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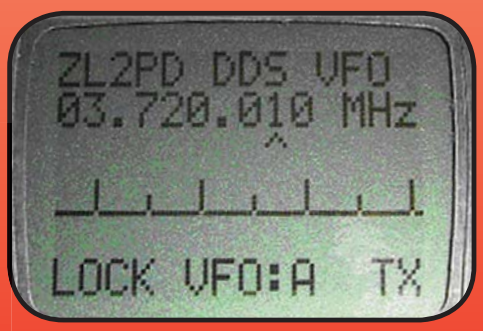
TEACH-IN 2010
LADDER LOGIC PROGRAMMING FOR THE PIC MICRO
Part 1: Getting Started – Working with Inputs and Outputs

EMERGENCY 12V LIGHTING CONTROLLER
Don't get left in the dark by power cuts



A DIGITAL VFO WITH LCD GRAPHICS DISPLAY
Uses a recycled Nokia LCD to display analogue and digital frequency readouts

$8.75 US $10.25 CAN
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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 - **£49.95**
Assembled Order Code: AS3149 - **£59.95**

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 - **£49.95**
Assembled with ZIF socket Order Code: AS3128ZIF - **£64.95**

'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 - **£29.95**
Assembled with ZIF socket Order Code: AS3117ZIF - **£44.95**

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 - **£27.95**
Assembled Order Code: AS3123 - **£37.95**

Introduction to PIC Programming

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

PIC Programmer Board

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

PIC Programmer & Experimenter Board

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

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU445 £7.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£38.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two & *Ten Channel versions also available.*
Kit Order Code: 3180KT - **£49.95**
Assembled Order Code: AS3180 - **£59.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£19.95**
Assembled Order Code: AS3145 - **£26.95**
Additional DS1820 Sensors - **£3.95 each**

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

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£74.95**
Assembled Order Code: AS3140 - **£89.95**

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 - **£64.95**
Assembled Order Code: AS3108 - **£79.95**

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 - **£59.95**
Assembled Order Code: AS3142 - **£69.95**

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 - **£34.95**
Assembled Order Code: AS3153 - **£44.95**

Telephone Call Logger

Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).
Kit Order Code: 3164KT - **£54.95**
Assembled Order Code: AS3164 - **£69.95**

Hot New Products!

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

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£69.95**
Assembled Order Code: AS3190 - **£84.95**

40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Stand-alone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£28.95**
Assembled Order Code: AS3188 - **£36.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**

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 - **£17.95**
Assembled Order Code: AS3067 - **£24.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£15.95**
Assembled Order Code: AS3179 - **£22.95**

Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£23.95**
Assembled Order Code: AS3158 - **£33.95**

Bidirectional DC Motor Speed Controller

Control 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 - **£22.95**
Assembled Order Code: AS3166v2 - **£32.95**

AC Motor Speed Controller (700W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction 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 - **£14.95**
Assembled Order Code: AS1074—**£23.95**

See www.quasarelectronics.com for lots more motor controllers

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Tools & Test Equipment

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

Two-Channel USB Pc Oscilloscope

This digital storage oscilloscope uses the power of your PC to visualize electrical signals. Its high sensitive display resolution, down to 0.15mV, combined with a high bandwidth and a sampling frequency of up to 1GHz are giving this unit all the power you need.
Order Code: PCSU1000 - **£399.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ **£169.95**

See website for more super deals!

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EVERYDAY PRACTICAL ELECTRONICS
FEATURED KITS

November '09

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

Jaycar Electronics

EMERGENCY 12V LIGHTING CONTROLLER

KC-5456 £20.50 plus postage & packing

Automatically supplies power for 12V emergency lighting during a blackout. The system is powered with a 7.5Ah SLA battery which is maintained via an external smart charger. Includes manual override and over-discharge protection for the battery. Kit supplied with all electronic components, screen printed PCB, front panel and case. Charger and SLA battery available separately.

Featured in this issue of EPE

STEREO HEADPHONE DISTRIBUTION AMPLIFIER

KC-5417 £10.25 plus postage & packing

Enables you to drive one or two stereo headphones from any line level (1volt peak to peak) input. The circuit features a facility to drive headphones with impedances from about 8-600Ω. Comes with PCB and components.

Featured in this issue of EPE

Also recommended: Box HB-6012 £2.00
Power Supply Kit KC-5418 £6.00

NEW TO EPE

PIC LOGIC PROBE

KC-5457 £5.00 plus postage & packing

Operating on 2.8-15VDC, this logic probe is suitable for use on the most modern circuits. Extremely compact with SMT devices on a PCB only 5mm wide. It's capable of picking up a pulse only 50mS long and will also detect and hold infrequent pulses when in latch mode. Kit includes PCB and all specified electronic components including pre-programmed PIC. You'll need to add your own case and probe - a clear ballpoint pen and a darning needle work well.

As Published in EPE July 2009

3V TO 9V DC-DC CONVERTER

KC-5391 £4.75 plus postage & packing

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

As published in EPE June 2007

PROGRAMMABLE HIGH ENERGY IGNITION SYSTEM

KC-5442 £27.75 plus postage & packing

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

- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment

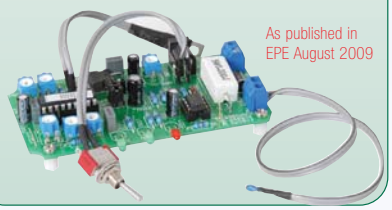
Also available to suit: Ignition Coil Driver Kit KC-5443 £13.75
Knock Sensor Kit KC-5444 £18.95

Featured in this issue of EPE

FAST NI-MH BATTERY CHARGER

KC-5453 £12.50 plus postage & packing

Ideal for RC enthusiasts who burn through a lot of batteries. Capable of handling up to 15 of the same type of Ni-MH or Ni-Cd cells. Build it to suit any size cells or cell capacity and set your own fast or trickle charge rate. Features overcharge protection and temperature sensing. Kit includes solder mask & overlay PCB, programmed micro and all specified electronic components. Case, heatsink and battery holder not included.



As published in EPE August 2009

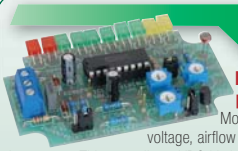
ROLLING CODE IR KEYLESS ENTRY SYSTEM

KC-5458 £19.00 plus postage & packing

Features two independent door strike outputs and recognises up to 16 separate key fobs. This advanced system keeps coded key fobs synchronised to the receiver and compensates for out of range random button presses. Supplied with solder masked and silk screen printed PCB, two programmed micros, battery and all electronic components. The receiver requires a 12VDC 1.5A power supply. Some SMD soldering is required.

Featured in EPE Aug/Sept 2009

VOLTAGE MONITOR



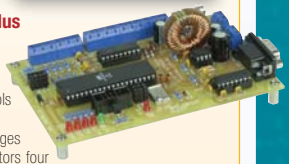
KC-5424 £6.75 plus postage & packing

Monitors either the battery voltage, airflow meter or oxygen sensor in your car. This versatile 12VDC kit features a 10 LED bar graph that indicates the measured voltage in 9-16V, 0.-5V or 0-1V ranges. Features fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay and all electronic components.

As published in EPE November 2007

SMS CONTROLLER MODULE

KC-5400 £17.00 plus postage & packing



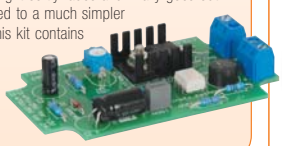
Control appliances and receive alert notification from anywhere. It controls up to eight devices by sending plain text messages and simultaneously monitors four digital inputs. It works with old Nokia handsets such as the 5110, 6110, 3210, and 3310, which can be bought inexpensively. Kit supplied with manual, PCB, pre-programmed microcontroller and all electronic components. Requires a common Nokia data cable found in many retail stores.

As published in EPE March 2007

COURTESY INTERIOR LIGHT DELAY

KC-5392 £6.00 plus postage & packing

Enables your car to have the same interior light delay feature you find in many modern cars, allowing you time to buckle up and settle in before the light softly fades and finally goes out after a set time. Upgraded to a much simpler universal wiring setup, this kit contains PCB with overlay and all electronic components.



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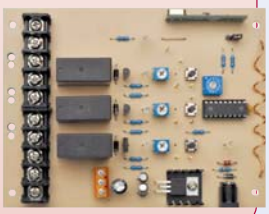
UHF ROLLING CODE REMOTE SWITCH

KC-5483 £29.90 plus postage & packing

High-security rolling code 3-channel remote control that can be used for keyless entry and control of garage doors and lights. Up to 16 transmitters may be used with the one receiver so it's suitable for small-scale commercial applications. The transmitter kit includes a three button key fob case and runs on a 12V remote control battery.

Additional UHF Rolling Code Transmitter Kit KC-5484 £11.75



BATTERY ZAPPER MKIII

KC-5479 £23.25 plus postage & packing

Prolongs the life of your lead acid batteries. Like the original 2005 project, this circuit produces short high level bursts of energy to reverse the sulphation effect. The battery condition checker is no longer included and the circuit has been updated and revamped to provide more reliable, long-term operation. It still includes test points for a DMM and binding posts for a battery charger. Not recommended for use with gel batteries

- PCB with solder mask and overlay Components
- Screen printed machined case
- 6, 12 & 24VDC

SLA BATTERY HEALTH CHECKER

KC-5482 £23.25 plus postage & packing

Checks the health of your SLA batteries prior to charging or zapping with a simple LED condition indication of fair, poor, good etc. An ideal companion to our Battery Zapper MKIII.

- Overlay PCB and electronic components
- Silk-screened front panel and machined case included

FUEL/AIR MIXTURE DISPLAY

KC-5485 £17.50 plus postage & packing

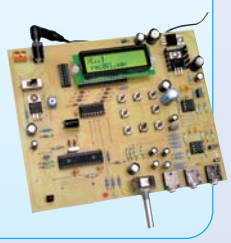
Displays your car's air-fuel ratio as you drive. Designed to monitor a wideband oxygen sensor and its associated wideband controller. Alternatively it can be used to monitor a narrowband oxygen sensor or for monitoring other types of engine sensors.

- 12VDC
- Double-sided plated PCB
- Programmed PIC
- Electronic components
- Case with machined and screen printed lid

SD CARD SPEECH RECORDER & PLAYER

KC-5481 £21.75 plus postage & packing

Use this kit to store your WAV files on MMC/SD/SDHC cards. It can be used as a jukebox, a sound effects player or an expandable digital voice recorder. You can use it as a free-standing recorder or in conjunction with any Windows, Mac or Linux PC. Short form kit includes overlay PCB, SD card socket and electronic components.

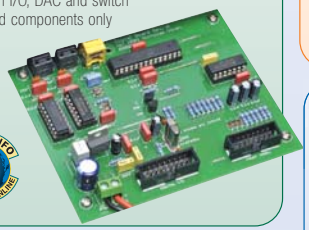


STEREO DIGITAL TO ANALOGUE CONVERTER

KC-5487 £40.50 plus postage & packing

Listen to CDs through a DVD player with this DAC kit to get sound quality equal to the best high-end CD players. With stereo RCA outputs, it has one coaxial S/PDIF input and two Toslink inputs. Requires SMD soldering.

- Short form kit with I/O, DAC and switch PCB and on-board components only
- Requires PSU KC-5418 £6.00
- Requires toroidal transformer

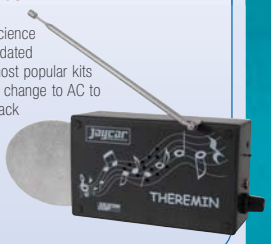


MORE INFO AVAILABLE ONLINE

THEREMIN SYNTHESISER KIT MKII

KC-5475 £21.75 plus postage & packing

Create your own eerie science fiction sound effects! Updated features to one of our most popular kits include extra test points, change to AC to avoid switchmode plugpack interference, and a new skew control to vary audio tone. Contains PCB with overlay, pre-machined case and all specified components.

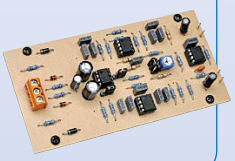


MULTIFUNCTION ACTIVE FILTER MODULE

KC-5480 £7.25 plus postage & packing

A versatile active filter module that can be used either as an active crossover, a low pass filter, or a high or band pass filter in a speaker project simply by changing a couple of jumper links. Short form kit only with PCB, overlay and all common components. Requires power supply (see specs), amplifiers, and additional components for configuration to PSU and operation frequency.

Input impedance: 47kΩ
Power supply: dual rail ±15-60VDC; single rail 12-30VDC or 11-43VAC
Current: 40mA max
S/N ratio: >100dB @ 1V
22Hz-22kHz filter

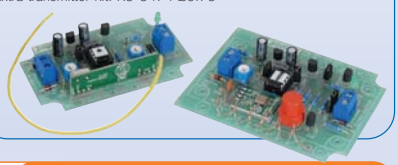


433MHZ REMOTE SWITCH

KC-5473 £13.25 plus postage & packing

Suitable for remote control of practically anything up to a range of 200m. The receiver has momentary or toggle output with adjustable momentary period. Up to five receivers can be used in the same vicinity. Short-form kit contains two PCBs and all specified components.

Extra transmitter kit: KC-5474 £6.75



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Competing technologies – survival of the fittest

The nineteenth century wasn't just the heyday of British engineering, when we were the 'workshop of the world', we also produced some remarkable scientists. Perhaps the most influential was Charles Darwin, whose birth bicentenary occurred earlier this year. Darwin revolutionised biology and our perception of ourselves with his theories of evolution and natural selection. While the natural selection analogy is not perfect, I often feel that in the electronics industry the struggle between competing technologies is every bit as cut-throat and ingenious as in the natural world. One of the most interesting rivalries is between hard disk drives (HDD) and Flash memory.

On the face of it, HDDs are an unlikely survivor. Introduced by IBM in 1956, they are a costly, complex and delicate mechatronic system that somehow refuses to die. You'd think that with all the inherent advantages of a pure solid-state memory system that once Flash memory technology matured then it would easily outclass a technology that is barely younger than transistors. And yet, despite the aggressive application of Moore's Law to Flash devices, the clever researchers who support HDD improvement just keep on coming up with novel ways to increase their capacity. A dozen or so years ago, I remember buying a 100MB drive for around £300 – this year, I bought 1TB for half that amount, a 20,000-fold improvement.

The competition between HDDs and Flash shows absolutely no sign of abating – each side spurring the other on to not just keep up with our insatiable desire for storage, but also to avoid being left behind as an also ran. I don't doubt that semiconductors will one day win this race… but I'd hate to say when.

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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NEWS

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

MOBILE PHONES AND BRAIN TUMOURS

A new report, *Cellphones and Brain Tumours: 15 Reasons for Concern, Science, Spin and the Truth Behind Interphone*, has been released by a group which includes Powerwatch and the Radiation Research Trust in the UK, and in the US, EMR Policy Institute, ElectromagneticHealth.org and The Peoples Initiative Foundation. Download it from: **http://www.powerwatch.org.uk/news/20090825_fifteen_reasons_cellphones.asp**

The exposé discusses research on cellphones and brain tumours and concludes:

- There is a risk of brain tumours from cellphone use
- Telecom-funded studies underestimate the risk of brain tumours
- Children have larger risks than adults for brain tumours

This report, sent to government leaders and media, details eleven design flaws of the 13-country, Telecom-funded Interphone study. The Interphone study, begun in 1999, was intended to determine the risks of brain tumours, but its full publication has been held up for years. Components of this study published to date reveal what the authors call a 'systemic-skew', greatly underestimating brain tumour risk.

The design flaws include categorizing subjects who used portable phones (which emit the same microwave radiation as cellphones,) as 'unexposed'; exclusion of many types of brain tumours; exclusion of people who had died, or were too ill to be interviewed, as a consequence of their brain tumour; and exclusion of children and young adults, who are more vulnerable.

International scientists endorsing the report include Ronald B. Herberman MD, Director Emeritus, University of Pittsburgh Cancer Institute; David Carpenter MD, Director, Institute for Health and the Environment, University at Albany; Martin Blank PhD, Associate Professor of Physiology and Cellular Biophysics, Columbia University; Professor Yury Grigoriev, Chairman of Russian National Committee on Non-Ionizing Radiation Protection, and many others.

For The Man Who Has Everything

A must have for Lamborghini fans – so says the Press Release, which follows – the gorgeous ASUS notebook is built for those who love living in the fast lane, with lashings of style and always on the cutting-edge of technology.

Available now at an SRP of £1,999, the VX5 comes in either a Dark Graphite Grey, or Ivory White finish on a robust chassis design that encapsulates the nonpareil styling and raw performance of the revered Lamborghini Reventón supercar.

Following its progenitor, the ASUS-Lamborghini VX5 notebook contains an array of simply outstanding futuristic technology that delivers super-performance coupled with attentive design finishes – all amalgamating into a luxurious and user-centric product truly deserving of the Lamborghini badge. With striking lines, elegant curves and a textural combination of mesh, chrome, ceramic and leather, the VX5 is a true reflection of the futuristic style and quality of its supercar counterpart.

So, if you understand all of that and want one, try searching for ASUS VX5

CONNECTOR PROTECTOR

Contralube770 is a new product for electronic/electrical engineers and enthusiast. Recommended for use with multi-pin connectors, spade, bullet and any other type of push-fit electro mechanical contact area. For problems such as vibration corrosion, oxidation, intermittent circuitry faults/gremlin problems, water penetration and general weatherproofing issues, the solution is Contralube770.

This state-of-the-art grease was created to help people that use electronic and electrical equipment that is exposed to the weather and/or circuit connections used alongside machinery, engines and any other equipment that vibrates.

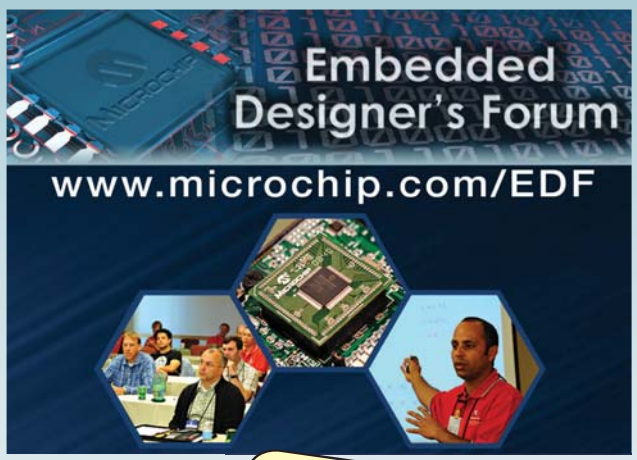
"We are confident Contralube770 will be a big hit with customers," Contralube's head of sales and marketing Peter Wilks said. "Contralube770 was originally designed for the automotive industry as they constantly battle with vibration corrosion and water ingress problems in their connectors and circuitry."

