal is available at the circuit input.

The IR sensor and relay types are not crucial and equivalents may be used, although the values of resistors R1, R2 and R7 may need changing to suit.

T.K. Hareendran
Kerala

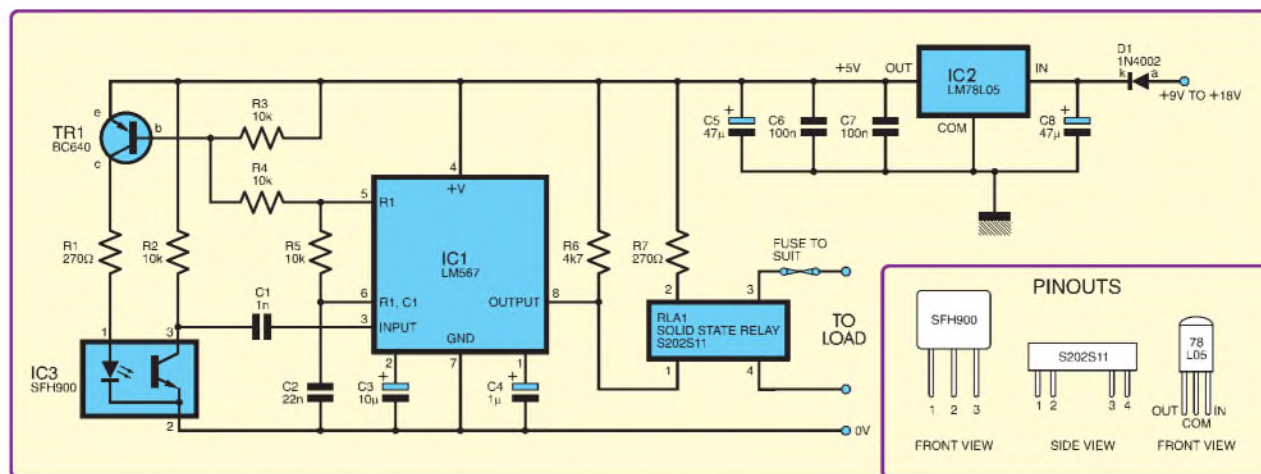
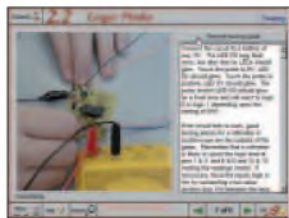


Fig.1. Circuit diagram for the general purpose Infrared Proximity Switch. Note that IC1 pins 5 and 6 are the timing element pins and that pins 1 and 2 are the output filter and low-pass filter pins respectively

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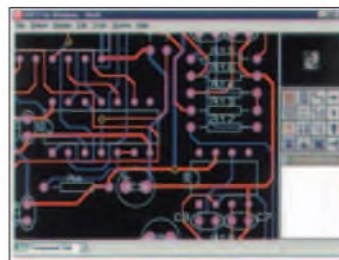


Logic Probe testing

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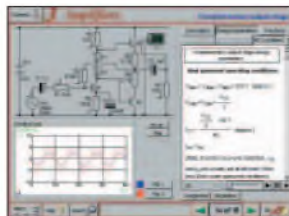
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ANALOGUE ELECTRONICS

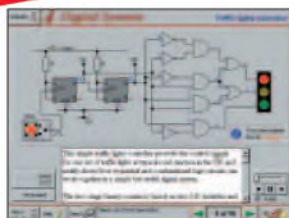


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Virtual laboratory – Traffic Lights

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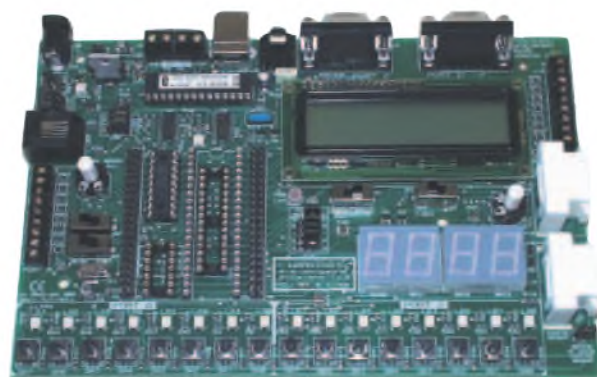
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- Virtual C PICmicro improves understanding
- Includes a C compiler for a wide range of PICmicro devices
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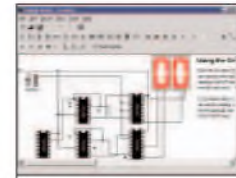
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MIDI DRUM KIT

BY JOHN CLARKE



PART 3 - BUILDING THE SENSORS AND STAND

As mentioned last month, there are two basic pad sensor types: those based around a piezo transducer and those based around an optical sensing circuit. Which one you use is up to you.

The piezo-based pads require tapping with drum sticks or similar items in the conventional 'drum' manner. The optical pads can be tapped by hand, making them easier to use.

We also use an optical pickup for foot-activated sensors.

This is because the system is more robust. A piezo transducer that can be attacked with a foot pedal may well be destroyed rather quickly.

Each pad type is described in the following separate sections.

Building the optical PC board

Circuit details were shown in Part 1 but are repeated here for convenience, along with the PC board overlay for the optical sensor (there is no PC board for the piezo sensor).

The optical sensor PC board is coded 657 and measures 52 x 31mm. Once again, before assembly check the underside for any possible shorts between tracks or breaks in the copper.

As you did for the other boards, install the resistors and diode (as shown), the PC stakes and the capacitor (which is mounted on its side to allow clearance above the PC board). Finally, the optical sensor is mounted directly onto the PC board, making sure it is oriented correctly.

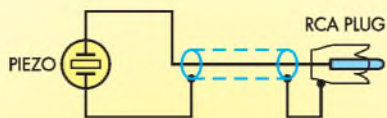


Fig. 5: PIEZO SENSOR

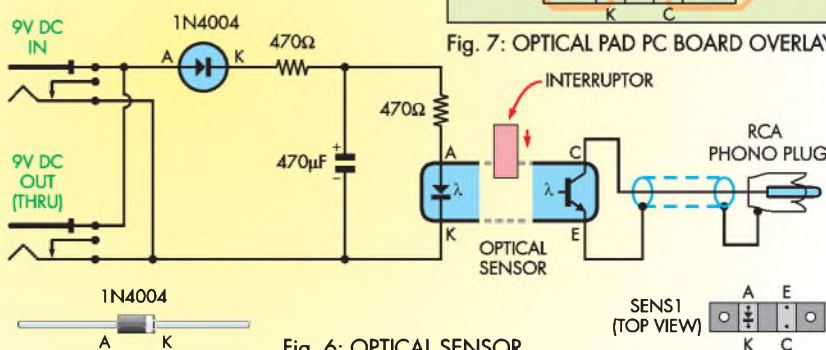


Fig. 6: OPTICAL SENSOR

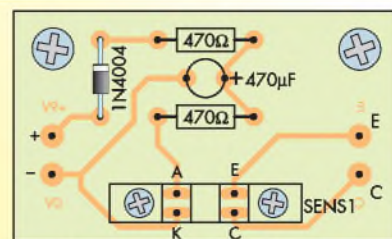


Fig. 7: OPTICAL PAD PC BOARD OVERLAY

Simple piezo sensor

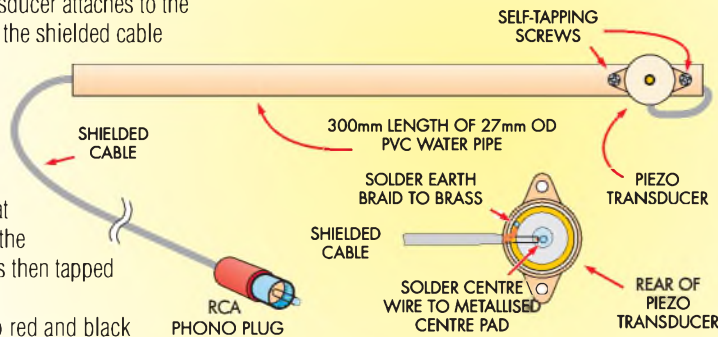
The simple piezo sensor is based around a length of 20mm (27mm OD) PVC water pipe. The piezo transducer attaches to the end of the pipe with the shielded cable connected to the transducer and the other end to an RCA phono plug.

To use, the pipe is held in the hand at the opposite end to the piezo and the pipe is then tapped with a stick.

Note that the two red and black wires that are supplied connected to the

piezo transducer need to be unsoldered and replaced with the shielded (screened) wire. You

must carefully prise off the back of the piezo case to gain access to the wiring.



Parts List – Piezo Sensor

- 1 piezo transducer
- 1 300mm length of 20mm PVC water pipe (27mm OD)
- 1 2m length of single-cored shielded cable
- 1 RCA phono line plug
- 2 No.4 self-tapping screws

Percussive (piezo) sensor pad

The percussive sensor pad needs to be mounted onto a frame using 25mm tubing (see separate diagram). The sensor is played with a drumstick or similar item. Note that the front edge is shown curved to ensure that there is a consistent response from the sensor when the pad is tapped around its circumference.

Do not be tempted to use a rectangular edge. This will give dead spots in several positions on the pad where the sensor will not detect a strike on the plate. In addition, do not use metal in preference to the MDF since this will resonate for too long after it is struck.

The sensor pad is constructed as shown below. Cut out the circular section of the MDF panel with a jigsaw and paint the pad with gloss black paint. The piezo transducer

needs to be rewired to have the shielded cable soldered to its piezo and brass sections. The rear of the piezo housing can be carefully prised off to gain access to this wiring.

We used an epoxy resin smeared around the edge of the back of the piezo housing before securing with the M2.5 screws into the MDF. This ensures a good physical contact with the MDF plate.

The top of the MDF sensor plate can be painted black or covered with a thin sheet of vinyl using contact adhesive. The vinyl can deaden the sound produced by striking it with a stick.

Alternatively, the stick can be rubberised. In most cases, the sound of the stick striking the painted MDF pad will not cause any concern.

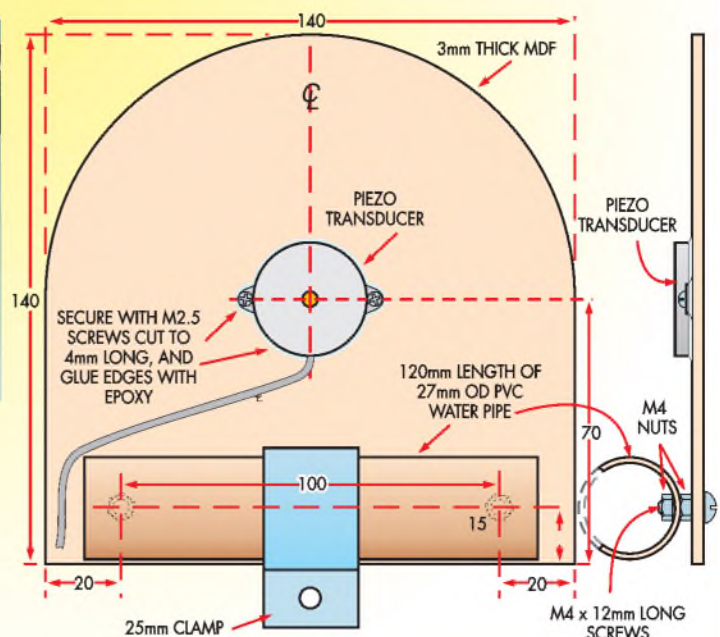
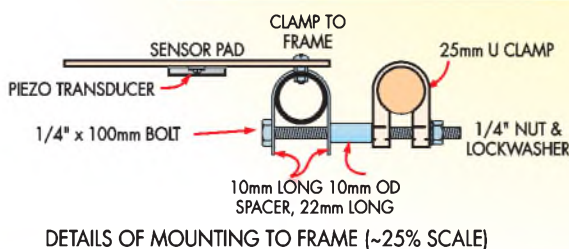
Parts List – Piezo Pad

- 1 piezo transducer
- 1 140 x 140mm piece of 3mm MDF
- 1 120mm length of 20mm PVC water pipe (27mm OD)
- 2 25mm cable cleats
- 2 M4 x 12mm screws
- 4 M4 nuts
- 1 6mm x 100mm bolt and nut
- 1 6.35mm ID x 9mm OD x 22mm long plastic spacer (electrical lamp fitting)
- 2 M2.5 x 4mm long screws

Miscellaneous

Gloss black paint, vinyl (optional), epoxy resin, contact adhesive

This upside-down view of a piezo sensor pad is mainly to show the method of mounting the transducer. It also shows the method of mounting to the stand via a clamp and length of PVC pipe (also see diagram below).



Bongo drums

The bongo drums are made using 12mm MDF and 18g (1mm) aluminium sheeting. The MDF makes up the top and bottom dual semi-circular sections while the aluminium sheet is wrapped around the sides of the MDF and secured in place with 6g x 20mm countersunk woodscrews.

Cutouts in the top are blocked off using MDF timber glued on the underside. These provide the mounting base for the optical sensor PC board to be secured using the 4g self-tapping screws. The MDF cut-outs and the semicircular shape can be cut using a jig saw. Glue the timber to the underside of the top panel cutouts and paint the timber.

Wiring the PC boards involves following the overlay diagram for the optical pad sensor and wiring. Note that only two DC sockets are necessary – the second PC board derives its power from the first using hookup wire between the two positive power terminals and the two negative terminals. The DC sockets mount on the aluminium sides of the drums. The signal leads pass through the aluminium via a rubber grommet. A cable tie holding the two signal leads behind the grommet will help prevent the leads pulling out. An alternative arrangement is to attach two RCA panel sockets to the drum and use RCA-to-RCA leads for the signal connections.

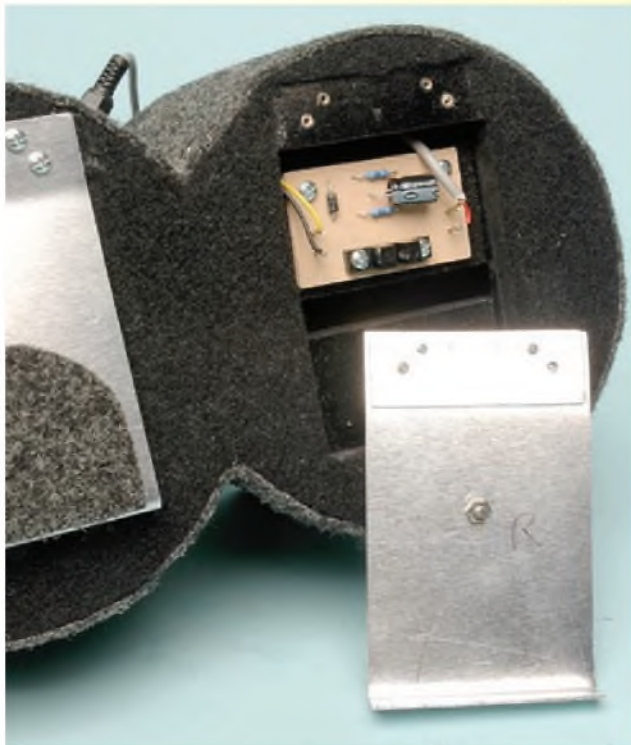
Make up a DC socket to DC socket lead and terminate the signal leads with RCA phono plugs.