Contralube770 is available in 75g tubes, will retail for around £5.99 and is available to purchase from Maplin Electronics via their website – **www.maplin.co.uk**

For more information and technical data on Contralube770, visit **www.contralube.com**

EMBEDDED DESIGNER'S FORUM

MICROCHIP has announced the opening of registration for its Embedded Designer's Forum (EDF), a worldwide series of technical learning events focused on innovative technologies that will help designers stay ahead in today's competitive environment. The forums will run from October 2009 through to February 2010 at 120 locations across the world, with 51 forums located in Europe and six forums across the UK and Ireland running in November and December. All attendees will receive a substantial discount on selected Microchip development tools, as well as a free, hands-on training class at any of Microchip's 37 worldwide regional training centres. To register, or for more information, please visit **www.microchip.com/EDF**.



Showcasing the latest PIC microcontroller (MCU) technologies, the Embedded Designer's Forums will teach designers how to add more features and functionality to their designs, for lower system costs and faster time to market. Each forum will include the following sessions:

- Lower your system power with the world's lowest sleep power MCU
- Getting the most out of the new 32MHz PIC16F enhanced 8-bit core MCUs
- Expand your application with PIC32 32-bit performance
- Add LCD and graphics displays to your products
- Improve your user interfaces using touch-sense technology
- Integrate USB connectivity into your embedded design

Please note that Microchip have moved their UK offices due to continued growth. Their contact details are:
Microchip Ltd, Microchip House, 720 Wharfedale Road, Winnersh Triangle, Wokingham, RG41 5TP, United Kingdom. Tel: Main office - 0118 921 5800, Sales - 0118 921 5869. Fax: 0118 921 5820.

EDF attendees will see demos of Microchip's easy-to-use development tools and free software libraries. Discounted tools include the MPLAB Starter Kits for PIC18 8-bit, PIC24F 16-bit, and PIC32 32-bit MCUs; the F1 Evaluation Platform for Enhanced 8-bit PIC MCUs; the mTouch Capacitive Touch Evaluation Kit; and the PICkit 3 Debug Express.

For further information, visit Microchip's website at **www.microchip.com/EDF**

World's Computer Carbon Footprint Offset

Australian company Little Green Genie (LGG) has embarked on a cause to help reduce the emissions created by the world's billion-plus computers through the introduction of, they claim, the world first computer carbon offset software.

Launched recently by the Hon Kate Jones MP, Queensland Minister for Climate Change and Sustainability, the LGG is a program that calculates how much energy is being used by a computer, and then uses this information to buy a proportionate amount of carbon credits to offset this use.

LGG spokesman, Bruce Nelson, says with the manufacture and energy used to run computers creating as big a carbon footprint as the global airline industry, green-minded computer users now have an option to offset their PC's carbon emissions.

"We think the public really feel a sense of duty to help offset carbon emissions, but many feel it can be too much of a hassle to really do anything," Mr Nelson says.

"The Little Green Genie program is easy to download and calculates the computer's emissions from energy use.

"It then automatically purchases carbon credits from Climate Friendly, a founding member of the international carbon reduction and offset alliance, which in turn supports renewable energy equal to the computer's energy use."

For the average computer user this will cost roughly ten dollars a year, with the simplicity of the program and its accuracy in calculating the emissions identified as major factors in its potential popularity with personal computer users as well as businesses.

For more information or to download the Little Green Genie, visit www.littlegreengenie.com

Counterfeit IC Detection

Soldertec Global believes that it can detect all blacktopped counterfeit ICs through its new service called the Ultimate Black Top Test. This new service uses the industry standard IDEA-STD-1010-A and then adds greater depth to the testing by looking at higher magnification and adding supplementary tests using advanced techniques.

Occasionally, some counterfeit parts will have been pulled from old boards and sometimes some faulty parts will not have been scrapped at the production facility. However, the vast majority of counterfeit parts will have been remarked to convince the buyer to think that what they are purchasing is exactly what they had ordered. Soldertec has the expertise and laboratory capabilities to identify the remarking, expose the fraud, and mitigate the risk.

"We are able to achieve this through using laboratory techniques which have never been used before. However, we will not divulge how it is done as the counterfeiter may devise a measure to counteract our testing", comments Soldertec Laboratory Manager, Dr Wayne Lam. "It is not magic, or if it is then it is £500,000 worth of magic, because that is the cost of all the equipment being used in the detection process."

The Ultimate test regime involves 25 different tests and is completed in approximately a day. This depth of testing enables the laboratory to pick up all signs of prior use and remarking, with many of the techniques supporting each other and reaffirming earlier suspicions. If a suspect part is found and confirmation is required, then the part can be de-capped and the die examined in fine detail to see if it really is what it purports to be.

For further details of all the testing available from Soldertec Global, please visit: www.Soldertec.com

Class-A Headphone Amplifier

By Ken Ginn

This superb project will drive a wide variety of headphones, with an impedance range from 30Ω right up to 250Ω

THE idea of a headphone amplifier was born purely out of need, as the author's current audio power amplifier was built without this provision.

This unit was designed to splice into a CD output, or tape output (MiniDisc recorder) to the power amplifier and drive a variety of headphones over an impedance range of 30Ω to 250Ω. This design was developed around a single-ended Class-A amplifier.

The design differs considerably from a design the author integrated into a Crimson preamp, built well over twenty years ago. That one was a Class-AB headphone amplifier. It was specifically designed to compliment the Crimson preamp and a Class-A power amplifier. It saw many years of service.

Why Class-A?

Class-A amplifiers are well known for their poor efficiency (less than 30%) – well below that of Class-AB, which is often used in this application. Using a Class-AB amplifier would certainly have reduced the power consumption, but when you consider this application, the quiescent current of 160mA would not be a problem when specifying the power supply components.

Design considerations

This particular design was adopted because it removes the problem of crossover distortion in the output stage, and has good audio characteristics. The signal-to-noise ratio was measured at >90dB; distortion was measured at 0.01% (THD+N) at 1kHz, measured at an output level of 200mW into a load of 35Ω. The residual DC level at the output was measured at 18mV.

In some audio equipment, little consideration is given to driving headphones. Sometimes, just a handful of components are dedicated to this function.

There are examples where just a simple potential divider from the main audio amplifier output drives the headphone output. In other designs, a dual op-amp, one driving each channel, may be employed. This is an adequate method of providing a headphone facility to the amplifier.

Since the headphone is an electromechanical device, some considerations could be made to treat them in much the same way as a loudspeaker. A dedicated circuit designed to drive headphones would result in better sound reproduction. Such a purpose-built circuit would be carefully designed to specifically drive headphones, and thereby produce a more defined and controlled sound.

In this project, a headphone amplifier that can be linked inbetween the CD player output and the amplifier input is described. Alternatively, the unit can sit between the tape input of the amplifier and the output of a tape recorder, in this case a MiniDisc recorder. It can be used to drive different headphones, with impedances ranging from 30Ω to 250Ω.

This is a single-ended Class-A amplifier, with a FET as the output device. The choice of this circuit is purely a matter of personal preference.

The circuit can be plugged into an existing amplifier that does not have a headphone output, and which will then have the capability to drive headphones with a good solid signal.

The circuit's design philosophy is to process the audio signal with as few components as possible, so as minimise distortion and the introduction of artefacts from the circuit into the audio path.

Circuit details

The Class-A Headphone Amplifier main circuit is shown in Fig.1 and the dual power supply in Fig.2. As can be seen from Fig.1, the circuit is not innovative, and although a little unorthodox, we'll consider the output stage first.

The amplifier is basically an operational amplifier (IC1) directly driving the gate (g) of a FET (TR2) in a source-follower configuration, with the feedback of the amplifier coming from the source (s) of TR2. This allows the output current drive of the headphone amplifier to be much greater than simply that of the op amp's output stage.

The source current of TR2 is regulated with a constant current generator with the aid of transistors TR1 and TR3. This circuit (formed by resistors R7, R8, R9, and transistors TR1 and TR3) is quite a common arrangement. It is often found as a protection circuit in low voltage power supplies, limiting the maximum output current (short-circuit protection). The constant current generator is set to approximately 150mA, and this sets the quiescent current operating TR2 in Class-A mode.

Note: TR2 and TR3 need heatsinks because each device will constantly dissipate over two watts in heat – with or without a music signal coursing through the amplifier.

Voltage regulation

Op amp IC1 is fed with its own supply of ±15V (via regulators IC2 and IC3); this is used to overcome TR2's gate-source voltage of 3.5V, and will provide, under maximum drive conditions, a peak-to-peak output signal of 16V before clipping at the output. These regulators supply minimal current to IC1, and therefore don't need heatsinking. The supply for the output stage is also fed with its own regulated supply of ±12V (regulators IC3 and IC4), and these regulators do require heatsinking.

The output stage voltage regulators are mounted on the same angled aluminium bracket as the output devices. This bracket is attached to the diecast aluminium case and forms part of the heat-sinking arrangement. The case does get warm, and with prolonged use will rise to around 40˚C, which was considered acceptable.

It was found that the amplifier could deliver a full output voltage of 7.0V RMS into a 300Ω impedance headphone (approximately 160mW RMS). For a low impedance headphone (24Ω to 30Ω) only 2.2V RMS is needed to drive them to a level of 200mW, which is well above what would be considered normal listening. Leaving more than 6dB of headroom above what would be expected: 110dB at 1V RMS.

The headphones used to develop this amplifier were Sennheiser's HD465, which have an impedance of 30Ω. A number of higher specification headphones were also used, including Beyer DT770 (250Ω impedance) and an old pair of Beyer DT431 (nominally 37Ω impedance).

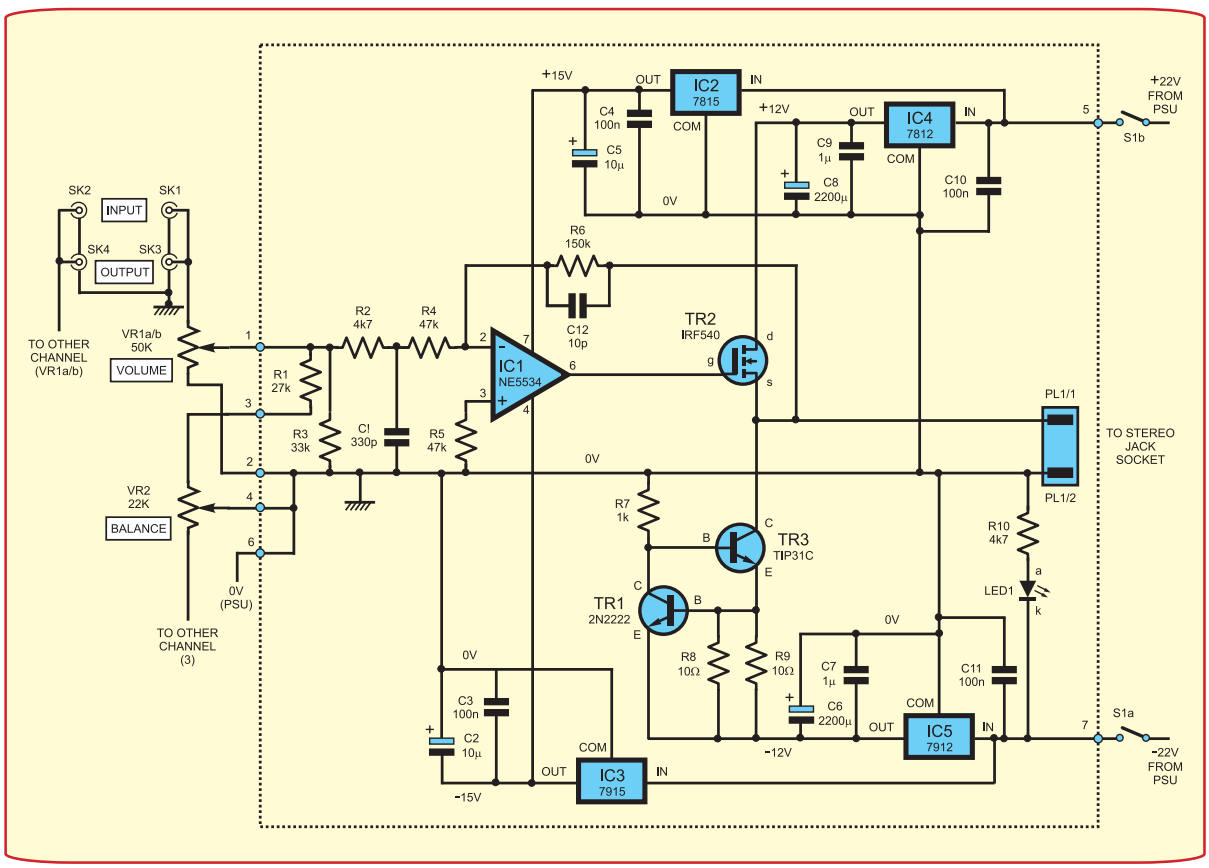


Fig.1. Circuit diagram for 'one channel' of the Class-A Headphone Amplifier. Note, R10 and LED1 are mounted off-board

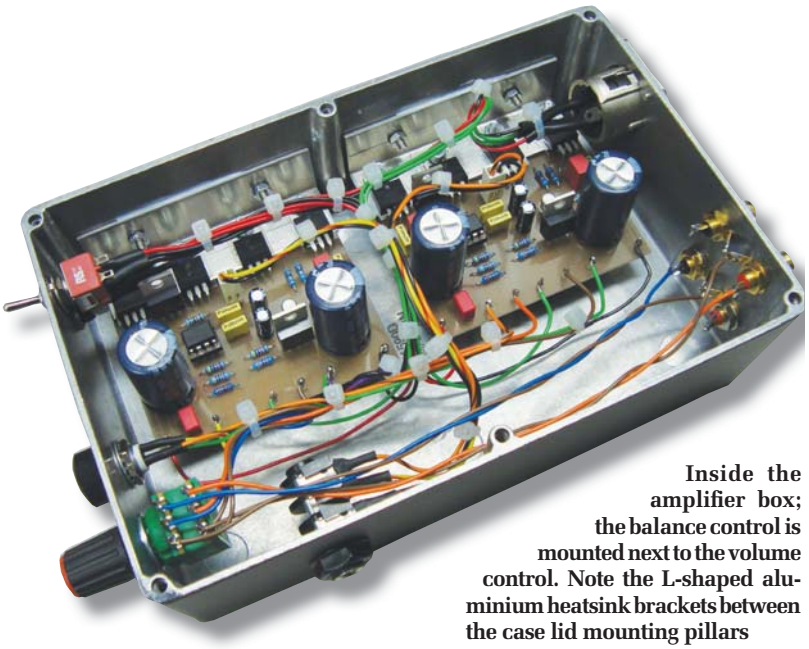
Breaking the law

The amplifier input signal is fed from the input phono socket (SK1/SK2) through the ganged (stereo) volume control (VR1). This is a linear potentiometer with a law-faking resistor (R3) on each amplifier circuit, between VR1's slider (moving contact) and ground (0V). The balance control (VR2) is arranged to give a slight amplitude adjustment, but since most audio sources need no adjustment, it can be omitted if desired. The associated series resistors with the balance control also form a part of the law-faking arrangement.

The 'law-faking' resistor enables a linear potentiometer to gives a good approximation of a logarithmic response. This is useful because log pot pairs are known for their matching problems – that is, the the track on the left channel may have a slightly different characteristic to its neighbour in the ganged control.

Making well-matched *linear* tracks with two-ganged pots is very much easier and the tolerance of linear tracks is much tighter than ganged log pots. So, for a modest price, the matching of a ganged linear control is much more consistent throughout the control's rotary travel.

The law-faking resistor effectively changes the linear pot to that of a close approximation of a log pot; this resistor is set between 25% and 33% of the potentiometers total value, in this case 47kΩ or 50kΩ. If a ganged log pot is used; then the law-faking resistor can be simply omitted from each amplifier.



Inside the amplifier box; the balance control is mounted next to the volume control. Note the L-shaped aluminium heatsink brackets between the case lid mounting pillars

If the balance control is omitted, then the law-faking resistor for a linear pot should be reduced to approximately 15kΩ. This compensates for the loss of the balance pot arrangement that forms part of a parallel arrangement that constitutes part of this law-faking arrangement.

Resistor R2 and capacitor C1 form a low-pass filter with a 3dB high frequency cut-off of about 90kHz, and the amplifier's overall response continues to roll off beyond this. Resistor R6 provides the feedback for the op amp, and thus the whole amplifier circuit, setting the gain for the amplifier in the prototype at three.

Residual DC at the output was found to be less than ±20mV, and remained stable and below this from switch on to many hours of use. Resistor R6 depends on the headphone impedance and was selected as 150kΩ. This can be changed within reason to adjust for different input levels and headphone impedances.

Note, however, that increasing this resistor (and hence the gain) too much could cause high frequency instability. This could be solved with a small capacitor placed in parallel with R6. About 10pF would be sufficient to restore stability and would not affect the overall high frequency response significantly.