The pressure plate is secured to the top of the drum using 4g screws. The screw that passes through into the optical sensor must be exactly located so that it fits neatly into the optical slot. The plate is bent as shown right and below.

Adjustment

The slight upward bend of the plate allows the screw to have clearance inside the optical slot. This screw needs to be adjusted carefully so that there is a change in voltage at the signal output when the plate is moved.

The easiest way to adjust this is to first make up an RCA phono socket to RCA phono plug test connector, as shown below right, and insert this in line between the signal output lead and the MIDI Drum Kit. Alternatively, access the rear of the RCA socket inside the MIDI Drum Kit. Plug into one of the RCA input sockets for the MIDI Drum Kit.



The completed bongo drums. In the photo below left the drums are partially disassembled, showing the optical sensors and plates.

Apply power to the drum kit and also connect the DC power lead between the drum kit's DC output socket and one of the DC input sockets on the bongo drums. Connect a multimeter set to read DC volts to the test connector. The voltage reading should be either small ($< 0.1V$) if the screw is too far out of the sensor gap or up to 5V if the screw is too far into the slot.

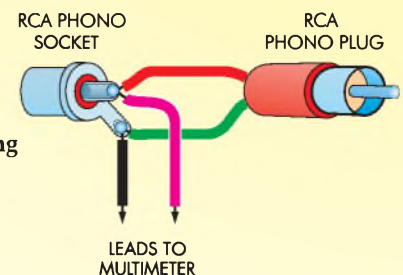
Adjust the plate angle and screw setting so that the normal voltage is very close to 200mV. This voltage should rise to close to 5V when the plate is pressed. Ensure the plate is free to move without scraping the sides of the MDF and without the screw scraping the inside of the optical sensor.

With the arrangement shown, having a nut on top and on the bottom of the plate, the screw can be turned in or out to make the adjustment. An alternative method is to cut the screw to length so that it does not need adjusting. If you have cut too much from the screw, the length can be built up with some solder. This makes it easy to file down so that the length is just right when the plate is secured down with the screws into the MDF panel.

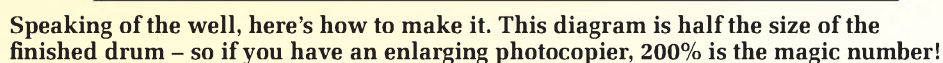
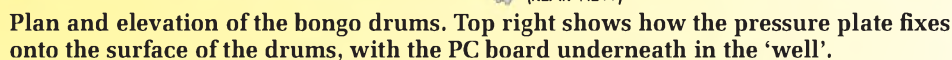
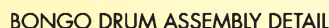
Finishing

We finished the drums by covering them with loudspeaker carpet. This is attached with contact adhesive. The covering is optional.

This easy-to-make jig will allow you to adjust the Bongo Drums (and other optical sensors) very easily, by connecting to your multimeter and adjusting the screw to give maximum voltage change.



OPTIONAL SENSOR TEST JIG



Parts List – Bongo Drums

- 2 PC boards code 657, available from the
EFE PCB Service, size 52 x 31mm
- 2 photo-interrupters
- 2 1N4004 diodes
- 2 470 μ F 16V PC electrolytic capacitors
- 4 470 Ω 0.25W 1% resistors
- 2 panel-mount DC sockets
- 2 line DC plugs
- 8 PC stakes
- 1 50mm long cable tie
- 4 metres single-core shielded cable
- 2 RCA phono line plugs
- 2 135 x 245mm pieces of 12mm MDF
- 2 30 x 220mm pieces of 12mm MDF
- 2 120 x 707mm sheets of 18g (1mm)
aluminium
- 2 61 x 108mm sheets of 18g (1mm)
aluminium
- 2 20 x 58mm sheets of 18g (1mm)
aluminium
- 8 4g x 12mm self-tapping screws
- 12 6g x 20mm csk wood screws
- 1 M3 x 12mm screw
- 1 3mm star washer
- 2 M3 nuts
- 1 6mm ID rubber grommet

Miscellaneous

Black paint, contact adhesive,
speaker carpet (optional),
PVA glue

In many ways, the optical sensor is similar to the Bongo drums in construction. Most of the construction for this applies to the optical sensor. The sensor is designed to mount onto a frame/stand described on the next page. When used as a foot controller it can be placed on the floor rung of the stand. The current design is not suitable for use on the higher rungs of the stand. This is because there will be too much stand movement when the sensor is pressed. A heavy-duty stand made from tubular steel could be used to support several optical pad sensors. The optical pad sensors would also need to be held in position with steel clamps instead of plastic ones.

The 12mm MDF will require trimming back in thickness by 3mm where the two plastic clamps attach at the rear of the pad. Use a chisel to do this. The reduction in thickness is so that the clamp will close up sufficiently to mount tightly onto the 25mm frame.

The sensor PC board is attached using M3 screws and nuts. You may need to use some Nylon washers to space the PC board slightly above the 3mm MDF baseplate. Note that the pressure plate needs the centre screw to be adjusted correctly, as described in the bongo drum section.

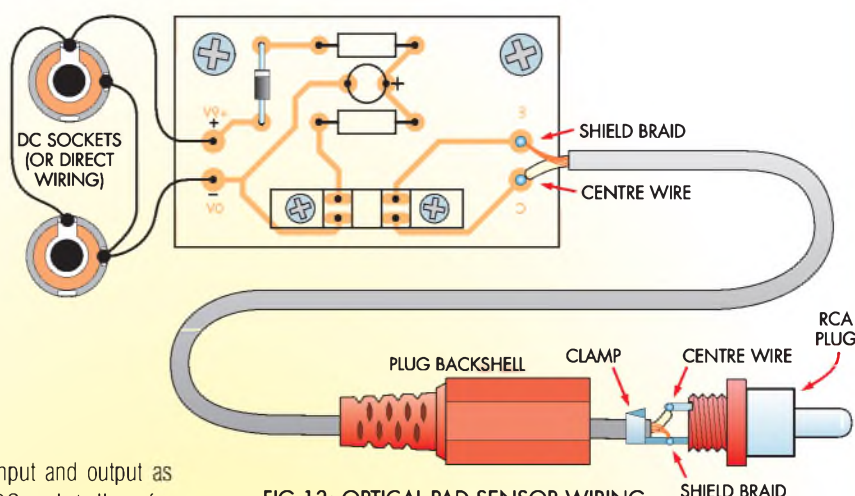
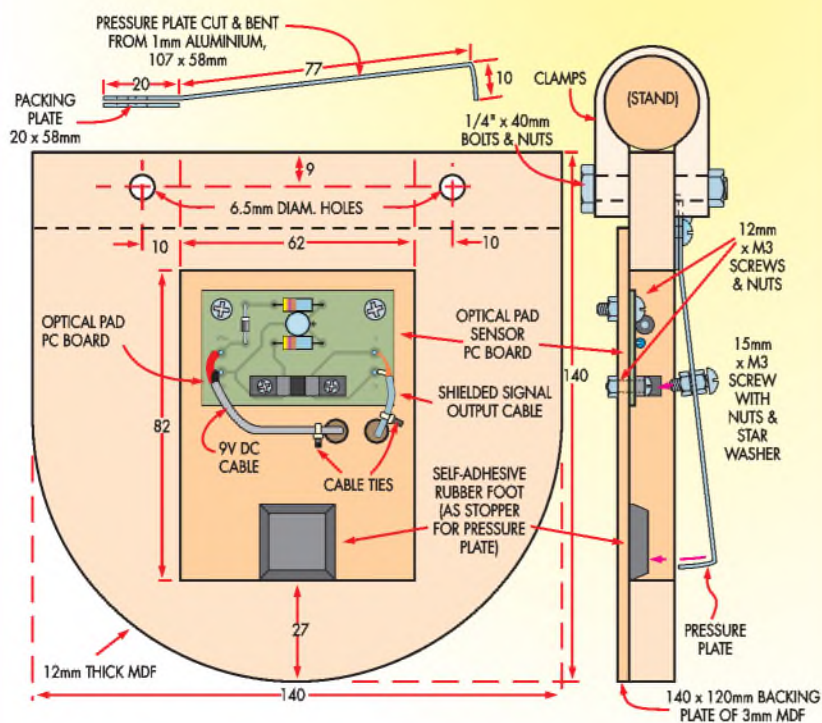


FIG. 13: OPTICAL PAD SENSOR WIRING

These optical pads are not ideal for hitting with a drumstick since it sets up resonance in the aluminium plate. This causes the drum sound to be played more than once for each strike. If you need to use the optical pads with sticks, then the setting-up procedure where the DC voltage is set to around 200mV needs to be changed. The initial voltage is set to the saturation voltage of the output transistor in the optical sensor. This is about 100mV and is observed to be the voltage that does not change until the pressure plate is moved by a millimetre or two. Best adjustment is found by trial and error, but the plate needs to be set so that it needs some movement before any voltage change is found at the sensor output.



Reproduced half size, this diagram shows how the optical sensor unit is constructed.

- 1 PC board coded 657, available from the *EPE PCB Service*, size 52 x 31mm
- 1 photo-interrupter
- 1 1N4004 diode
- 1 470 μ F 16V PC electrolytic capacitor
- 2 470 Ω 1/4W 1% resistors
- 1 line DC plug
- 4 PC stakes
- 1 2-metre length of single-core shielded cable
- 1 RCA phono line plug
- 1 140 x 142mm piece of 12mm MDF
- 1 140 x 120mm piece of 3mm MDF
- 1 61 x 108mm sheet of 18g (1mm) aluminium
- 1 20 x 58mm sheet of 18g (1mm) aluminium
- 2 25mm cable cleats
- 4 M3 x 12mm screws and M3 nuts
- 4 4g x 12mm self-tapping screws
- 1 M3 x 12mm screw
- 1 3mm star washer
- 2 M3 nuts
- 2 6mm x 100mm bolts
- 2 6mm nuts
- 4 3mm Nylon washers
- 2 50mm cable ties

Black paint, PVA glue

Building a playing stand

One or two sensors alone are fine sitting on a bench (or even the floor!) but when a number of sensors are used, some form of frame or stand is necessary so they can mount in their correct positions for playing.

We made up a stand using conventional hardware components. Broomsticks were used instead of dowell because they're usually a lot cheaper!

The stand was glued together with builders' adhesive for the Tee joins and PVA glue for the MDF bracket to the 25mm rod. It was painted in a gloss black.

Note that the design allows the top rung to be removed. This is for easy transport of the frame on the back seat of a car.

The broomstick pieces are cut to length, noting that the stick is passed right through the T-piece rather than cutting it at this point. Each T-junction is made stronger by making a 25mm hole part way into the side of the straight-through broomstick.

Note that the T-pieces must allow the broomstick to pass easily through it. Some brands may need drilling or filing out to allow the stick to enter right through the piece.

The MDF right-angle bracket is included to give extra support in the forward and backward direction.

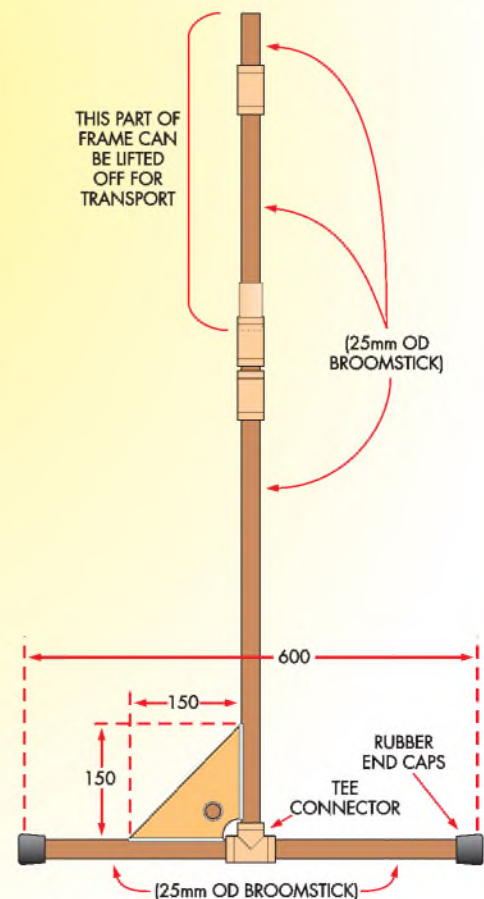
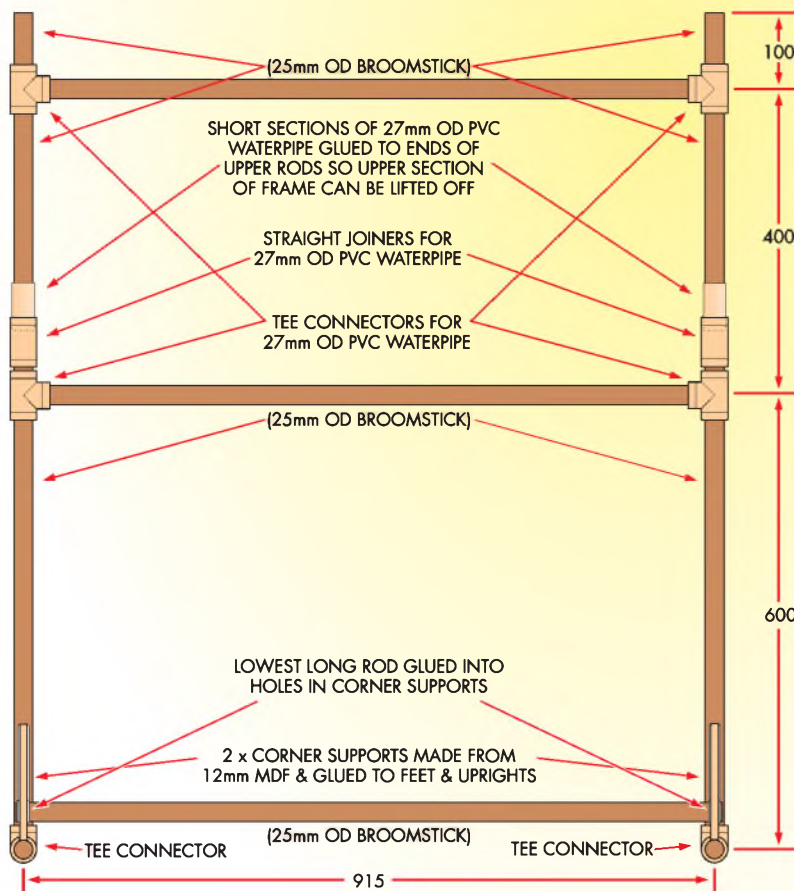


Parts List

6 broomsticks, 25mm in diameter
6 20mm PVC water pipe Tee pieces
2 20mm PVC water pipe joiners
1 150 x 150mm x 12mm MDF sheet
4 25mm rubber pipe ends

Miscellaneous

Black gloss paint, PVA glue, builder's adhesive



STAND CONSTRUCTION (10% SCALE)

This is the stand we put together from bedknobs and broomsticks (OK, not too many bedknobs). It's just one possible arrangement for mounting the controller and various sensors, giving room for foot pedals underneath.