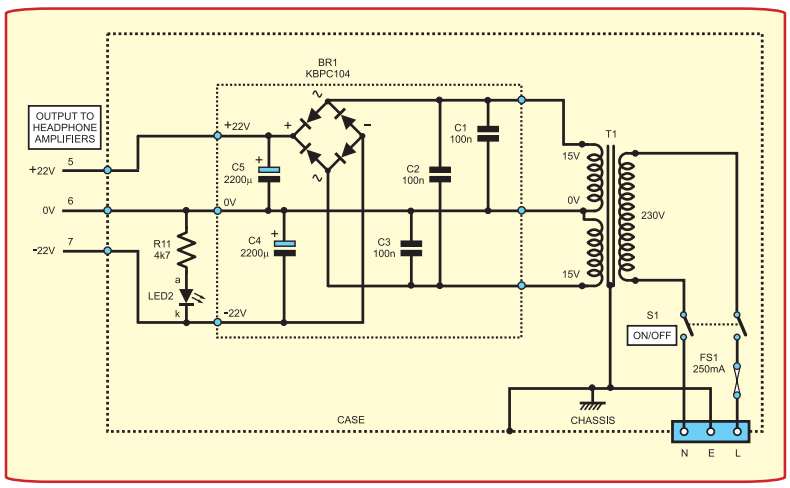


Fig.2. Circuit diagram for the dual power supply module

Power supplies

There is considerable power supply decoupling on each amplifier circuit, with a 10µF electrolytic (C5/C2) and a 100nF polycarbonate (C4/C3) capacitors as close to the op amp as possible on the circuit board (PCB). This is for each 15V (+ and –) power rail. In addition, a 2200µF electrolytic (C8/C6) and a 1µF (C9/C7) capacitor is augmented on each amplifier's ±12V supply.

The decoupling forms part of the power supply, and helps to smooth out any residual high current demands from either of the two voltage regulators. It also provides a low and stable AC impedance for the amplifier power supply, which is essential for an effective Class-A design.

One positive 12V regulator (IC4) and a negative 12V regulator (IC5) are present on each channel. These supply the amplifier and the quiesant current to each channel amplifier output stage and need heatsinking in the same manner as TR2 and TR3. In fact, all four devices share the same heatsink. The other regulators supplying ±15V stand alone and require no heatsinking.

Construction.

The Class-A Headphone Amplifier modules are built on separate printed circuit boards (PCBs); one amplifier (two for stereo) and one power supply board. The component layout and copper foil master for the amplifier PCB are shown in Fig.3 and the PCB details for the power supply in Fig.4. The boards are available from the *EPE PCB Service:* code 731 for the amp (pair); 732 for the power supply.

The completed prototype amplifier and power supply were housed in two separate diecast boxes. The unit can be housed in one enclosure, containing all three (for stereo) printed circuit boards.

Parts List – Class-A Headphone Amplifier

AMPLIFIER

(Two of each component required, except where indicated)

PC board, code 731 Amp (pair), available from the *EPE PCB Service*, size 76mm × 64mm

L-shaped aluminium heatsinks

2-way keyed pin headers

1 diecast aluminium box, size 188mm × 120mm × 56mm

4 phono sockets (2 red, 2 black) (SK1-SK4)

1 6.35mm (¼ in.) chassis mounting stereo jack socket (JK1)

1 XLR 3-pin chassis plug (power input)

1 DPDT on/off toggle switch (S1)

1 small plastic knob

Insulating kits for T0-220 devices; heatsink compound; connecting wire; nuts, screws and stand-off spacers for circuit boards; solder pins

Semiconductors

NE5534 low-noise op amp (IC1)

7815 +15V 1A voltage regulator (IC2)

7915 -15V 1A voltage regulator (IC3)

7812 +12V 1A voltage regulator (IC4)

7912 -12V 1A voltage regulator (IC5)

2N2222 *NPN* small signal, high frequency transistor (TR1)

IRF540A *N*-channel power MOSFET (TR2)

TIP31C *NPN* high power transistor (TR3)

1 5mm red light emitting diode (LED1)

Capacitors

10pF 100V resin dipped ceramic, 0.1in pitch (C12)

330pF 100V polypropylene, 0.2in. pitch (C1)

100nF 63V polyester, 0.2in. pitch – 8 off (C3, C4, C10, C11)

1μF 63V metallised polyester, 0.2in. pitch – 4 off (C7, C9)

10μF 63V radial elect., 0.1in. pitch – 4 off (C2, C5)

2200μF 35V radial elect., 0.3in. pitch – 4 off (C6, C8)

Potentiometers

1 50kΩ dual-ganged rotary carbon, linear (VR1a/b)

1 22kΩ panel mounting cermet, linear (VR2)

Resistors (All 0.6W 1% metal film)

10Ω 4 off (R8, R9)

1kΩ (R7)

4k7Ω 3 off (R2, R10)

27kΩ (R1)

33kΩ (R3)

47kΩ 4 off (R4, R5)

150kΩ (R6)

POWER SUPPLY

(Only one of each component required, except where indicated)

PC-Board, code 732 PSU, available from the *EPE PCB Service*, size 44mm × 64mm

50VA mains transformer: 230V AC primary and two 15V AC secondary windings (T1)

Diecast aluminium box, size 180mm × 120mm × 82mm

Finned heatsink for bridge rectifier

DPDT mains on/off toggle switch

XRL 3-pin chassis plug (power output)

XRL 3-pin in-line power sockets (2 off), with interconnecting cable

IEC chassis plug filter (optional – see text)

250mA fuse and chassis mounting fuseholder

Semiconductors

KBPC104 2A 400V PIV bridge rectifier, or similar (BR1)

5mm red light emitting diode (LED2)

Capacitors

3 100nF 100V disc ceramic, 0.2in. pitch (C1 to C3)

2 2200μF 35V radial elect., 0.3in. pitch (C4, C5)

Resistor

4k7Ω 0.6W 1% metal film (R11)

In the prototype, one box was used to house the mains transformer and bridge rectifier/smoothing capacitor board. The second enclosure housed both amplifier boards, with the headphone jack socket (JK1), volume and balance controls on the front, and the power and phono sockets mounted on the rear – see photographs.

The amplifier diecast box also forms part of the heatsinking arrangements and helps to cool the semiconductors. The case will get warm to the touch in use, additional heatsinking could be arranged with a finned heatsink mounted on the top of the aluminium casing, but really this is unnecessary.

In the prototype, unscreened wire was used for the input signals from the phono sockets to the volume control and from then on to each amplifier board. Using this arrangement caused no adverse affects in performance because the wires for each channel were separated, and no noise or hum was perceivable on either amplifier during listening tests or recorded on test equipment. Purists will replace these wires with screened cable.

Two-part assembly

The reason for the two-part assembly was to ensure that the power supply did not introduce mains hum to the amplifier. The power supply was connected to the amplifier unit with a three-core cable, delivering the unregulated plus and minus supplies to the amplifiers. The main power supply was mounted remote from the rest of the headphone circuitry with a half-metre cable.

In practice, with the amplifier module resting on top of the power supply module, there was no increase in the amplifier's noise or hum levels.

Each amplifier (stereo) is built on its own PCB; the six components for the power supply are on a separate board on the power supply assembly. The bridge rectifier requires a small finned heatsink to help dissipate the heat it generates.

Four components (IC4, IC5 and TR2, TR3) mounted on the amplifier PCBs also require heatsinks, provided by the usual TO-220 insulating washer, heatsink compound (if using mica washers) and small insulator bushes to mount these components to the metal bracket. This metal bracket is attached to the diecast box, with heatsink

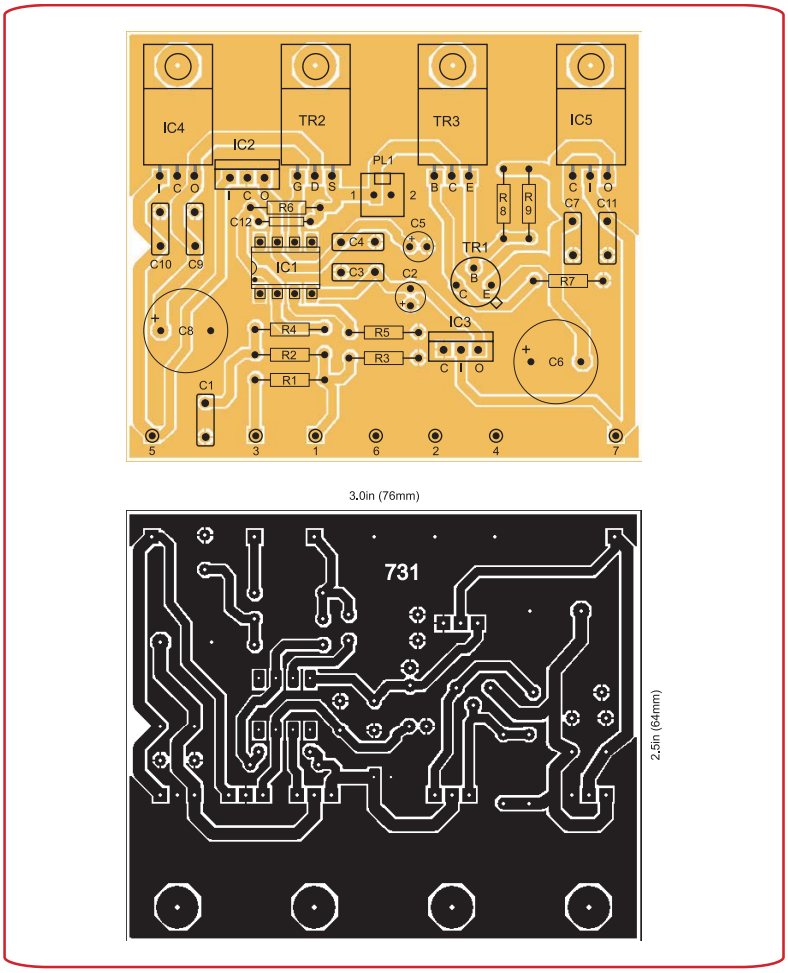


Fig.3. Printed circuit board component layout and full-size copper foil master pattern for the amplifier board. Two boards are required for stereo

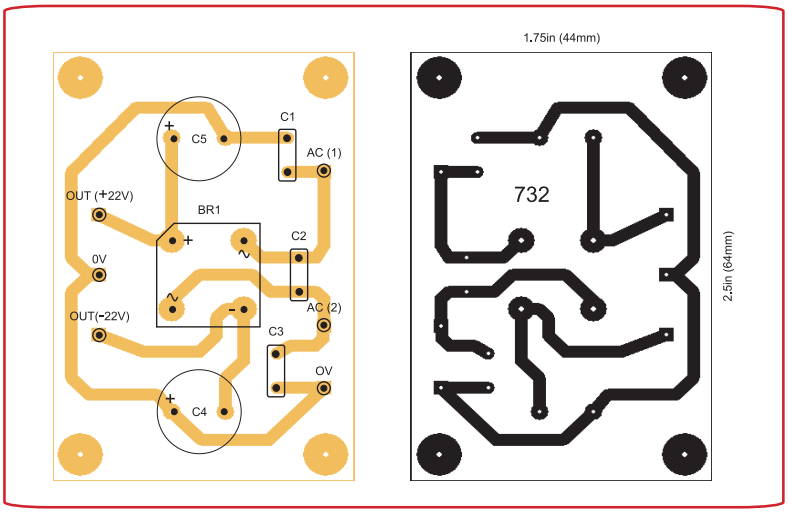


Fig.4. Power supply printed circuit board component layout and full-size copper foil master

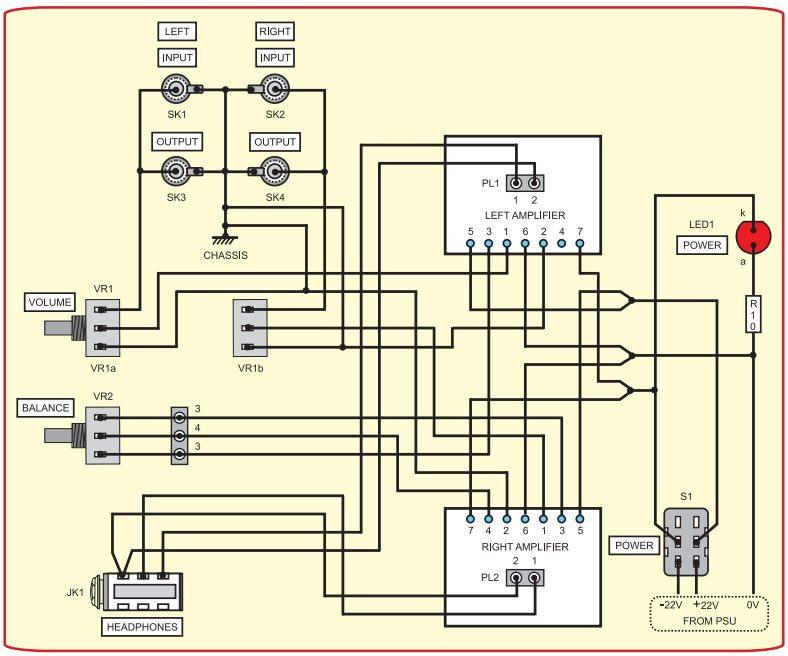
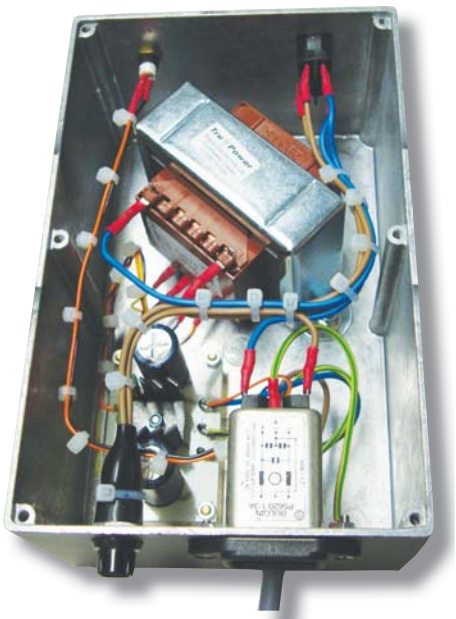


Fig.5. Interwiring details between the two circuit boards and off-board, case mounted, amplifier components

compound to assist heat transfer away from these devices.

Always double check the wiring and orientation of components and the integrity of solder joints, both on the track side of the PCB and any other component (solder pins, connectors). Check for 'dry joints' and solder bridges at this stage, as this could save a good deal of heartache at a later date. A magnifying glass is essential for this.



Inside the power supply unit. An IEC mains filter was used in the prototype; this can be omitted if desired. The circuit board is mounted in the left-hand corner of the box on small stand-off spacers

Danger: mains-powered circuit!

Constructing any circuit that uses mains voltages (230V AC) must be done carefully and safely. Following the design here should produce a safe design and a few checks throughout construction will aid in this aspect.

Check for earth continuity between the supply earth connection at the mains plug and the power supply metal casing or any exposed metal parts. Bond **all** metal parts – this means the two halves of the diecast box. This resistance should be as low as possible, certainly measuring less than one ohm from the mains plug earth to any metal part.

Check the isolation between the mains Earth and the Live and Neutral connections of the mains supply input, with the mains power switch in both the on and off positions. This should be measured with a DMM, and you should expect a resistance certainly higher than 200MΩ. If not, look for the fault and rectify it.

Last, check the isolation between the mains input and the power supply output, this again should be measured with a DMM and be higher than 200MΩ, ie open circuit.

Check the electrical continuity from the tabs on the power devices to the chassis (heatsink), this resistance should be 'infinite', greater than 200MΩ, ie open circuit.

Testing

The power supply unit is best checked on its own without the

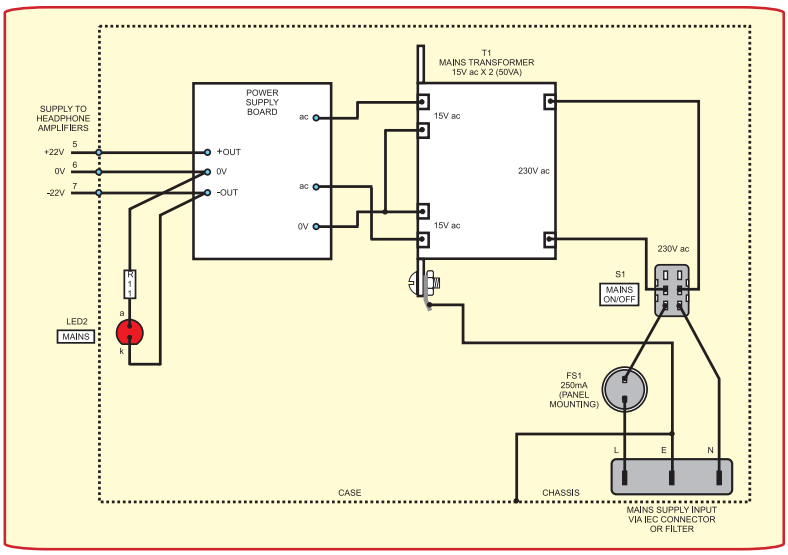


Fig.6. Power supply interwiring details between the mains transformer, circuit board and off-board components

amplifiers connected. This enables the unregulated supplies to be checked before being connected to the rest of the circuit. The output voltage of the power supply unloaded should read in the region of ± 25V DC.

There are no bleed resistors on the power supply, since the headphone amplifier is a sufficient load to discharge the smoothing capacitors when in use and switched off. This does, of course, mean that during testing, the capacitors have to be discharged manually when used in isolation. Use a 1kΩ resistor held across each output to accomplish this.

With circuits like this, it is always best to check the headphone amplifier and the power supply separately if possible. For the amplifier, use a dual bench power supply set to ±22V, current limited to 500mA if available. Turn any current damping off on the power supply.

If a dual DC variable regulated supply is at hand, then this will make testing of the unit far safer. Connect just the headphone amplifiers to a regulated supply, and advance both the voltage supplies slowly to +22V and –22V, noting the current drawn. This should not rise above 160mA per amplifier, some 320mA maximum, certainly no greater than 350mA.

Next, inject a sinewave at 1kHz at the input of each amplifier (phono sockets). You should see the output level rise to a maximum of 16V peak-to-peak at clipping, at the headphone output. Any DC offset should be measured at less than 20mV at each of the headphone outputs.

How does it sound?

The author's eclectic music tastes range from the sounds of the 60s and 70s through to contemporary music From rock to folk (Queen, REM, Eric Clapton, Tom Petty) but with a great emphasis on acoustic guitar from Gordon Giltrap, Martin Taylor, William Ackerman and others too numerous here to mention.

Tests were conducted using a variety of music, comparing results from an old Mission Cyrus amplifier fed from a CD player, with the same CD player directly feeding the headphone amplifier. Naturally, the same headphones were used with both configurations. In the new system, I perceived tighter control of bass and midrange frequencies.

Rear view of the amplifier showing the pairs of phono sockets and the XLR chassis plug power connector

The higher frequencies were neutral, and the sibilance distortion that was apparent with the Mission amplifier was removed.