Foot controller

The foot controller is generally used to control a bass drum sound. We show how to build a foot controller for this purpose using an optical sensor. An alternative foot controller is shown under the Optical pad heading.

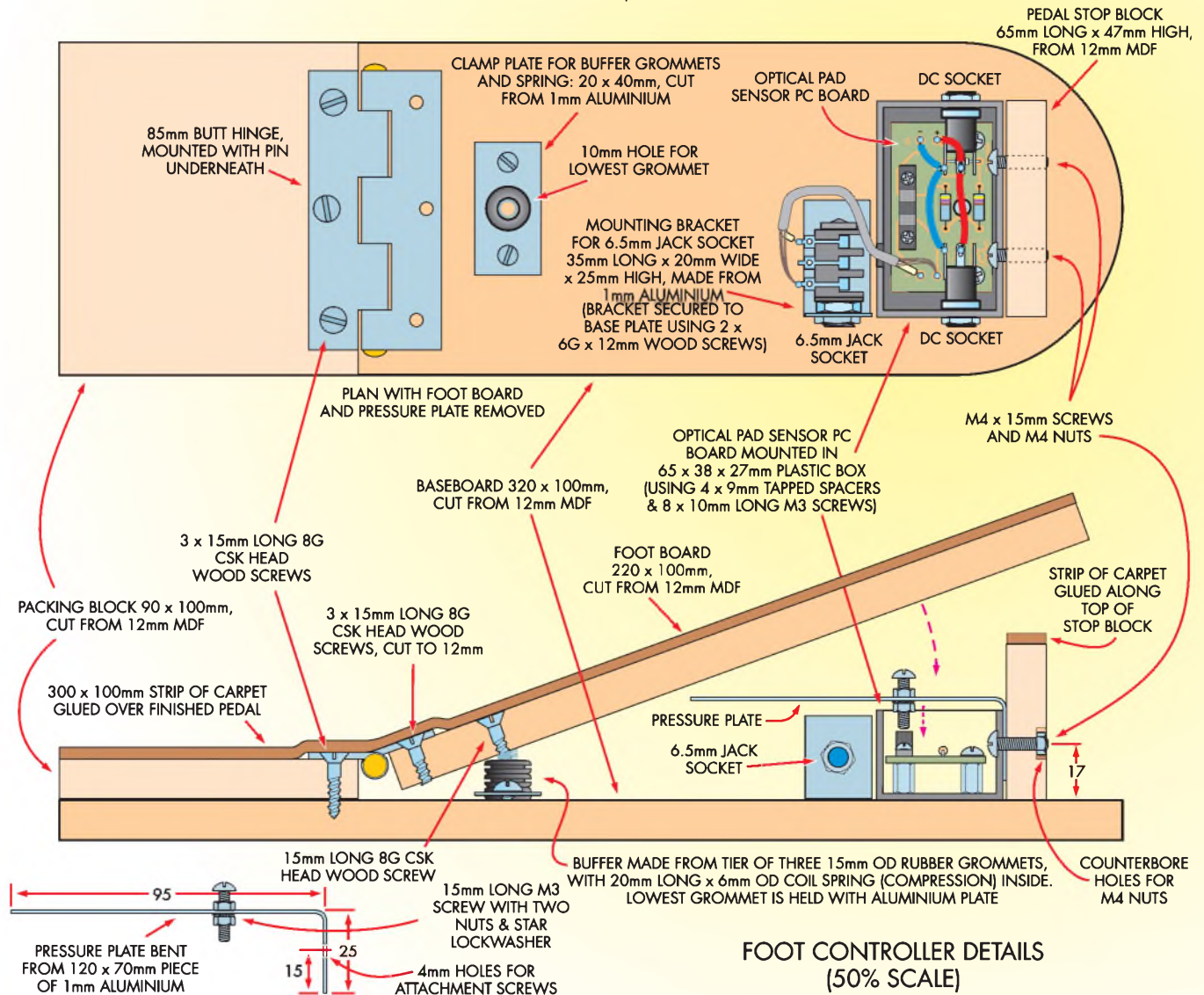
The optical pad is housed in a plastic box and secured to the upright MDF piece with M4 screws and nuts. This also sandwiches the pressure plate between the box and MDF. The PC board for the optical pickup is supported on M3 tapped standoffs (9mm long) and held using M3 x 10mm screws.

The screw mounted in the pressure plate to interrupt the optical sensor must be adjusted as described in the Bongo drums set-up.

The DC sockets are mounted at each end of the box. The signal output is wired to the 6.35mm jack socket that is mounted on an aluminium bracket. You will need to make up a 6.35mm jack plug to RCA plug lead for the connection between the foot controller and the MIDI Drum Kit.



The footswitch is made using the MDF panelling as shown below. We painted the assembly with black paint and covered the foot areas with speaker carpet.



If you want to build your own foot controller, here is how to do it. The alternative is to use the information in this diagram to modify a commercial foot pedal.



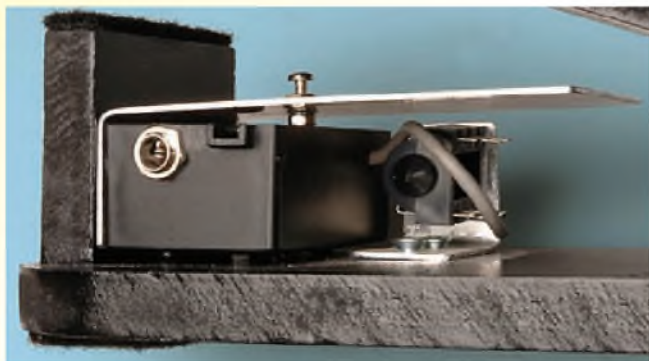
Parts List

- 1 PC board coded 657, available from the *EFE PCB Service*, 52 x 31mm
- 1 bulkhead plastic box, 65 x 38 x 25mm
- 1 photo-interrupter
- 1 1N4004 diode
- 1 470 μ F 16V PC electrolytic capacitor
- 2 470 Ω 1/4W 1% resistors
- 1 6.35mm mono jack socket
- 2 line DC plugs
- 4 PC stakes
- 1 2-metre length of single-core shielded cable
- 1 6.35mm mono plug
- 1 RCA line plug
- 1 65 x 120mm length of 1mm aluminium
- 1 20 x 40mm length of 1mm aluminium
- 1 60 x 20mm 1mm aluminium
- 1 100 x 35mm sheet of 1mm aluminium
- 1 85mm butt hinge
- 6 8g csk wood screws cut to 12mm
- 7 6g csk wood screws cut to 12mm
- 1 5g x 20mm screw
- 1 M3 x 15mm screw
- 1 3mm star washer
- 2 M3 nuts
- 2 M4 x 15mm screws
- 2 M4 nuts
- 4 M3 tapped x 9mm spacers
- 8 M3 x 6 screws
- 1 20mm long by 6mm OD compression spring (from clothes peg)
- 3 15mm OD x 6mm ID rubber grommets
- 1 100 x 320mm length of 12mm MDF
- 1 100 x 80mm length of 12mm MDF
- 1 100 x 220mm length of 12mm MDF
- 1 65 x 47mm length of 12mm MDF

Miscellaneous

Black paint, PVA glue, speaker carpet, contact adhesive

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Footswitch

The footswitch is a commercially made unit – all it really needs is to have an RCA plug wired to its end. However, the wiring supplied with the switch is a little too thick for the RCA phono plug, so it is best replaced with single-core shielded cable instead. Connect the wire between the normally open and common connections on the microswitch.