The listening experience with headphones became much more enjoyable, with more detail revealed by the headphone amplifier. Overall, there was an improvement in sound quality and it was a more comfortable listening experience, which was the object of this exercise.

Specifications

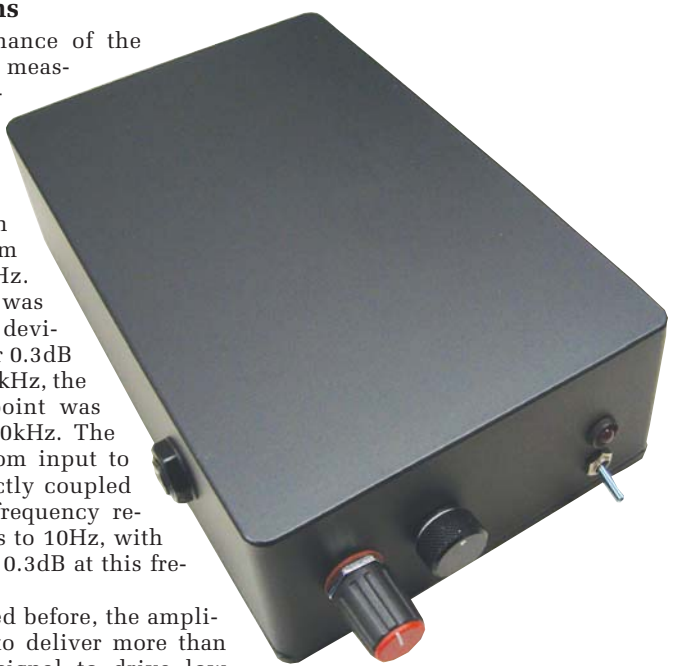
The performance of the amplifier was measured on laboratory test equipment. The frequency response was stable to within ± 0.05dB from 20Hz to 12kHz. The response was shown only to deviate by a further 0.3dB from 12kHz 20kHz, the upper –3dB point was measured at 90kHz. The signal path from input to output is directly coupled and the low frequency response extends to 10Hz, with a drop of only 0.3dB at this frequency.

As mentioned before, the amplifier was able to deliver more than an adequate signal to drive low impedance headphones. The higher impedance units (250Ω) worked very well, driven with a maximum level of 7V RMS.

The signal-to-noise ratio was measured at better than 90dB, proving the design to be very quiet. Distortion measured at 1kHz was found to be 0.01% at a maximum output of 7V RMS.

Acknowledgements

To the people who wish to remain anonymous my thanks for your help and encouragement in the production of this article. ***EPE***



The completed Headphone Amplifier, with optional balance control

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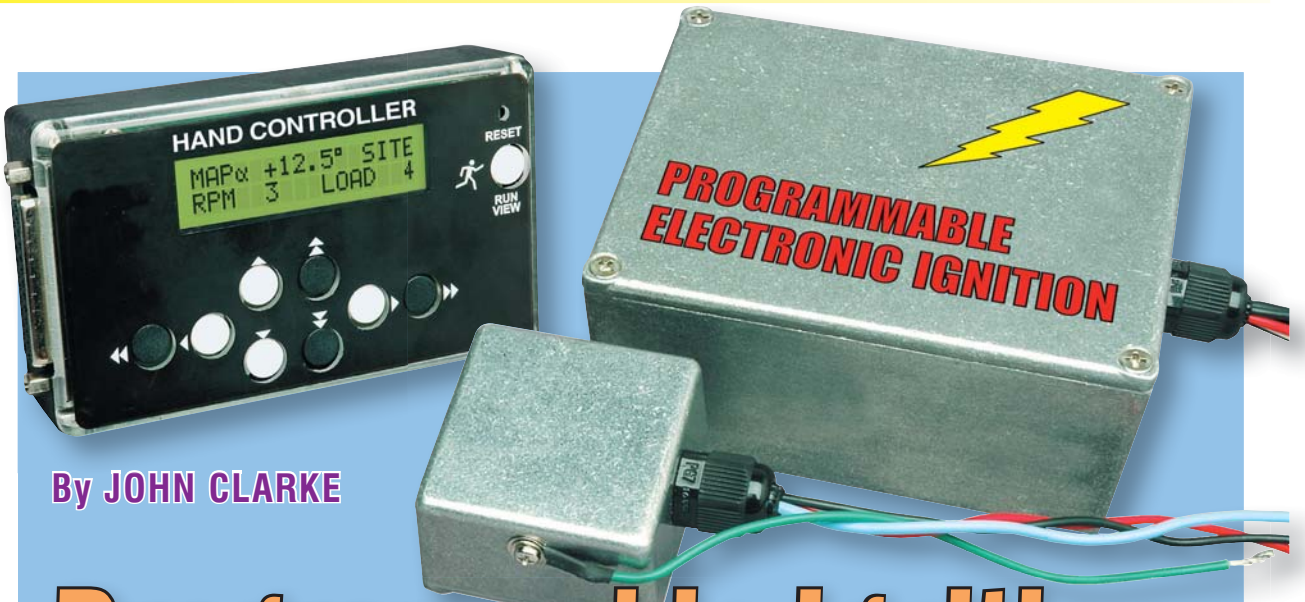


By JOHN CLARKE

Programmable Ignition System For Cars Part 3

Last month, we described how to build all the modules that comprise the Programmable Ignition System. This month, we describe the installation and setting up procedures and show you how to plot the ignition timing.

AS MENTIONED in Part 1, the Programmable Ignition System can either be used as a complete ignition system or as an interceptor.

Whether it behaves as an interceptor or not depends on the input signal that's applied to the unit. In most cars, the ignition system will already provide ignition advance with respect to RPM and engine load. This applies not only to cars that have full or partial engine management, but also to older cars that simply have mechanical RPM and vacuum advance systems.

When used as an interceptor, the Programmable Ignition simply modifies the existing ignition timing. By contrast, when it's used as a complete ignition system, we dispense with any existing timing system that may exist and re-map the timing using the Programmable Ignition Timing Module.

If you intend using the unit as an interceptor, then there's no real need to know what the engine's existing timing map is for RPM and engine load. That's because we are simply using the unit to modify the existing timing values at various engine RPM and load sites.

Why would you want to do this? Well, you may want to advance the timing at some sites to gain power and/or retard the timing to prevent detonation (ping) at certain trouble spots within the RPM and engine load map.

Note that although the original timing curve does not have to be known for interception, you do need to know the RPM and engine load range. This is necessary to ensure that the full mapping range is utilised with the Programmable Ignition System (more on this later).

Conversely, if the unit is to be used as a replacement ignition, it will be easier to program in a timing map if the original engine timing is known. That way, the Programmable Ignition can initially duplicate the original timing, which can then be adjusted as necessary in a similar manner to an interceptor – eg, to extract better performance and/or to prevent detonation.

Warning!

Programming an incorrect timing map into the Ignition Timing Module could result in serious engine damage.

Do NOT modify your car by fitting this device unless you know exactly what you are doing.

Also, be sure to install this ignition system in a manner that does not compromise safety. It must be ruggedly built and correctly installed to ensure that no leads or components can come adrift.

Finally, make sure that the device does not compromise the operation of other systems controlled by an existing engine management unit – for example, ABS, traction control, stability control, air-bag control etc.

In some cases, full timing information will be available from the car's manufacturer or from a workshop manual. Usually, however, there will be no information available.

The solution is to actually measure the timing advance against changes in RPM and engine load. This is easy to do in cars with a mechanical vacuum advance mechanism, as this operates independently of engine RPM.

Plotting the timing values in cars that use engine mapping and a MAP sensor for vacuum measurement is only slightly more difficult. It's done by externally altering the pressure sent to the MAP sensor or actuator. The exact procedure is described in the panel headed 'Plotting The Original Ignition Timing Values'.

Cars that utilise Mass Air Flow (MAF) sensing of engine load are much more difficult when it comes to mapping ignition advance. That's because the engine will have to be run with varying degrees of load throughout the RPM range, and this can only be achieved on a dynamometer.

Interceptor or replacement?

Note that the Programmable Ignition System should be used only as an interceptor on cars that already have an engine management system. That's because the manufacturer's timing map will have been carefully designed for your engine. Furthermore, the timing would have been mapped against air inlet temperature, engine temperature and the air-fuel ratio to provide the best performance in all conditions.

By using the Programmable Ignition System only as an interceptor in such cars, the original timing variations according to fuel ratio, temperature, RPM and load will be retained.

By contrast, we do advocate using the Programmable Ignition System as a complete replacement in older cars, go-carts and on engines that do not currently include RPM or vacuum advance.

Many old cars provide both RPM and vacuum advance by mechanical means. Because of their age, the RPM advance system is now likely to be worn and sticky in its operation, while the vacuum actuator will often be leaky or may have failed altogether.

Most drivers do not notice if a vacuum actuator has failed because when it fails, it remains at the maximum engine load position. As a result, power under load is retained.

Timing Problems With Reluctor Triggers

In some cars, when using the Programmable Ignition, you may find that the ignition trigger exhibits a type of stiction effect, with the timing initially failing to advance from about 0 – 5°. This effect is due to the coil firing just before the trigger signal (due to the advance setting) and the resulting high-tension signal within the distributor then interfering with the normal operation of the trigger sensor.

Reluctor triggers are the most likely to be affected in this way. Hall effect, optical, engine management and points triggers are unlikely to be affected.

In some cases the effect may be dialled out by careful adjustment of VR1. Also, make sure the high-tension lead and the reluctor leads are spaced well apart and only intersect at right angles if they do need to cross.

If this does not solve the problem, then you can avoid programming low values of advance into the Programmable Ignition. This can be done in one of two ways. First, the static timing can be set to say 10° of retard (eg, –10°) so that you need at least 10° of advance from the Programmable Ignition to get 0° timing. Of course, the entire timing map would have to be changed to include this extra 10° for all values.

An alternative method is to set the static timing to greater than the maximum amount of advance in the timing map. This value would then be subtracted from the required timing value for each map site in order to determine the retard setting required for each site in the Programmable Ignition.

For example, if the static timing is +40° and the timing map value is 22°, the programmable ignition map setting would be –18° (22° – 40° = –18°).

Our experience

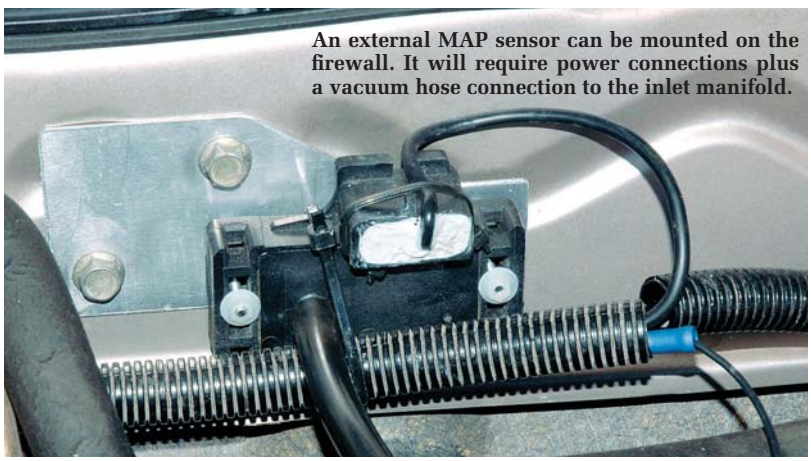
During our tests, we eliminated the original mechanical RPM and vacuum advance systems in a 1988 Ford Telstar and used the Programmable Ignition System to provide the timing advance instead. As a result, the engine became far more responsive to throttle changes and was more willing to rev than before.

There are a couple of reasons for this improved performance. First, the 'flying weight' system in the distributor that provides RPM advance is fairly sluggish to respond to RPM changes. By contrast, the Programmable Ignition System provides 'instantaneous' changes to the timing map.

Similarly, the vacuum actuator that moves the distributor's trigger firing point is slow to respond compared to using a pressure (or MAP) sensor with the Programmable Ignition System.

Installation

Typically, the Ignition Timing Module is best mounted inside the cabin of the car; eg, somewhere under the dashboard. This allows the Hand Controller (see last month) to be easily attached and used while someone else does the driving (this should be



An external MAP sensor can be mounted on the firewall. It will require power connections plus a vacuum hose connection to the inlet manifold.

Plotting the original ignition timing values

IT'S QUITE EASY to plot the timing advance values for an existing ignition system by using a timing light. In fact, there are several ways to go about this.

Typically, most cars only provide timing marks that show Top Dead Centre (TDC) and up to about 10° or 12° before TDC using a scale, or mark, on the engine block. These marks are ideal for setting up the ignition timing at idle, but are not sufficient to measure advance at higher RPM values. This is because the advance will go beyond the 10° or 12° timing mark.

One way round this is to make up an extended timing scale to directly indicate the advance at higher RPM values. Another option is to use a timing light that includes advance adjustment.

Yet another option is to use the Programmable Ignition System and a spare ignition coil and spark plug. This system can shift the timing light's stroboscopic flashing so that it is delayed by as many degrees as the advance. That way, you can use the existing engine timing marks.

Fig.23 shows how to set up this system. Note that the coil shown here is not the ignition coil used in the car, but a separate one that independently fires the timing light. If you do not have a spare coil, they are readily available from automotive wreckers or you could temporarily borrow one from another car (just about any single output ignition coil can be used).

The spark plug is necessary to provide a spark gap for the coil to discharge. This is important because if the coil's high tension output is left open, there is the risk that the coil will internally breakdown and suffer permanent damage.

The Ignition Timing Module takes its signal from the car's trigger sensor or existing ECU output, but note that this signal must include the timing advance (not always the case with trigger sensor information). If the trigger signal does not include the timing advance, then be sure to use the output from the ECU.

Before actually plotting out the timing values, there are a number of adjustments that must first be made to the Ignition Timing Module, as follows:

Reluctor adjustment

If your car uses a reluctor pick-up, then VR1 (on the Ignition Timing Module) must first be adjusted. Begin by setting VR1 fully clockwise and measure the voltage at pin 6 of IC1. If the voltage is close to 0V, wind VR1 anticlockwise several turns until the voltage at pin 6 of IC1 goes to +5V. When it does, wind VR1 anticlockwise about two turns more and leave it at this setting.

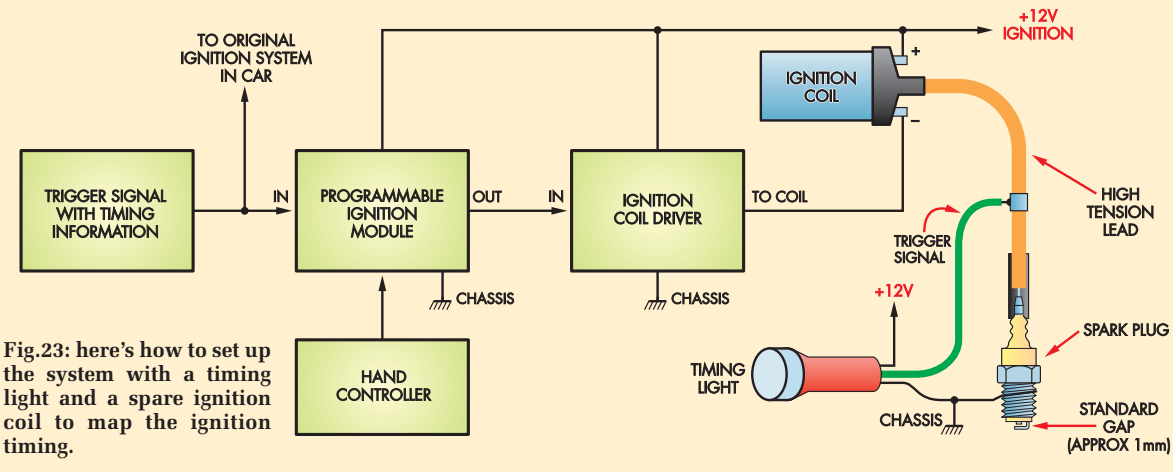


Fig.23: here's how to set up the system with a timing light and a spare ignition coil to map the ignition timing.

done on a racetrack or some other closed or private road).

It is also best to mount the Ignition Timing Module in the cabin if the Sensym pressure sensor is used. This helps keep the sensor cool.

Alternatively, the Ignition Timing Module can be mounted in the engine bay if you cannot find room for it in the cabin. Make sure it is well away from the exhaust manifold though, to prevent excessive heat exposure. It can be mounted using suitable brackets to the chassis.

The big disadvantage of mounting the unit in the engine bay is that it is much harder to connect the Hand Controller for driving. In some cases, it may be possible to feed the connecting lead through a window and under the rear of the (closed) bonnet. Alternatively, it may be possible to temporarily feed the connecting lead through the firewall (not so easy) or through an air vent (easier).

Note that the lid of the Ignition Timing Module must be left off when the Hand Controller is connected. This also allows jumper LK1 to be easily changed, to select either the settings or timing display modes. **Note that LK1 should be placed in the settings position when the Hand Controller is subsequently disconnected.**

If the voltage at pin 6 of IC1 is +5V when VR1 is wound fully clockwise, then rotate VR1 fully anticlockwise and wind it clockwise until the voltage goes to +5V. As before, now wind on VR1 by an extra two turns (clockwise this time).

Initial settings

Now for the programmed settings; here's the step-by-step procedure:

1) Install jumper LK1 in the settings position.
2) Set the number of cylinders for your car, the edge sense to HIGH and the diagnostic setting to 'No Interpolation'.
3) Set the dwell to 0ms and set the oscillator to ON.
4) Increase the dwell value until the timing light fires reliably. Note that the dwell value does not change until the Up switch on the Hand Controller is released.
5) Move LK1 to the timing position and press the Reset switch on the Hand Controller so that all the timing values for the selected map return to 0.

If you now start the engine and aim the timing light at the flywheel timing marks you should see the amount of advance. If this does not seem correct, then change the edge sense to low in the settings mode (ie, temporarily move LK1 back to the settings position). If the strobing is erratic, try selecting the 2ms debounce option (again found in the settings mode).

Note that with this strobe set-up, the timing light will fire for every spark firing, rather than just for cylinder 1. This will make the visible contrast of the timing mark a little less than it otherwise would be. You can compensate for this by dabbing some white paint on the flywheel marker.