Parts List

- 1 footswitch
- 1 1m length of single-core shielded wire
- 1 RCA phono line plug



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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 ★

Surface Mounted Rework

Dear EPE,

I read the letter on surface mounted rework with interest in the Oct '07 issue and I would like to put forward some more suggestions when dealing with surface mounted devices (SMDs).

I am a professional electronics engineer with many years experience dealing with SMDs. I mainly repair Sky digital boxes for a living, as well as TVs, videos and the odd microwave oven. I have a high street shop and also do mail order set top box repairs and I regularly receive requests from other dealers to replace SMDs on various PCBs.

On the whole, people tend to be frightened of dealing with SMDs. Usually they have had a bad experience trying to replace a chip, with disastrous consequences and have been put off SMDs for good. I have some very expensive kit for dealing with SMDs, an infrared reflow station costing nearly £5k, which is well out of reach for the general hobbyist, but did you know you can successfully replace SMDs with a little known method and a layout of less than £100?

When replacing SMDs there are two most important things you need to know, board pre-heating and use of flux. Get these right and replacing SMDs is child's play. Let's take the board pre-heating issue first. Imagine a 15W soldering iron fitted with a needle point tip, as soon as you touch the tip on a cold SMD, heat is drawn away from it and it becomes virtually impossible to heat the joint above the solder melting point, which for conventional 60/40 leaded solder is approximately 183°C.

If you pre-heat your circuit board first to between 100 and 120 degrees C, the tip of your soldering iron will not cool on contact with a cold solder joint and it becomes possible to solder at lower temperatures. Pre-heating also cushions the thermal shock of both the component and the circuit board. This is important when replacing SM ceramic capacitors, which can crack if soldered from cold, while a cracked capacitor may appear to function correctly after replacement, in the passing of time moisture from the atmosphere can enter through the hairline crack and cause

the capacitor to become resistive, or 'leaky'.

Next, the flux issue, this is what most people do not understand and it is where they go wrong when trying to replace SMDs. A thin skin of oxide forms on molten solder when it is exposed to atmospheric oxygen, causing a dry oxidised solder joint to form. Applying flux to the molten solder removes the oxide skin and allows the solder to flow properly. It also prevents solder bridging between two adjacent pins when soldering fine pitched SMDs with a conventional soldering iron.

The choice of flux is very important, it must be non-corrosive and cause no long-term surface insulation resistance, especially where cleaning cannot take place, such as the underneath of a chip. Over the years I have tried many different types, but one I have found outstanding is a 'no clean' thick gel type specially developed for BGA chips (the square chips with no pins visible from the outside) but excellent results are obtained with any type of component, which can be obtained from Blundell production equipment (contact details at the end).

Replacing small multi-pin chips up to about 48 pins is better done with hot air. I use a Weller pyro pen, which costs about £80, but shop around and you can probably get a cheap copy for less than £30. A professional board pre-heater could set you back £700, but there again a cheap copy which is well capable of the job can be bought for less than £70 (see later).

Now let's examine the replacement of say a 14-pin SMD IC. Using this method is incredibly simple and it's possible to replace the chip without even being able to tell it's been done. First give the pins of the chip to be removed a very light brush with a fibreglass pencil, not too much as these are very abrasive, then run across all the pins with flux.

Now place the PCB on the pre-heater and heat the board to 100°C. Hold the chip with a pair of fine tweezers and using a hot air pencil, heat the top of the chip directly, within five seconds or so the chip can be lifted off and the solder will remain on the board, leaving a set of perfectly formed solder pads and no need for any additional solder. Don't worry about

heating the top of the chip, contrary to popular belief this will not damage the chip as long as it's not heated for an extended length of time. This is something you really have to see to believe!

In manufacture, BGA chips are fitted this way by directly heating the top of the chips until the solder balls underneath collapse. Remove the board from the pre-heater and let it cool, then wash off the flux with a flux remover.

Now you have removed the old chip and the board is ready to receive the new one. First give the pins of your new chip a good clean with the fibreglass pencil and apply flux to the pins. Also apply a little flux to the solder pads on the board and sit your new chip on top, carefully line up the pins onto the centre of the pads, if you are using a thick gel flux this will hold the chip in place as you will be sitting it on top of a 'solder bump'. Now pre-heat the board to 100°C and then run down each side of the pins with a hot air jet for a few seconds, as the solder melts you will see the chip sit down onto the PCB. As soon as this happens turn off the pre-heater and let the board cool – simple.

A bit of practice may be required to perfect the operation and I would suggest starting with an 8-pin chip first, then moving up to more pins later. A good way of practising is to get hold of an old model Sky Digibox; the first generation ones which now run very slowly can be picked up working for just a few pounds. They are full of SMDs. Remove a chip and see what effect it has, then replace it and see if the box still works. Removal of most parts will result in a box which is stuck in standby so you will soon know if your removal and replacement has been successful.

Useful contacts: Blundell Production Equipment Ltd, 0247 647 3003, www.blundell.co.uk. No clean BGA flux comes in a 5cc syringe, Inter Flux IF8300, £11.08 plus VAT. Allendale Electronics Ltd sell a board pre-heater made by Aoyue, model 835A for £69.95 inc. VAT. 01992 450780, www.pcb-soldering.co.uk.

Michael Dranfield, Digifix Ltd, Buxton, Derbyshire

Many thanks, a very thorough description Michael.

Alan replied to Barry:

Thanks Barry, the only use I can think of is to melt an already soldered solder pad on a PCB – which is what they do in their promotional videos, soldering a broken wire back onto a PCB – the solder shorts out the iron's tip and melts, and that's pretty much it. Otherwise I cannot think that the Coldheat soldering iron is of any use to the electronics constructor at all.

Alan Winstanley, via email

Coldheat Soldering SMDs

Dear EPE,

I've just read Alan's very thorough assessment of the Coldheat soldering iron and can heartily agree with him on all points. I bought one for the odd time that I use a soldering iron in the house, but it was a total failure. I do not think I made one good joint with it. It was very disconcerting to see sparks fly when connected to a joint. In fact, it made me jump back a bit, whereupon I broke the tip.

I was so disappointed that I took it straight back and got an Antex SZ004W0

cordless iron and that worked fine for the very limited use I had for it.

I have been working on all types of electronic soldering since school. In fact, I did an apprenticeship with BT and got trained in the art of soldering. I currently work on SMD circuits using hot air and conventional soldering techniques. A novice would have very little chance of any real success using the iron. I think in fact you are more than generous about using them for anything useful. It was also of note that Maplins did not give me a second look when I returned it!

Barry GILHL, via email

Epson ESC/2P Codes

Dear EPE,

Amazing how each edition of *EPE* gets you thinking! August *Readout* includes a contribution from David Whale regarding DOSPRINT, software that generates dot-matrix Epson print format. My current inkjet printer responds to Epson ESC/2P format codes, does this amount to the same thing, is that what David actually means?

You're not likely to know the answer just from the information you've been given, so I was rather hoping that you could invite David to reply.

**Godfrey Manning G4GLM,
via email**

Well David, are you reading this? Care to send me a reply via EPE which I can quote here?

PIC Terms

Dear EPE,

Regarding Pat Alley's letter in the Oct '07 issue, I must say that for someone who has obviously had an interest in PICs for sometime, I am surprised that they have no idea that most of their queries relate to PIC Special Function Registers (SFRs) and peripheral hardware modules (Try downloading and reading *PICmicro*™ *Mid-Range MCU Family Reference Manual* DS33023A, or try a PIC beginner's book that will perhaps give an insight into the PIC core and its many peripherals.)

In a PIC related article, I would suggest it is acceptable for the author to use such abbreviations freely and without further explanation. However, if it is remembered that not all readers will have a deep knowledge of the area under discussion, I think that it is good practice never to use an abbreviation in an article without first using the full form followed by the abbreviation in brackets, as I have done above. This avoids any ambiguity, enlightens beginners and even reminds old hands!

The use of terms such as 'bit bashing' is a little more fraught. If you've ever written a serial output routine for a micro without a Universal Asynchronous Receiver/Transmitter (UART) module, then you'll certainly know what bit bashing is! If you haven't, you may well not.

So how should such terms be handled by a magazine such as *EPE*? I think there are three choices:

1. Don't use them at all. This would be a shame; once learnt and understood such terms provide a colourful and succinct way to describe various functions – that's why they evolved

2. Explanation in a footnote. Could get messy as it would need to be repeated each time it was used

3. Inclusion in an expanding glossary of unusual terms (not abbreviations!) included in each month's magazine (don't panic Editor, it shouldn't run to much more than a page). To my mind it's the best option and the glossary will become a good reference source

The reader with internet access has, of course, another alternative – Google the term. This will normally throw up at least one source of explanation.

**David Sims,
via email**

Thanks David. We try to explain things as appropriate, but space limitations prevent constant repetition. A Glossary is a nice idea, but we regret we don't have the space. Googling is often my preferred way of checking on info.

CFLs and Dimmers

Dear EPE,

I noticed your coverage of CFLs and dimming: it seems a pity that CFLs are not available with an IR sensor, through which they can learn brightness up/down on/off from a spare remote/extra (dummy) device on a multi-device remote. This would allow remote control dimming without any rewiring. Dimmer adaptors like this are available for filament bulbs, so it seems logical to simply build this feature into some CFLs.

**Alan Bradley,
via email**

I agree in principle Alan – thoughts anyone?

Standby Power Saver

Dear EPE,

The *Standby Power Controller* in *EPE* Oct '07, was particularly interesting to me as I developed a similar device a couple of years ago and have been using it ever since. I was driven to develop this having bought a cheap Freeview set-top box, which sported a standby mode that actually had the same power consumption as the 'on' mode.

My device had some key differences to yours in that my prime objective was really to make the thing as energy-efficient as possible. I didn't want to use batteries and I wanted it to consume as little power as possible. To achieve this I decided that:

1. It would use any existing IR remote control (having a 'learn' mode for the on and off commands). As the remote would already be being used to control a device, I didn't consider this to be an extra battery

2. The receiver would use a capacitive power supply consuming only a few mW (or less) at all times

3. It would need some extra on and off delays to cope with the start-up times of devices being controlled and to cope with devices such as a TV projector which required fans to run-on for a few minutes after power-off

To use the capacitive power supply (which can only provide a few mA), I used a latching relay with a switch time of <10ms and controlled the whole thing with a PIC16F684, running in standby-mode and woken by activity on the IR sensor or the programming controls. The device generates no heat and, as far as I can tell, is very energy-efficient.

My reason for writing is to question whether your project actually solves the problem you set yourself. The use of a dedicated controller unit and, even worse, the use of an always-on transformer is not, in my opinion, much more energy-efficient than the poor standby implementations already present in many devices. You don't back up your device with any figures on its power consumption, which is telling.

I realise that part of the reason for your practical projects is to show some novel use of electronics and your device's wireless implementation is interesting. However, given the introductory text for the article, it would really have been better to examine how a really efficient device could be constructed, with details of how power consumption could be accurately measured, particularly when it is very low. I have been unable to measure the actual power consumption of my device as I couldn't get a figure to register on the monitoring device I was using.

**Peter Bissell,
via email**

Thanks for that Peter. There seemed little point in quantifying my unit's

consumption, which I'm sure is far less than any standby mode of commercial equipment. Congratulations on your refined unit!

Energy Saving

Dear EPE,

Having read Tony Jaques' recent *Readout* letter regarding energy saving, I have to say I totally agree with his points. I have never understood why some radiator pipes are insulated, when all the heat 'lost' ends up in the house anyway!

What I also would like to comment on, though, are the misconceptions regarding energy saving lamps. It seems that no-one takes into account the extra energy and pollution involved in the mineral extraction and manufacture of these devices.

These CFLs are stuffed with electronic components, which we all know are not exactly 'green'. They also have plastic parts, made from oil. Oh, not to forget the cocktail of toxic chemicals within the tubes themselves. They are generally dumped in the bin when they stop working – which is quite often well within the time we are led to believe they last!

Condensing boilers, according to a few engineers I know, are also less efficient than first appears. It seems that they have a shorter life than traditional boilers, require replacement parts on a regular basis and consume much more energy and parts to manufacture in the first place.

While I believe we should all be doing our 'bit' to help reduce the human impact on the Earth, perhaps we are being subject to a little more 'spin' than truth?

**Chris Potter,
Cornwall**

Probably so Chris, but we do all need to conserve more.

Historical Equipment

Several readers responded to the letter by Graham Bartlett in the Nov issue:

D.B. Venuti: Graham says many of us hoard things, me included!, so a couple of suggestions spring to mind. First, I suspect that quite a few amateur radio clubs would be interested in equipment/components, for obvious reasons. Second, I know that in Norfolk the Muckleborough Collection has a lot of gear of all sorts, and would no doubt be grateful for some of the older items, at least to show to the public. It has a radio hut section, and can be found at www.Muckleborough.co.uk.

Andy Mills: As a collector and repairer of vintage gear, I am always on the lookout for sources of components/spares etc, as featured here. I would be grateful if you can pass my contact details to Graham.

Godfrey G4GLM: I know the difficulty of handling the affairs of deceased enthusiasts ('Silent Keys' as we say when a licenced radio amateur passes on). For my part, I am collecting the oldest possible semiconductors and will gladly pay costs plus a charitable donation, all working surplus items go into my 'bank' ready to dish out (no charge made) to any other enthusiast who has genuine need. As for the rest, try: UES&S Ltd, Units 6 & 7, Bayfield Brecks Farm, Holt, Norfolk NR25 7DZ. Tel: 01263 710054. Email: sales@surplus-electronics.co.uk

D.A. Pike: I would like to avail myself of any meters – RF, moving coil, frequency etc.

All letters were passed on to Graham. Thanks everyone.

Net Work

Alan Winstanley

All in one search results

Last month I highlighted the case of a friend's laptop that became the unwelcome host for IE Defender, an unlovely infection that hijacks Google and Yahoo search results in a particularly offensive way to give the impression that the machine has suddenly been 'infected' – which indeed it has, by IE Defender!

I explained that even a neophyte user could evaluate the problem by doing a little Google research on an uninfected machine: when you see blogs, forums and websites all asking the same thing (namely, how to remove IE Defender malware) then you know that you are on the right track. I also explained the steps I took to banish IE Defender from the laptop, which after several days on its knees sprang satisfyingly back into life.

Another issue worth remembering is that if you search for, say, 'spyware removal' tools Google will return paid-for sponsored links that point to web sites trying to sell you yet another software download. Unless you know specifically what you are looking for, be wary of lookalike or soundalike products that could, in fact, contain more spyware or malware.

Searching for the popular 'Spybot Search & Destroy' (from www.safer-networking.org) pointed to all sorts of similar looking products and it was only through experience that I recognised the genuine article. Again, some judicious googling will help you form a consensus whenever you are unsure.

Google remains the world's best known search engine, closely followed by Yahoo, then a distant third comes arch-rival Microsoft Live (www.live.com) and lastly Ask (www.ask.com), formerly Ask Jeeves. Search results from these major search engines also find their way into portal web pages, such as AOL or Tiscali.