	RPM Site	RPM0	Min RPM RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	Max RPM RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1												
	LOAD2												
	LOAD3												
	LOAD4												
	LOAD5												
	LOAD6												
	LOAD7												
	LOAD8												
	LOAD9												
	LOAD10												
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 1: this table shows the interpolated advance values vs RPM for the high load site (in this case, LOAD11). These values are measured with the vacuum advance line disconnected and plugged – see text.

Checking the advance

Having gone through all these initial adjustments, the next step is to disable any vacuum advance by removing and plugging the rubber hose that connects to the vacuum advance pressure sensor (or MAP sensor). The timing advance at idle should be set according to the manufacturer's specifications.

For the Ford Telstar, the initial timing is 6° BTC (before top centre) and this should be indicated by aiming the timing light at the timing marks. In this case, the Ignition Timing Module can now be programmed (using the Hand Controller) for a timing advance of –6.0° (retard). When this is done, the timing light should now show the timing to be at exactly TDC on the flywheel marks.

Plotting the RPM advance values from here is straightforward. It's just a matter of running the engine at specific RPM values and adjusting the 'retard' value programmed into the Ignition Timing Module until the timing light shows TDC in each case. The programmed values then represent the timing advance (in degrees) for each selected RPM value.

For example, let's say that the programmed value necessary for the timing light to show TDC is –22° when the engine is doing 3400 RPM. This simply means that, in this particular case, the standard ignition has a timing advance of 22° at that engine speed.

OK, so how do we actually do this? Simple – just select the timing display mode (using LK1) and then select DIAG so that the RPM is displayed. You can now plot out the advance versus RPM values by increasing the engine RPM in suitable steps (eg, 1000 RPM) all the way to the red line and adjusting the programmed retard value so that the timing is shown at TDC. Keep a record of these advance values as you proceed.

This RPM versus timing advance is generally the high-load map because the vacuum advance line is disconnected and plugged. However, it is not the high load map for turbo-boosted engines (see below).

The recorded timing information can now be plotted on a graph and the interpolated values transferred to the individual RPM sites. This is done as follows:

1) Decide whether you want the two

. . . continued next page

By contrast, the Ignition Coil Driver must be mounted in the engine bay. It can be secured to the chassis using suitable brackets and should be located close to the ignition coil. If you are using a separate MAP sensor, then this can be mounted on the firewall.

Make sure there is a good connection between the metal cases of both units and the chassis. If necessary, you can run separate earth leads to ground (bolt them to the chassis via crimp eyelet connectors).

Once you've made the connections, use your multimeter (set to its ohms range) to confirm that the metal cases are correctly grounded. You should get a reading of zero ohms between each metal case and ground.

Fig.15, in Part 2 last month, shows the external wiring details. Note that all wiring between the Ignition Timing Module and the Ignition Coil Driver should be run using automotive wire and automotive crimp connectors. Similarly, use automotive wire and crimp connectors for the connections to the ignition coil, the +12V supply and to chassis.

The +12V supply should be taken from the fusebox. Be sure to choose a connection point that delivers +12V only when the ignition is on.

Plotting The Original Timing Values – Continued

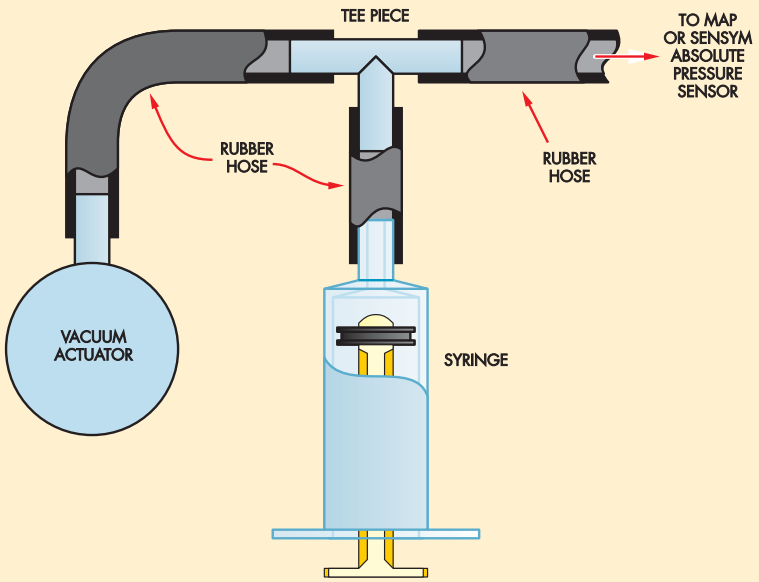


Fig.24: here's how to check the LOAD values in a car with a mechanical vacuum actuator. The syringe is used to vary the pressure.

11x11 maps or the single 15x15 map and select this in the settings mode.

2) Select either 1° or 0.5° resolution.
3) Set the Minimum RPM and Maximum RPM values to suit the range of the engine. The Minimum RPM value is simply the idle speed, while the Maximum RPM value is the engine red line. The idle speed can be measured by setting the display to DIAG, so that it shows RPM.

When setting the Maximum RPM, adjust the RPM/SITE value so that the Maximum RPM is at or just over the value required. You can also adjust the Minimum RPM setting if necessary (see Part 1 – Sept '09).

The Minimum RPM value becomes the RPM1 site. The RPM step value for each site is shown in the Maximum RPM settings display. If this is 400 RPM, for example, then the RPM2 site will be 400 RPM higher than the Minimum RPM setting. Similarly, the next RPM site will be 400 RPM higher again, and so on up to the final RPM site, which will be equal to (or slightly higher than) the Maximum RPM value.

You should now have a timing table that is similar to the one shown in Table 1. Note that we have included RPM0 on a different line because it is only there to show that the advance setting remains the same for RPM values below the Minimum RPM site (RPM1).

Finally, you may wish to recheck the advance values assigned to each RPM site. For example, for the table shown, you would recheck the advance at 1000, 1400, 1800, 2200, 2600, 3000, 3400, 3800, 4200, 4600 and 5000 RPM.

Vacuum advance

Having determined the RPM site advance values, you now need to plot the LOAD values.

First, let's assume that you have a car with a mechanical vacuum actuator. In this case, you will need a T-piece in order to connect this existing vacuum actuator (via a hose) to the MAP sensor used with the Programmable Ignition System.

Note, however, that a T-piece is not required if your car is fitted with an existing MAP sensor. In this case, the same signal from the MAP sensor is used both for the existing ignition and for the Ignition Timing Module.

In either case, it will be necessary to feed a MAP sensor signal to the Ignition Timing Module. If you are using the Sensym sensor, then a vacuum hose has to be connected to this.

The T-piece does not have to be anything too complex. You can buy these at an automotive shop or make your own.

As shown in Fig.24, a syringe is used to vary the pressure. However, be careful not to introduce excessive pressure into the MAP sensor, as it may be damaged.

For 1-bar sensors, the syringe should be pressed all the way in before connecting it to the vacuum hose. That way, you can only 'draw' a vacuum by pulling on the syringe plunger (and not increase the pressure). The maximum value is typically around 200, but could be as high as 230 and is equivalent to a 4V to 4.5V output from the sensor.

If you are using a 2-bar sensor, first check the LOAD value at normal atmospheric air pressure. At 2-bar, this value will be about 100 greater. Do not increase pressure above this increased value (ie, the atmospheric plus 100 value).

In this case (ie, for a 2-bar sensor), the syringe should be inserted into the hose with the plunger set half-way down. If you cannot get a sufficient pressure range with this, then you will have to do the pressure changes in two steps: (1) for vacuum, insert the syringe when the plunger is fully in and draw out the plunger for vacuum; and (2) for boost pressure measurements, insert the syringe nozzle into the hose with the plunger fully drawn and apply boost pressure by pressing on the plunger.

During this process, be sure to always monitor the sensor output level by setting the Hand Controller to DIAG mode (the second line shows the pressure sensor LOAD value). If the value stops increasing as you apply more pressure, then *stop immediately*. This indicates

that you have reached the maximum pressure that the sensor can detect and any further increases could damage it.

Plotting vacuum advance

Let's assume that your car uses a vacuum actuator and you have made the necessary vacuum hose connections using the T-piece. The vacuum advance plot can now be made at a fixed RPM setting that coincides with an RPM load site value.

However, do not choose the idle load point because the engine RPM will alter as vacuum advance is applied, and you need to be able to adjust the throttle to maintain the fixed RPM setting. Choose the RPM2 site value instead (1400 RPM in our example).

It's now just a matter of plotting the RPM advance against the pressure sensor LOAD reading, as shown on the Hand Controller's display. To vary the LOAD reading, just vary the position of the syringe plunger. Be sure to adjust the throttle to compensate for pressure changes, to maintain engine RPM at the RPM2 site value.

In practice, the vacuum advance value will stop increasing beyond a certain minimum pressure value. This value should be recorded as the minimum load. Similarly, it will also cease changing at a certain maximum pressure value and this should be recorded as the maximum load value. Enter these two values into the Minimum LOAD and Maximum LOAD settings.

Remember that the maximum load value can only be changed by increasing the LOADS/SITE value. In our example, the LOADS/SITE value is 40 and it ranges from a minimum of 151 (which becomes LOAD1) through to a maximum of 191 (LOAD11).

You can now insert the load timing values into a table, as shown in Table 2.

Note that the voltage output from electronic pressure sensors (including MAP sensors) usually decreases with increasing vacuum (lower pressure). This means that the minimum load (maximum vacuum) gives the lowest value on the DIAG display, and so this becomes the minimum load site (LOAD1).

		RPM0	Min RPM									Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
Value	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
151	LOAD1			18.5									
155	LOAD2			17.5									
159	LOAD3			16.5									
163	LOAD4			15.5									
167	LOAD5			14.5									
171	LOAD6			13.5									
175	LOAD7			12.5									
179	LOAD8			11.5									
183	LOAD9			10.5									
187	LOAD10			9.5									
191	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 2: the LOAD site values are all made at a fixed RPM setting, but do not use the RPM1 value. Choose the RPM2 or RPM3 rev value instead.

		RPM0	Min RPM									Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1	16	16	18.5	21.5	23	25.5	29	32	36	38	42.5	44
	LOAD2	15	15	17.5	20.5	22	24.5	28	31	35	37	41.5	43
	LOAD3	14	14	16.5	19.5	21	23.5	27	30	34	36	40.5	42
	LOAD4	13	13	15.5	18.5	20	22.5	26	29	33	35	39.5	41
	LOAD5	12	12	14.5	17.5	19	21.5	25	28	32	34	38.5	40
	LOAD6	11	11	13.5	16.5	18	20.5	24	27	31	33	37.5	39
	LOAD7	10	10	12.5	15.5	17	19.5	23	26	30	32	36.5	38
	LOAD8	9	9	11.5	14.5	16	18.5	22	25	29	31	35.5	37
	LOAD9	8	8	10.5	13.5	15	17.5	21	24	28	30	34.5	36
	LOAD10	7	7	9.5	12.5	14	16.5	20	23	27	29	33.5	35
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 3: once you've completed Table 2, the rest of the table can be filled in by adding or subtracting the RPM advance steps to the RPM2 LOAD site values. This is the result for a 1988 2-litre Ford Telstar.

If, for some reason, the pressure readings are reversed (ie, the value increases with decreasing vacuum), then the load site numbering will have to be reversed so that the maximum load becomes LOAD1. This is because the lowest value must be entered as the minimum load site.

Completing the table

Because the vacuum actuator advance system provides the same advance curve at all RPM values, it's quite easy to complete the table. In our example, the advance increases by 1° for each decreasing LOAD site. Table 3 shows the result.

MAP sensor

If your car has an existing MAP sensor, then the load advance will have to be plotted for each RPM site. The table then may not have a consistent change between LOAD sites, but its value will be dependent on the ignition mapping.

Programming

The Ignition Timing Module can now be programmed with the timing map. This is done using the VIEW setting, to enable stepping through all the map sites.

Normally, the distributor would be adjusted so that the trigger sensor delivers a firing signal at TDC and the timing map entered on this basis. Alternatively, you can set the distributor to deliver a firing signal at a preset advance or retard value. The entered advance values would need to be adjusted to account for this initial advance or retard setting of the distributor.

Make sure that the distributor's rotor is still within its range for firing with the values set in the programmable ignition. If you do not change the settings much beyond the original ignition timing curve, then the rotor will remain within range to allow the spark to bridge the gap within the distributor cap to fire the spark plugs.

Finally, don't forget to set the interpolation back to 'on' after plotting the ignition timing.

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Using an existing coil driver module

IN SOME CASES, it may be possible for the output from the Ignition Timing Module to drive an existing ignition module (or coil driver) instead of using our Ignition Coil Driver module.

There are a few things to sort out before doing this, however. First, you must find out the voltage sense used for the trigger signal. This can easily be determined if the trigger signal is produced by the ECU. For other triggers, the sense may need to be determined by trial and error.

Initially, you should set the Ignition Timing Module's EDGE setting to LOW. If it doesn't work, try reducing the 470Ω output resistor in the Ignition Timing Module to 220Ω in order to drive the original coil driver module.

If it still doesn't work, try changing the EDGE setting to HIGH. In addition, the Ignition Timing Module output must be inverted for positive-edge firing by taking the drive from transistor Q4 – see Fig.14 in last month's article.

ECU trigger signal

What if you are using the trigger signal from an existing ECU (or engine management unit)?

In this case, the output may normally be at +5V, with a low signal then applied to the ignition module to 'charge' the coil and a high-going signal subsequently used to fire a plug. Alternatively, the signal sense could be completely reverse to this.

Generally, it's easy to determine the voltage sense by measuring the voltage from the ECU when the engine is idling, using a multimeter set to read DC. The meter will show the average voltage of the trigger signal and so a normally low output will give a voltage below 2.5V and a normally high output will give a voltage above 2.5V.

If the measured voltage is less than +2.5V, then the plugs fire on the low-going signal edges (ie, the ECU's output goes to +5V to 'charge' the coil). In this case, the EDGE setting in the Ignition Timing Module should be set to LOW.

Conversely, if the voltage is greater than +2.5V, it means that the coil charges when the ECU output goes to 0V and the plugs fire on the high-going signal edges. In this case, the EDGE setting in the Ignition Timing Module should be set to HIGH. In addition, the signal output from the Ignition Timing Module must be inverted (by taking the output from transistor Q4), as shown last month in Fig.14.

Small engine use

For some motorcycles, go-carts and other engines, the ignition can be operated without using a MAP sensor. In this case, the MAP sensor input on the PC board should be connected to the 0V (ground) supply pin provided for the external MAP sensor. This will set the programmable ignition at a single fixed load setting.

In the settings, set the minimum load to about 20 and the maximum load to around 200. The ignition will then be programmed for RPM load sites only and at the fixed load setting. RPM mapping would be over 11 RPM sites (or 15 RPM sites if the single 15 × 15 map is selected).

In addition, **make sure that this +12V rail DOES NOT drop to 0V when the ignition is switched to START,** otherwise the engine will never start.

In our case, we used twin-core shielded cable to connect between the Ignition Timing Module and an external MAP sensor mounted on the firewall – see photo. Alternatively, you can use automotive cable.

Note that the MAP sensor must be wired with the correct polarity, so double-check the wiring and voltages before making the final connection to this sensor. If you are using an existing MAP sensor, then you won't need to make the supply connections, since these will already be present (see panel on page 17 last month).

A toggle switch will need to be mounted on the dashboard if you want to be able to select between two 11×11 maps. The wires for this are connected to the S1 terminals on the Ignition Timing Module PC board. If you just want one map (either an 11×11 or a 15×15), then switch S1 is unnecessary.

Adjusting VR1

If you are using a reluctor pickup to trigger the Ignition Timing Module, the first thing to do is adjust trimpot VR1. That is done as set out in the accompanying panel, headed 'Plotting the original ignition timing values' (see text immediately following 'Reluctor adjustment').

If you have plotted the RPM advance curve (see panel), then most of the parameters within the Ignition Timing Module will have already been set. You will, however, need to set the dwell for the ignition coil.

Conversely, if none of the parameters have been set, then you will have to start from scratch. The various settings were detailed in the first article in Sept '09.

The first step is to place jumper LK1 in the settings position. That done, set the number of cylinders for your car, then set the edge sense to high (or to low if you know it should be this setting). The diagnostic setting should then be checked to ensure it is set for 'interpolation on'.

Next, decide whether you want the two 11×11 maps or the single 15x15 map and select this in the map setting. Follow this step by selecting either the 1° or 0.5° resolution, and set the debounce to 0.4ms.

Note that the latter may need to be set to 2ms if there are problems. This higher debounce period is usually required only for points triggers.

Dwell setting

Now for the dwell setting. First, attach an *external* spark plug to the HT lead from the coil and connect the plug's metal thread to chassis (ground). You can use a heavy-duty lead with alligator clips at either end to make this connection.

Now set the dwell to 0ms and set the internal oscillator in the Ignition Timing Module to on. That done, increase the dwell until the spark plug appears to give its best spark.

Note that the dwell value will not change until the Up switch on the Hand Controller is released, so be sure to release the switch each time you make a change. Stop increasing the dwell when the spark appears to have reached its maximum intensity.

Disabling Original Ignition Systems

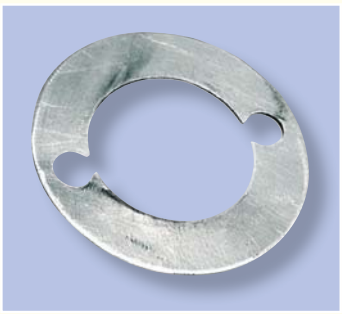
IF YOUR CAR already has a fully electronic ignition, it can be disabled quite easily. Just disconnect the trigger sensor from the existing ignition and connect it to the Ignition Timing Module instead.

Note that with some ignition systems, you will not be able to find a suitable trigger signal that does not also include timing information. In this case, you can only use the *Programmable Ignition System as an interceptor*.