The Google search engine was founded by University statisticians and mathematicians who relished the challenge of analysing stacks of data, with a view to generating extremely accurate search results. Consequently, the search engine is constantly refining its algorithms and has created an artificial intelligence all of its own: Google's avowed intention is to analyse and assess web sites accurately in order to generate relevant answers to specific search queries (more than 100 calculations are made by Google before it decides what results to display).

As the years pass by, Google's database becomes ever more refined. It learns from its search results, it knows what constitutes a popular website, and as many website owners have found to their cost, Google drops from its index any sites that it thinks are subverting Google's accuracy. Simply remember that Google is staffed by some of the finest statistical and analytical brains in the business.

The funny thing is, though, if I google for 'search engines' – the number one result is... Dogpile! This interesting



site (see www.dogpile.com) streams results in from all the major search engines and is definitely worth testing.

Viral vouchers

At the time of writing, Christmas 2007 is less than two weeks away, bringing with it the fallout from the squeeze on spending and a credit crunch looming on the horizon. The writer's eyes lit up – just before they narrowed, anyway – when he received an email from a correspondent that offered 'free Marks and Spencers [sic] vouchers from Persimmon Homes.' M&S are a major retail chain and Persimmon Homes claims to be the 'U.K.'s leading housebuilder'. All I had to do was circulate the email to 20 contacts and receive £500 (\$1,000) in free M&S vouchers! Also, I was supposed to cc: the emailshot to some unfortunate soul's address at Persimmon Homes.

The email was very cleverly constructed as a 'viral' message – a marketing message that relies on word of mouth to spread the word rather than a static advertisement in the press or on TV. Examples include Ford SportKa's infamous Evil Twin (search www.youtube.com) advert that upset some easily offended pigeon lovers: no, they did not use real pigeons.

Marks & Spencers, in conjunction with Persimmon Homes, are giving away free vouchers. Marks & Spencers are trying word-of-mouth advertising to introduce its products and the reward you receive for advertising for them is free non-refundable vouchers to be used in any M&S store.

To receive your free vouchers by email, all you have to do is to send this email out to eight people (for £100 of free vouchers) or 20 people (for £500 of free vouchers). Within two weeks you will receive an email with your vouchers attached. They will contact you through your email address.

Please mark a copy to: xxxxx@persimmonhomes.com

The email is very plausible, and of course, if anything sounds too good to be true then it always is. A simple google search for a phrase

such as 'marks and spencers persimmon' returns in 200 milliseconds a list of hits including 'Phoney Marks and Spencer email spreads like wildfire' and 'Marks and Spencer Voucher Giveaway Hoax'. Surely this tells the recipient of an enticing email everything they need to know about a viral hoax that is at least six months old.

The same can be said for a number of urgent-sounding emails that warn us of impending doom if we open a certain file or read a certain email. A good resource is McAfee's list of hoaxes at <http://vil.mcafee.com/hoax.asp>. I am sure readers will recognise some of the hoaxes listed.



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Computing & Robotics

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N. Kantaris and P. R. M. Oliver

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EASY PC CASE MODDING

R.A. Penfold

Why not turn that anonymous grey tower, that is the heart of your computer system, into a source of visual wonderment and fascination? To start, you need to change the case or some case panels for ones that are transparent. This will then allow the inside of your computer and it's working parts to be clearly visible.

There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including: Electro luminescent (EL) 'go-faster' stripes. Internal lighting units: Fancy EL panels. Data cables with built-in lighting. Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube. Digital display panels: LED case and heatsink fans. Coloured power supply covers.

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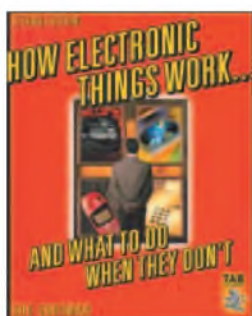
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A interface board with 5 digital input & 8 digital output channels. In addition, there are two analogue inputs & two analogue outputs with 8 bit resolution. All communication routines are contained in a Dynamic Link Library (DLL). You may write custom Windows (98SE, 2000, Me, XP) applications in Delphi, Visual Basic, C++ Builder or any other 32-bit Windows application development tool that supports calls to a DLL.

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With a total of 33 input/outputs: including analogue / digital and +1PWM output. Connection to the computer is galvanically optically isolated, so that damage to the computer is not possible thus providing a high level of secure implementation. Supplied with test software & examples.

K8061 Kit £44.85

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Remote Control by Telephone

Turn up to three devices on or off over the telephone. It is also possible to check the condition of a switch (open or closed). A major advantage of this circuit lies in the fact that audio signals are used to tell whether a specific output has been turned on or off. Operation is protected by a user defined code, which is simply keyed in from the telephone keypad.

K6501 Kit £26.95

USB DMX Interface

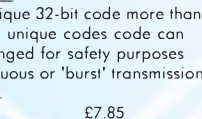
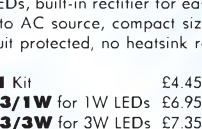
Control DMX fixtures using a PC and USB interface, test software and "DMX Light Player" software is included, a DLL is provided to write your own software. Stand-alone test function that outputs all 512 channels at a time, with adjustable levels.

Supplied with case, lead & CDROM
K8062 Kit £43.45
VM116 Assembled £49.95

Remote Control Transmitter

For use with the K8057/VM109 2-channel RF receivers. Generates unique 32-bit code more than 1,000,000,000 unique codes code can easily be changed for safety purposes choose continuous or 'burst' transmission LED indicator.

K8059 Kit £7.85



Remote Control Receiver

Two relay contact outputs for use with K8059 and VM108 two channel RF codeclock transmitters, toggle or pulse function selectable per output, can learn a unique 32-bit code from the transmitters, store up to 31 transmitters, LED indicators for outputs and functions

K8057 Kit £10.95

Remote Control Transmitter

Compact 2-button IR keychain remote compatible with most Velleman IR receivers, 2 powerful IR LEDs for a range of up to 15m, 16 channels (allow use of multiple transmitters in one room), easy channel configuration, no jumpers required

MK162 Mini Kit £6.25

Remote Control Receiver

Two channels with relay output (24VAC/DC 1A max.) ultra compact channel and reception indication through LEDs toggle / pulse selection for each channel learn mode for channel ID all settings are stored in EEPROM compatible with most Velleman Kit IR remotes.

MK161 Mini Kit £6.85

3-30V 3A Power Supply

Suitable as a power supply for all common Velleman kits using a stabilised DC voltage between 3 and 30V, 3A max. Of course this power supply unit can also be used for other purposes. By replacing the trimmer by a potentiometer, it may even be used as an adjustable power supply unit. Supplied with heat sink.

K7203 Kit £17.95

Sound to Light Unit

Low, mid and high channels. Sensitivity adjustment per channel. LED indication per channel. Attractive translucent enclosure. Microphone included. Noise suppressed according to EN55015

K8017 Kit £24.95

Clap On/Off Switch

Operate your lighting simply by clapping your hands. Good immunity against surrounding noises, '1-clap' or '2-clap'-mode selection, '2-clap'-mode features built-in safety turn-off timer (approx. 5h), output relay 'pulse' or 'toggle' selection.

MK139 Mini Kit £7.35

Voice Changer

Make your voice sound like a robot, add vibrato effect, use the 'pitch'-buttons and make your voice sound lower or higher, built-in microphone and power amplifier with volume control, just add a speaker.

MK171 Mini Kit £6.95

Ultrasonic Radar Module

Buzzer output: fast / slow / continuous distance indication with 3-LED-bar adjustable alarm. LED alarm indicator, dry contact NO/NC relay

VM125 Assembled £16.45

IR Light Barrier

Audible (85dB) and visible (LED) alert, range: 1 to 4m, on/off switch provided, power supply: 9V battery, holder and adapter jack included

MK120 Mini kit £4.95



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