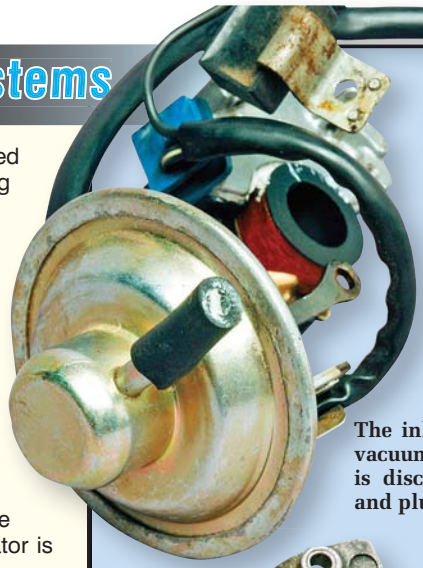
To disable a mechanical advance system, you first need to remove and disassemble part of the distributor. Make sure you turn the engine to TDC for cylinder 1 *before* removing the distributor.

The distributor must be stripped down to give access to the mechanical weights, so they can be locked in place. We used an aluminium plate to lock the weights to the minimum advance position. The vacuum actuator hose is disconnected (to set the advance to the maximum load setting) and the inlet to the actuator is plugged.

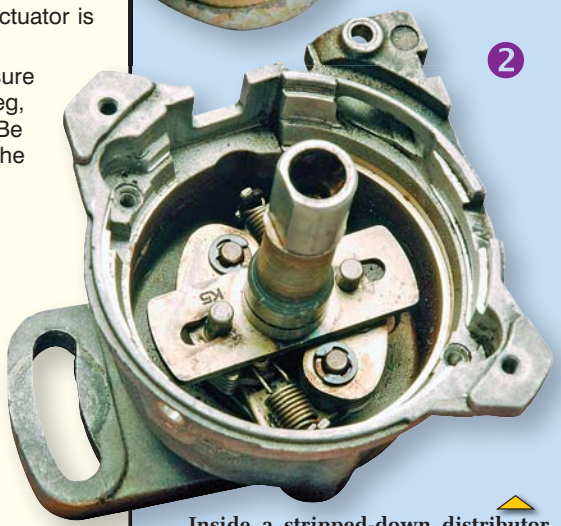
The vacuum hose is then connected to the manifold pressure sensor that's used with the Programmable Ignition System (eg, to an external MAP sensor or the on-board Sensym sensor). Be sure to reinstall the distributor with its rotor pointing towards the cylinder 1 high-tension terminal on the distributor cap.



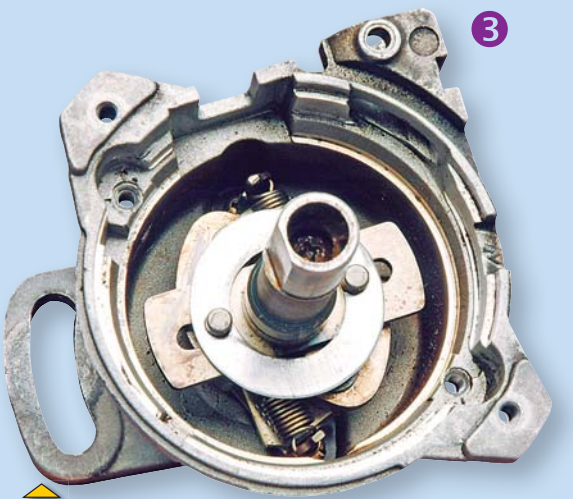
Left: you can use a simple aluminium plate like this to lock the mechanical timing weights inside a distributor. It simply slides over the distributor cam and the timing weight posts, as shown in the photos.



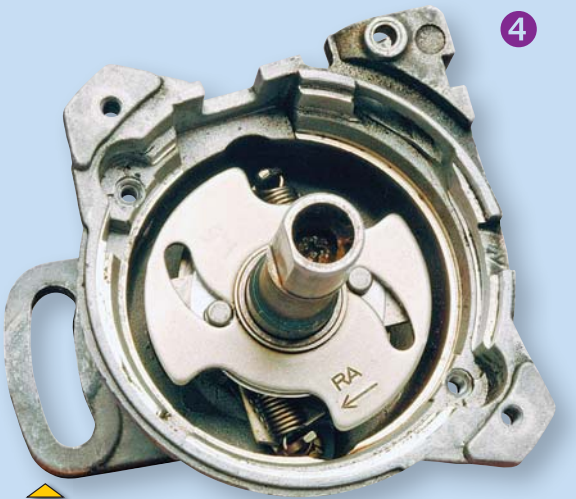
1 **The inlet to the vacuum actuator is disconnected and plugged.**



2 **Inside a stripped-down distributor, showing the timing weight posts.**



3 **The aluminium plate prevents the posts attached to the weights from sliding in their slots as the RPM increases, thus locking them in position.**



4 **The partially reassembled distributor with the advance plate back in position. Because the weights are locked, the advance plate is now also locked.**

Programmable Ignition Software: How It Works

THE CIRCUIT DESCRIPTION in Part 1 (Sept '09) details many of the functions of microcontroller IC1 and explains its pin assignments. However, it doesn't explain what goes on inside the microcontroller, so let's take a closer look at this.

As we've already seen, the trigger signal is applied to IC1's RB0 input and the RB3 output subsequently switches off the ignition coil via the driver circuit to fire a spark plug. We'll assume here that a positive signal edge at the RB0 input is the trigger point for turning off the ignition coil.

Alternatively, this could be set for negative-edge triggering instead by selecting the EDGE LOW setting via the LCD Hand Controller.

If the Programmable Ignition is set for no advance or retard, the RB3 output will go low and turn off the ignition coil (to fire a plug) at the instant the RB0 input goes high. However, we also need to 'charge' the coil so that there is sufficient energy stored in it at the point of 'firing' so as to provide a spark. The duration required to fully charge the coil (to provide maximum spark energy) is called the 'dwell' period.

In order to provide this dwell period, we need to predict when the coil is going to 'fire' the next plug. Based on this prediction, we can then determine when to start 'charging' the coil (ie, the start of the dwell period).

Fig.25 shows the waveforms associated with this. The top waveform is the trigger signal applied to RB0 and the positive-going edges are the firing points.

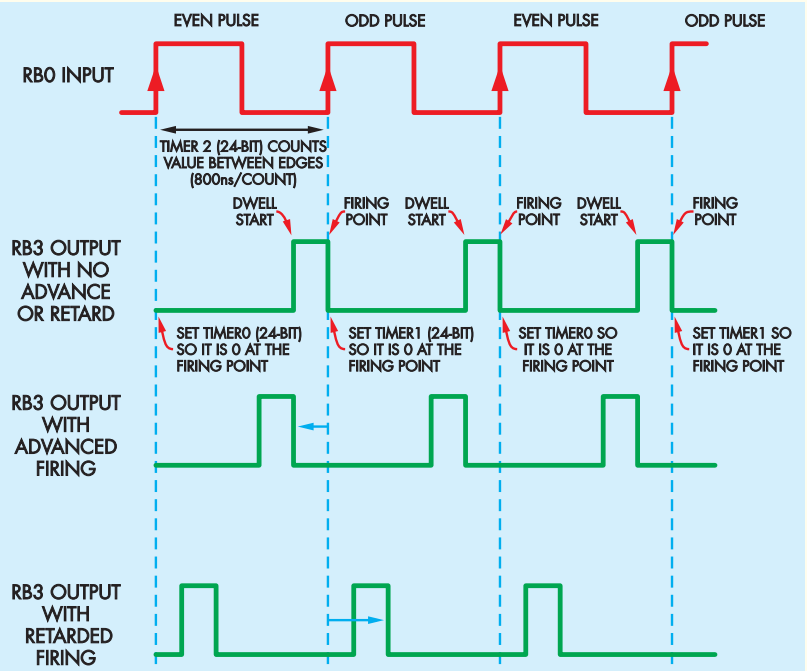


Fig.25: the top waveform in red represents the trigger signal applied to the RB0 input of the microcontroller in the Ignition Timing Module. The green waveforms show the three possible RB3 output signal conditions.

The RB3 output on the waveform below this initiates the dwell period before firing occurs at the positive edge of RB0.

To predict the next firing point, we use a timer (Timer2) that counts up by one for each 800ns between the positive edges of RB0. This count value then becomes the predicted count for Timer2 to indicate when the next firing will occur. This is true when the engine is running at a constant RPM. However, when the engine is increasing in speed, the firing point will occur somewhat earlier than the previous Timer2 count value.

Conversely, the firing point will lag behind the previous Timer2 count value when the engine is slowing down. These changes are not significant, since the engine RPM value cannot quickly change to any extent between successive input trigger signals.

The dwell period can be initiated before the next firing by doing some

Once you've finished, switch off the ignition and reconnect the HT lead correctly so that the car will run. The internal oscillator will automatically be off when power is re-applied.

MAP sensor and RPM ranges

If you intend using the unit as an interceptor (ie, to modify the timing output from an existing system), then you will need to know both the existing pressure (MAP) sensor and RPM ranges. This means that the Ignition Timing Module should be set up so that it initially makes no changes to the timing.

The range over which the existing MAP sensor works can be found by monitoring the LOAD value in the DIAG display mode. First, record the maximum load value by checking the LOAD reading with the ignition on, but without the engine started. This should be done only for normally aspirated engines when the barometer shows 1013hPa of atmospheric pressure (ie, the standard pressure at sea level).

If you are at a higher altitude, then add another 3% to the reading for every 300m above sea level to compensate for the loss in air pressure. Alternatively, vary the reading by the percentage that your local air pressure differs from 1013hPa. Increase the reading for lower air pressure and decrease it for higher air pressure.

calculations using the Timer2 count value. If, for example, the required dwell for the coil is 4ms, we can calculate that this period is equal to a count of 5000. This is because 4ms requires counting 5000 of the 800ns count periods. We can then start the dwell at a count of 5000 before the next expected firing point.

Initiating the dwell start and switching off the coil to fire a plug requires another counter. At every positive signal edge on RB0, this second counter (Timer0) is set at a value so that it will reach a count of zero at the next expected firing position. Before it reaches zero, the counter is checked every 204.8ms to see if it has reached the value to start the dwell period. If this value has been reached, RB3 goes high and remains high until the counter reaches zero, at which point RB3 goes low to fire the plug.

In order to advance or retard the firing point, instead of setting Timer0 to fire at the next expected RB0 positive edge, we either fire before this for advance, or later than this for retard. The dwell is also shifted to start earlier as the timing advances or later as the timing retards.

We need to make some calculations in order to set Timer0 to a value that will give the correct amount of advance or retard in degrees. As we know, the Timer2 value provides us with the count between firing pulses. Firing pulses occur twice per engine revolution for a 4-cylinder 4-stroke engine, and three times per engine revolution for a 6-cylinder 4-stroke. So, for a 4-cylinder 4-stroke engine, we divide the Timer2 count by 180 because plug firings are 180° apart, with two pulses per 360° engine revolution. This gives us the count per degree.

For the 0.5° resolution setting, we divide by 360 instead of 180 to get the number of counts per 0.5°. Similarly, for a 6-cylinder engine, we divide by 120 for the 1° resolution setting because there are three firing pulses per 360° engine revolution. The number of degrees of advance or retard required is then multiplied by the count per degree value. This is then either added to the Timer2 value to retard the timing or subtracted from the Timer2 value to advance the timing.

Timer0 is then set so that it reaches a count of zero at this altered Timer2 value. In this way, RB3 is controlled by Timer0 to set the dwell and fire a plug (when Timer0 is zero) at the required advance or retard setting.

Well, that's basically how the system works, but in practice it's a bit more complicated that that. In reality, there are two timers: Timer0 and Timer1. Timer0 is used to decide when to drive RB3 high (for the dwell) and low (to fire the plug) between each of the even-numbered positive edges from RB0.

By contrast, Timer1 is used to drive RB3 high and low between each of the odd-numbered RB0 positive edges.

The reason we need two timers is because one of them might still be in use, determining when to drive RB3, when the next positive edge from RB0 occurs. If only one timer was used, it could not be made ready for the next firing sequence, as this would affect the current firing position. The only alternative is to use two timers, as described.

Note that the firing point is calculated from the previous RB0 positive edge and may not exactly match the current RB0 edge when there is no advance or retard adjustment. This can happen when the engine revs are changing.

In this case, we fire the coil when the RB0 output goes high. In addition, when the timing is set to retard, the firing point is recalculated when the next RB0 positive edge occurs. If the timing is set to advance, the plug will also be fired at the positive RB0 edge if it has not already fired.

Another calculation made within the microcontroller is for the engine RPM value. This calculation first divides the Timer2 count value by 16 and the result is then divided into 93,750/cylinder for a 4-stroke engine. The result is a value for the number of '100 RPM' increments.

For example, lets assume that Timer2 has a count of 37,500 and we are running a 4-cylinder engine. The 37,500 is then divided by 16 to give a result of 2343. Dividing this value into 93,750/4 gives a value of 10. This is the number of '100 RPM' increments, which in this case is equivalent to 1000 RPM.

This calculation is correct because with a Timer2 count of 37,500, the period between pulses is 30ms because each count represents 800ns (800ns × 37,500 = 30ms). A 30ms period is 33.333Hz or 2000 pulses per minute. Since the engine is a 4-cylinder 4-stroke, there are two pulses per revolution and so the engine speed is 1000 RPM.

Calculations are also required to convert the RPM and pressure sensor values to site values. These calculations are based on the size of the map selected (11×11 or 15×15) and the minimum and maximum RPM and load values. Further calculations perform the interpolations for the advance and retard values between both the RPM and load sites.

For turbo engines, the maximum reading from the pressure sensor is found at maximum boost.

The minimum load value can be found by driving the car downhill, with the engine being overrun (eg, by shifting to a lower gear than normal). Note, however, that some cars tap the vacuum line for the vacuum measurement before the butterfly valve that's located within the air inlet throat. In this case, vacuum measurement is not available on a fully-closed throttle because the butterfly valve is also closed. What's more, just slightly opening the throttle in this case will cause the vacuum to reappear.

Once you've measured the minimum load value, enter it into the settings as the Minimum LOAD. That done, enter the Maximum LOAD by altering the loads/site value so that it is equal to or a little over the value previously measured.

You now need to set the minimum and maximum RPM values to suit the range of the engine. Just set the Minimum RPM value to the idle speed and the Maximum RPM value to the engine red line.

Note that the idle speed can be measured using the Programmable Ignition System, with the display set to DIAG to show the RPM.

When setting the Maximum RPM, adjust the RPM/SITE value so that the maximum RPM is at or just over the

Converting From Points To A Hall Effect Sensor

You can replace your existing points with a Hall effect sensor – *but be warned, it takes quite a lot of precision work*! All the details are shown in Fig.26.

First, rotate your engine so that the rotor button in the distributor is facing the high-tension outlet for cylinder number 1. Also note the direction that the rotor button moves when the engine is turned in its correct direction. Set the timing mark on the flywheel to the number of degrees before Top Dead Centre (TDC) specified in the workshop manual and indicated by the engine block timing marks.

Now place a mark on the edge of the distributor body to show where the timing mark on the rotor button arm is positioned. This sets the alignment for the Hall effect modification. The distributor can now be removed from the engine.

The Hall effect sensor is designed to be used with a rotating vane that passes through the gap incorporated in its housing. The Hall sensor is mounted on the distributor advance plate and secured using the rivets incorporated on its housing. The rotating vane needs to be made so that it spins with the distributor shaft and its vanes pass through the sensor gap.

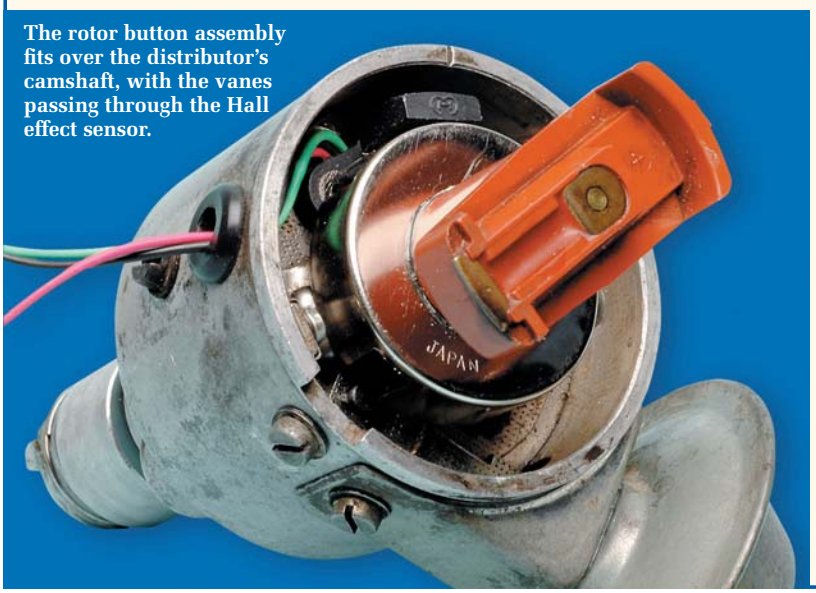
For this to happen, the rotating vane needs to be cup-shaped. The horizontal face has a hole to allow it to be placed on the distributor shaft and locate with the rotor button. The vertical section needs to have slots cut in it to appropriately trigger the sensor.

The number of slots on the vane equals the number of spark-plugs for which the distributor caters. So a 4-cylinder car with four spark plugs will use four slots. These slots need to be evenly spaced around the circumference of the rotating vane. **It is essential to be accurate here, as a 1° difference between slots represents 2° on the engine.**

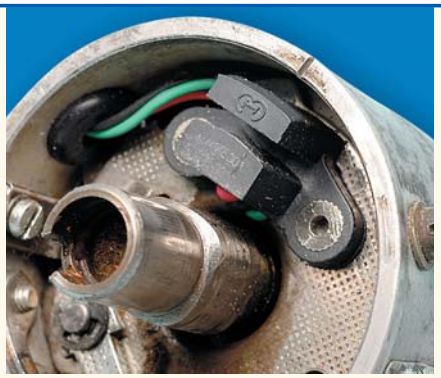
A 4-cylinder engine will have each slot positioned 90° apart. 6-cyclinder and V8 cars will require slots spaced 60° and 45° apart, respectively.

Making the disc

Making the disc is easier if you can start off with something that is already preformed. We used the tin-plated backing from a high power potentiometer. A suitable one is the Jaycar RP-3975 15W potentiometer. This provides us with a cup that is 40mm in diameter.



The rotor button assembly fits over the distributor's camshaft, with the vanes passing through the Hall effect sensor.



This photo shows how the slotted Hall effect sensor is rivetted to the vacuum advance plate inside the distributor.

All that is required is to drill out a hole in the top for the distributor shaft and cut the slots in the side.

Mounting the sensor

When this has been done, the Hall sensor can be mounted on the distributor advance plate. The sensor needs to be located so that the centre of its slot is 20mm away from the centre of the distributor shaft. This will allow the 40mm diameter cup to spin without fouling the Hall sensor.

Drill the two holes in the distributor advance plate and countersink the holes on the underside of the plate. This will allow space for the rivets in the Hall sensor to be peened over.

Before riveting, check that the Hall effect wires do not foul against the points cam (this happened in the distributor we were modifying!). To prevent this, the wires were passed under the Hall sensor by filing a small channel beneath the sensor, so that the wires could be fed through to the other side. The wires were then fed through a grommet in the distributor's body.

Rotating vane

The rotating vane should be placed over the distributor shaft and should sit on the top of the points camshaft. Check that there is sufficient clearance between the vanes and Hall sensor gap. If the cup needs to be higher than this, it can be placed over the rotor button shaft.

In this case, the rotating vane must be electrically connected to the distributor shaft to prevent static build up

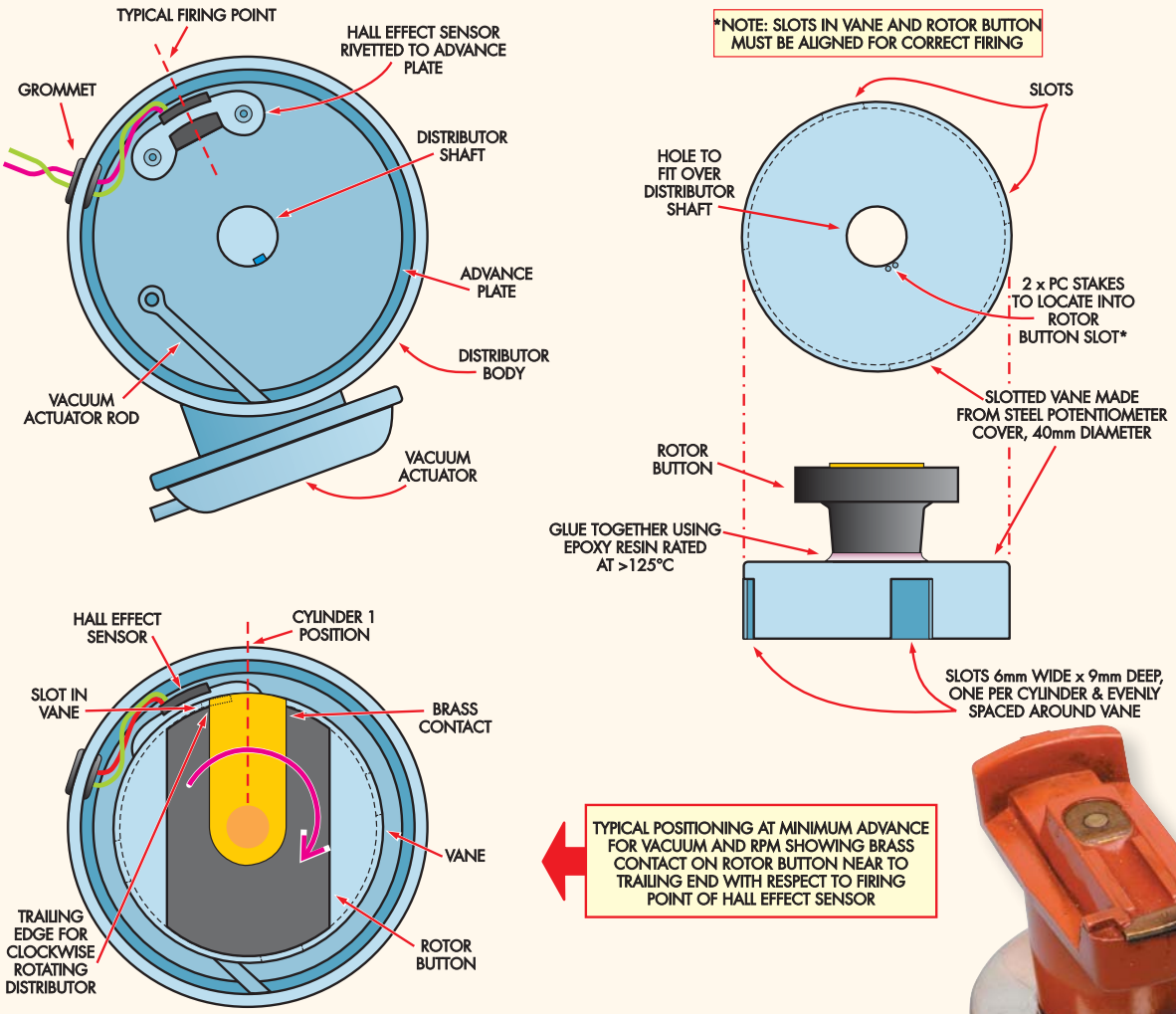


Fig.26: these diagrams and the accompanying photos show how to replace the points with a Hall effect sensor and make the rotating vane assembly. Note that the slots in the vane must be accurately positioned – see text.

which may damage the Hall sensor. A small piece of tinplate soldered to the vane and bent so it passes up inside the rotor button to make contact with the distributor shaft is suitable.

When the Hall effect sensor has been mounted, place the rotating cup over the distributor shaft and hold it in place with the rotor button. Check that the vane spins freely through the Hall sensor slot.

Now you are ready to align the disc. Rotate the rotor button to the alignment marks set previously. Remember, these indicate the centre position of the rotor button at number 1 cylinder timing. Move the rotating vane relative to the rotor button so that the gap is just leaving the centre of the Hall effect sensor.

Note that you must be turning the distributor in the direction that it travels when installed in the car. Mark the position on the rotating vane and rotor button using a marking pen (do not use a scriber on the rotor button or the high tension voltage may travel down this). We soldered in a couple of PC stakes inserted into holes drilled in the top of the vane, to align the vane position – these keyed into the locating slot in the rotor button.

Gluing the vane

Finally, the rotating vane can be glued to the bottom of the rotor button using high-temperature epoxy resin. We used JB Weld epoxy steel resin, a two-part epoxy. This is suitable for temperatures of up to 260°C. The quick-setting version can be used for temperatrures up to 150°C.

value required. You can also adjust the minimum RPM setting to achieve the best compromise for the adjustment.

Testing

The Programmable Ignition System should now be ready for it first real test. If you are using it as an interceptor, make sure that all the initial timing map values are zero. You can ensure this by pressing the Reset button on the Hand Controller and waiting one second so that RESET is shown on the display. This will clear all the timing values to zero – but only for the map selected.

If you want to clear both the alpha and beta maps, then you will need to use switch S1 to select the alternative map and press the Reset button again. Of course, this only applies if the two 11x11 maps have been selected. The 15x15 map is fully reset to zero using just the Reset switch, regardless of switch S1's position.

Now try to start the engine. If it refuses to start, then the edge setting (for the input trigger signal) may need to be set to low rather than high.

Assuming that it does start, check that it runs properly when the throttle is quickly pressed to increase the revs. If it falters, then the dwell period may need increasing a little. Additionally, the response to the low-speed RPM setting may need to be increased by a few hundred RPM above the idle speed for best 'take-off' acceleration.

Altering the timing a little from its standard setting can sometimes smooth out the idle speed if it tends to be rough. It needs to be tested by both advancing and retarding the existing value to find the optimum setting. This setting becomes the cranking advance as well.

These two settings (for cranking and idle) may not be compatible because the idle advance setting may make the engine hard to start. If necessary, the cranking timing can be made independent of the idle timing by lowering the minimum RPM setting to below idle, but above the cranking speed. This will set the RPM1 sites for cranking only. Cranking RPM can be measured on the DIAG display during starting.

Both the off-throttle and cruising settings can generally be advanced further to improve fuel economy. However, too much off-throttle and cruising advance can produce poor engine response if extra throttle is suddenly applied for acceleration.

Any pinging (detonation) problems at high loads can be solved by reducing the advance. Note that with the 11×11 map, there are 121 individual adjustments that can be made at the various RPM and engine LOAD sites. You will probably not need to alter too many of these. Just adjust those sites that need to be changed to eliminate pinging (reduce the timing value) or to provide more power under load (increase the timing value).

In practice, the vehicle can be driven with the Hand Controller connected if you wish to fine-tune the adjustments (get someone else to do the driving). However, it's important to note that the Programmable Ignition will work best when the Hand Controller is in the settings mode, as selected using link LK1 on the Ignition Timing Module.

The microcontroller then doesn't spend time updating the LCD module and this allows its program to be solely devoted to updating the timing. As a result, any responses to manifold pressure changes and RPM changes will not be hampered by display updates.

The Hand Controller can be disconnected when all the settings have been entered. **Note that it should only be connected or disconnected with the power to the Ignition Timing Module switched off.** *EPE*

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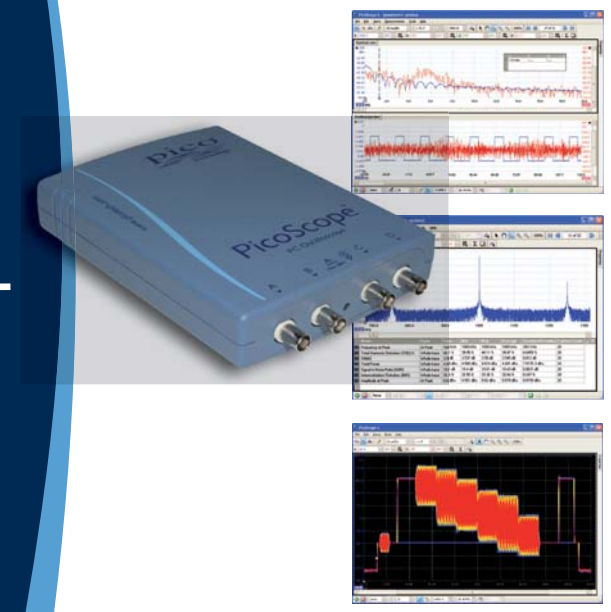

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SP130	100 x Mixed 0·5W C.F. resistors
SP131	2 x TL071 Op Amps
SP133	20 x 1N4004 diodes
SP134	15 x 1N4007 diodes
SP135	5 x Miniature slide switches
SP136	3 x BFY50 transistors
SP137	4 x W005 1·5A bridge rectifiers
SP138	20 x 2·2/63V radial elect. caps.
SP142	2 x CMOS 4017
SP143	5 Pairs min. crocodile clips (Red & Black)
SP144	5 Pairs min.crocodile clips (assorted colours)
SP146	10 x 2N3704 transistors
SP147	5 x Stripboard 9 strips x 25 holes
SP151	4 x 8mm Red LEDs
SP152	4 x 8mm Green LEDs
SP153	4 x 8mm Yellow LEDs
SP154	15 x BC548B transistors
SP156	3 x Stripboard, 14 strips x 27 holes
SP160	10 x 2N3904 transistors
SP161	10 x 2N3906 transistors
SP164	2 x C106D thyristors
SP165	2 x LF351 Op Amps
SP166	20 x 1N4003 diodes
SP167	5 x BC107 transistors
SP168	5 x BC108 transistors
SP172	4 x Standard slide switches
SP173	10 x 220/25V radial elect. caps
SP174	20 x 22/25V radial elect. caps
SP175	20 x 1/63V radial elect. caps.
SP177	10 x 1A 20mm quick blow fuses
SP178	10 x 2A 20mm quick blow fuses
SP181	5 x Phono plugs – asstd colours
SP182	20 x 4·7/63V radial elect. caps.
SP183	20 x BC547B transistors
SP186	8 x 1M horizontal trimpots
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A Digital VFO with Graphics Display

This DDS VFO uses a widely available recycled Nokia cellular phone LCD to display analogue and digital frequency readouts, text and VFO status messages

FOR several years, I've wanted to build my own DDS (direct digital synthesis) VFO (variable frequency oscillator).

Analog Devices makes one of the most popular ranges of DDS chips, which digitally generate precise sine-waves covering frequencies from 'practically DC to daylight'; well, up to many hundreds of MHz.

Some time ago, I managed to obtain several samples, but that was as far as things went. I was just too busy with work and family matters to devote any dedicated time to the project.

In addition, I couldn't locate a suitable design to build. Practically all existing designs use one of the PIC microprocessor family. Others use several PIC microprocessors; and yet others use a further large bunch of ICs to interface displays and keypad functions. With my microprocessor development tools all focused on the 8051 family – and being fundamentally of a contrary nature – I was determined to use an 8051 chip in my DDS VFO, rather than mess about gearing up for another microprocessor. I also wanted to keep the chip count minimal.

Underlying this was a feeling that if I wrote my own software, I could customise it to suit my precise requirements and be better placed to develop one or two other DDS-based projects I had in mind. Of course, that naively assumes I'll find the time to complete those new designs.

Operator interface

First, let's not forget the operator interface. Practically all existing designs use a standard 2-line × 20-character alphanumeric display. An earlier popular design used high-current

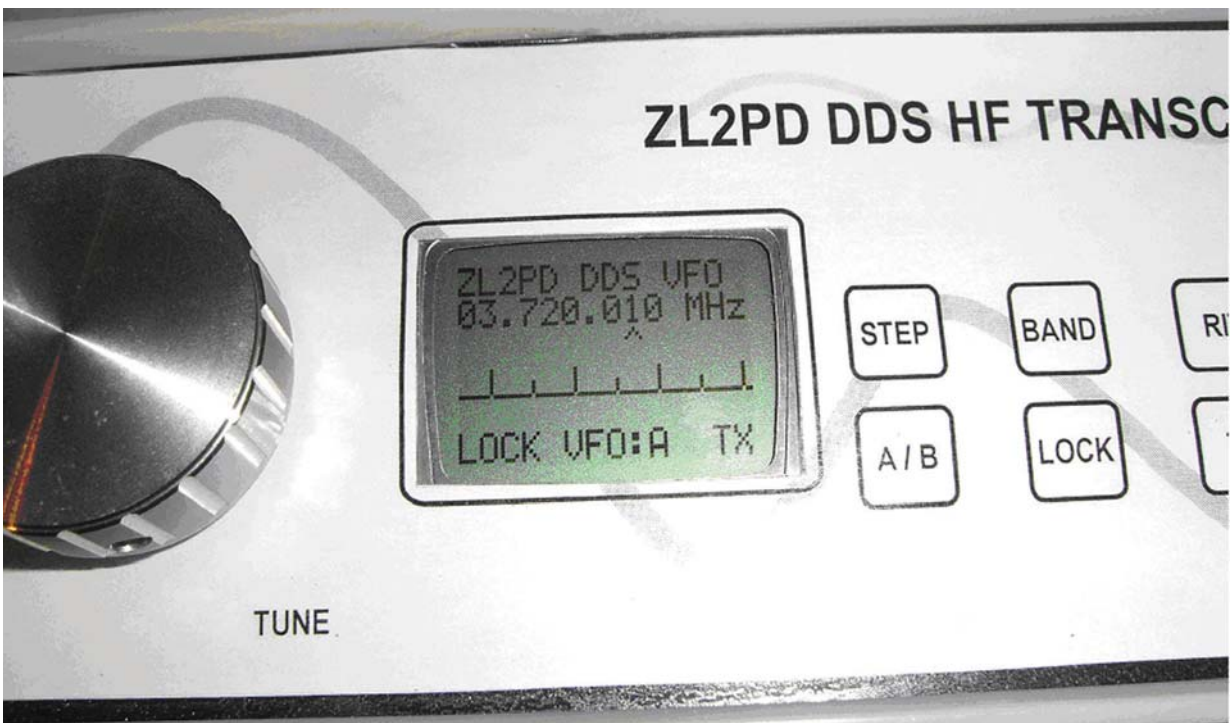


Fig.1: the promise of things to come? The DDS VFO with its cellular phone 'readout' mounted inside an HF transceiver the author is currently working on . . .

LCD

By Andrew Woodfield, ZL2PD

Fig.2: the readout, from a Nokia cellular phone, is capable of displaying simple graphics.

7-segment LED displays. The size of both of these displays and the limited information presented to the operator didn't seem ideal to me.

They certainly weren't well-suited for the small HF transceiver I've also been building.

This led to another delay while I looked for alternative displays and a series of experiments with some small cheap, graphical LCD modules. These monochrome LCDs were used in many older cellular phones, as well as in some current low-cost entry-level models.

I built several small projects using one of the most commonly used graphical LCDs, the Nokia 3310 LCD module (Fig.2). This LCD turned out to be very useful – it offers an 84 × 48 pixel display, with a visible area of about 35 × 25mm.

DDS oscillators

Direct digital synthesis (DDS) is a digital method to generate waveforms, usually sinewaves. In contrast to the more common phase-locked loop (PLL) approach, which uses a voltage controlled oscillator, digital dividers and a phase detector to generate frequencies in defined steps, data stored in an internal DDS chip table is passed to a digital-to-analogue (D/A) converter at a specific clock rate. If the table contains values equivalent to the amplitude of a sinewave, then a sinewave at a frequency related to the clock rate will be produced.

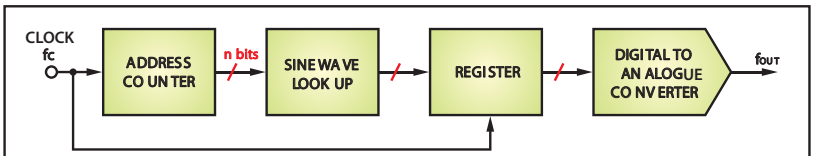


Fig.3: basic Direct Digital Synthesis system.

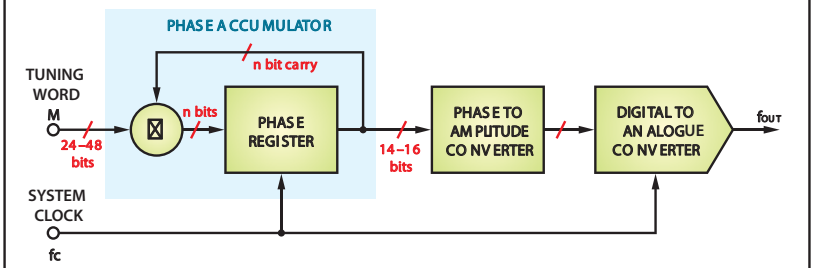


Fig.4: a typical DDS (direct digital synthesis) system.

One such basic DDS is illustrated in Fig.3. By changing the clock speed, a wide range of sinewave frequencies can be generated. If the clock is fast enough, frequencies can readily be generated across wide ranges and at sub-Hz increments.

The completely digital nature of the DDS oscillator and its ability to generate very fine frequency increments are the main advantages over PLLs.

In practice, a DDS device uses the arrangement shown in Fig.4. The tuning word, which is usually 32 or 48 bits wide, is used to modify a phase accumulator. This outputs a 14 to 16-bit word for onward signal generation.

With this approach, and with a 32-bit tuning word, it is possible to generate more than four billion specific frequencies.

For more information on DDS chips, the introductory documents on the Analog Devices website at **www.analog.com** are highly recommended.

The most significant problems with DDS oscillators are noise and spurious emissions. These can be minimised by using D/A converters with relatively long digital words. Many DDS devices are limited to 10-bit words, but new devices more often use 12-bit or 14-bit words.

This DDS VFO uses an Analogue Devices AD9850 chip (IC4), which uses

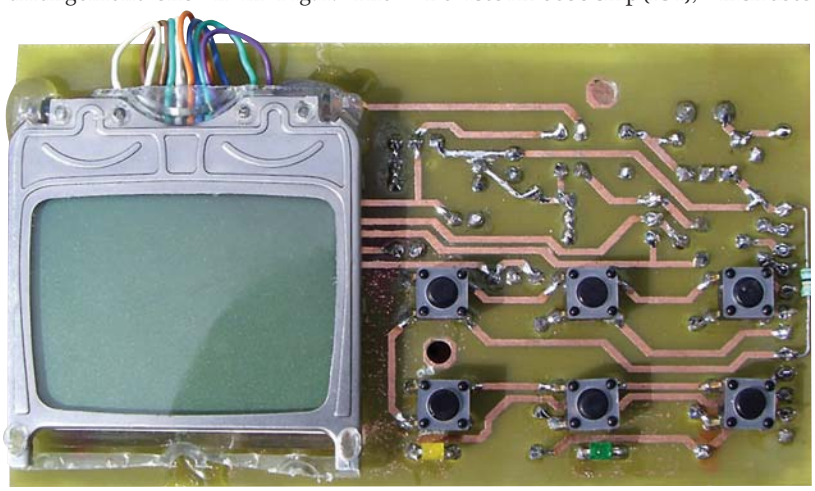


Fig.5: the LCD is shown here mounted on the back of the PC board, along with the control switches. There are minor differences to the final layout shown in Fig.8.

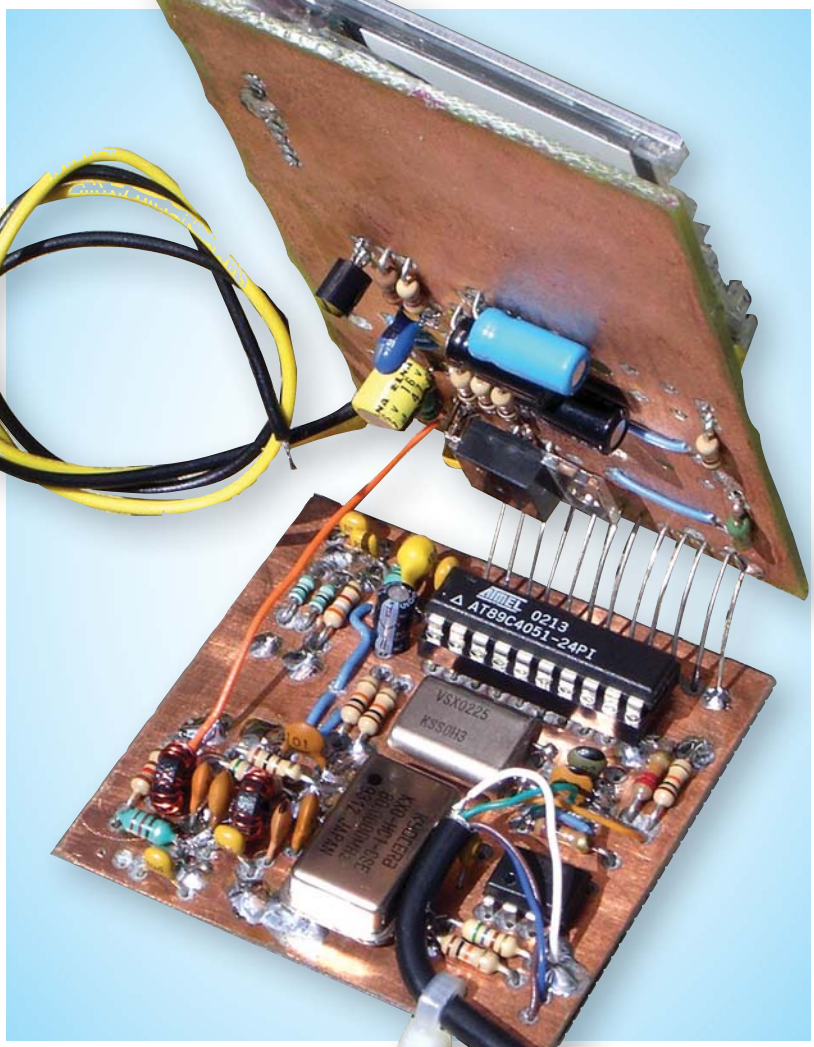


Fig.6: there are two ways to construct the DDS VFO – cut the board and 'sandwich' the two sections as shown here, or leave the board intact (the tracks for the two sections are provided). As you can see from this photo, the component side of the PC board(s) is a groundplane, formed by using a double-sided PC board blank.

a 10-bit DAC. This delivers a spurious emission level of –50dB.

Frequencies are selected using 32 bits of a 40-bit tuning word, allowing better than 0.03Hz frequency steps with the 80MHz DDS clock used in this design. The balance of the 40-bit word is used for phase and control functions.

Since this level of resolution exceeds most requirements, many DDS VFO designs use a larger step size. In this VFO design, the user can select 10Hz, 100Hz or 1kHz steps to give three tuning rates – slow, medium and fast.

Functionality

The DDS VFO covers all amateur radio bands between 160m and 10m in 10Hz, 100Hz or 1kHz increments, and will happily tune outside these bands. The LCD module displays the current operating frequency and mode of the VFO. A key feature of this design is an analogue-style graphics-driven dial displayed on the LCD. It sweeps up and down just like a conventional mechanical dial while tuning the VFO.

The VFO design also features two independent VFOs, a programmable receiver IF offset capability, full RIT (receiver incremental tuning) and VFO locking. All of this software is handled within a single 20-pin low-cost Atmel 89C4051 microprocessor.

The DDS drivers within the microprocessor are quite compact, but much of the space within the 4K bytes of flash program memory is actually required for lookup tables to handle the Nokia 3310 LCD.

Unlike standard 2-line × 20-character alphanumeric displays, all the information displayed has to be generated, dot-by-dot, by the 89C4051 microprocessor. Each and every character, every graphical feature, all resides within the 4K of program memory.

The VFO code itself amounts to less than 1.5Kb, the balance taken up by the graphics tables. There is also some room in the program memory to permit builders to add other features to suit individual requirements.

The code uses no special features of the AT89C4051, and so it may be used with almost any 8051-type processor possessing adequate memory.

One option might be the addition of country-specific frequencies (for example) not currently supported by the present VFO software. To that end, the fully commented source code is available from the author's website, as well as the Intel hex file for direct programming of blank microprocessors.

Above is the optical encoder, made from a surplus mechanical mouse

The design

The full circuit diagram for the Digital VFO with LCD Graphics Display is shown in Fig.7.

In contrast to other designs, this DDS VFO design is almost minimalist, using just four chips (excluding the regulators) – the microprocessor, the

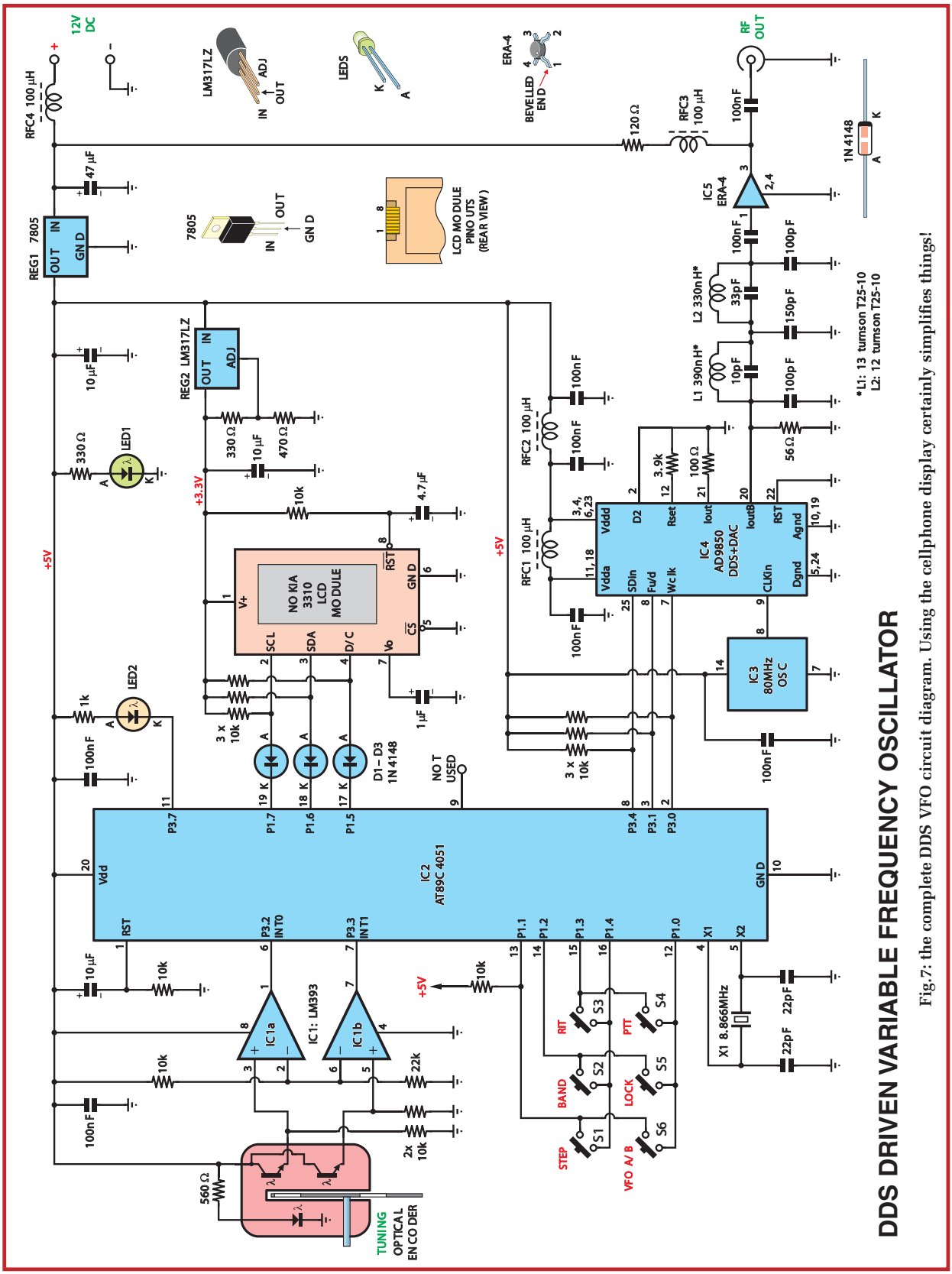


Fig.7: the complete DDS VFO circuit diagram. Using the cellphone display certainly simplifies things!

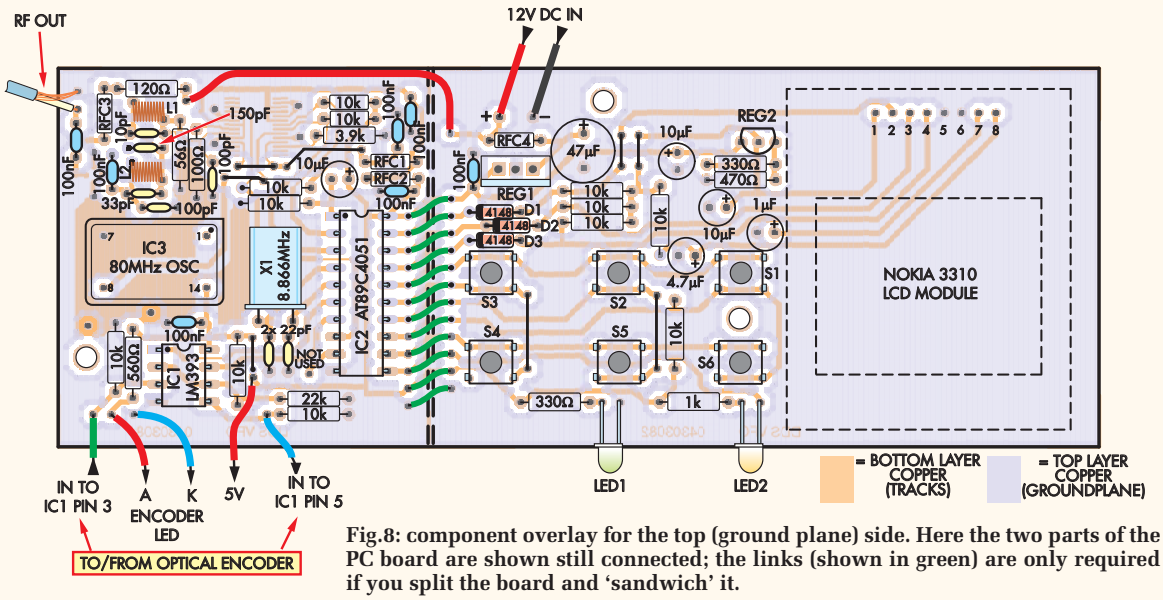


Fig.8: component overlay for the top (ground plane) side. Here the two parts of the PC board are shown still connected; the links (shown in green) are only required if you split the board and 'sandwich' it.

optical encoder interface chip, the DDS and an RF amplifier chip – see Fig.7.

This avoids the approach used in a number of other designs, which requires a microprocessor dedicated to the encoder and display, and a second processor dedicated to the DDS.

The microprocessor (IC2) is operated at a very leisurely 8MHz. I actually used a PAL TV colour-burst crystal of 8.866MHz, but any crystal from 8 to 12MHz will probably work fine. The top speed for this micro is 24MHz, so clearly nothing much is being pushed hard in this design.

This might suggest that the 8051 is significantly more efficient than other 8-bit microprocessors used in similar designs.

Software

My software is all written in hand-coded assembler, often far more efficient than higher level languages and the code (possibly) makes a little better use of interrupts.

This approach allows the optical encoder (the main tuning control) to be very rapidly read without causing any measurable delays in the main DDS and display routines, despite the fairly intensive data transfers required by the Nokia 3310 LCD whenever it is being updated.

Interrupt-driven routines tend to be a little more complex to write, but are necessary here to handle rapid updating of the digital display and the analogue dial graphics, while also reading the dial and checking for any pressed buttons.

These functions can add up to quite a lot of work for this modest 8051 microprocessor to manage, but it is made possible by minimal mainline software functions and a relatively fast background interrupt cycle. This interrupt cycle is focused on reading the encoder, the most time-critical function.

Powering up

When power is applied to the VFO, the microprocessor begins by initialising the LCD module. This features a brief animated set of graphics, which illustrate some of the flexibility of the display and makes use of some spare ROM space. The 89C4051 (IC2) then initialises the DDS VFO to the bottom of the 80m band in receive mode, with an offset assuming an IF of 8.467MHz, and with RIT turned off.

These parameters are all set by the software and are very easy to change to suit other applications and user preferences. These settings are all very clearly highlighted in the source code.

The DDS (IC4) requires a 40-bit serial word transfer from the microprocessor. As the encoder is rotated, the DDS frequency is updated, the new frequency displayed and the dial graphics dynamically changed according to the direction of tuning knob rotation.

The 40-bit word sent to the DDS is calculated from a series of predetermined lookup values, one for each digit in the 7-digit frequency of the VFO, the values depending on the DDS clock used.

In this case, they assume an 80MHz clock (IC3), the highest frequency crystal oscillator I could buy locally.

The DDS output is filtered using a fifth-order elliptical low-pass filter, with a cut-off frequency of about 35MHz. The output from the filter is then amplified by IC5, an ERA-4 surface-mount MMIC. This gives an output level of about 1V peak-to-peak, or +13dBm into 50Ω from the VFO, ideal for diode mixers. Since the DDS

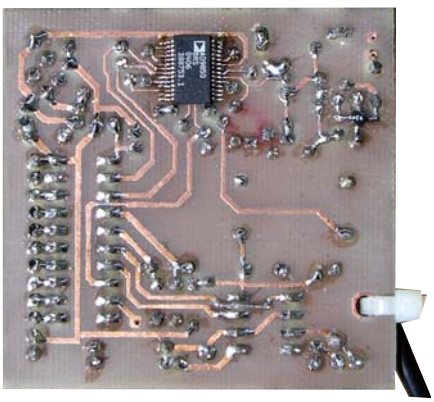


Fig.9: soldering that SMD chip (IC4) requires a steady hand, a fine iron and a magnifying lamp.

output level follows a sin*x*/*x* envelope, the output reduces to 0.8V peak-to-peak by 30MHz.

This 2dB roll-off is of little concern in transceiver applications such as this project, but it should be borne in mind if the software is adapted/reused for applications such as a signal generator.

The 80MHz DDS oscillator (IC3) is the reference for the VFO's output frequency. By contrast, the microprocessor crystal (X1) is a nominal 8MHz crystal and, as noted earlier, its exact frequency is not critical. Since output frequency accuracy and stability depends on the 80MHz DDS oscillator (and few of these have any external frequency adjustments available), any users requiring absolute output frequency accuracy can make the simple frequency alignment adjustments within the software.

I found my VFO was accurate to a few hundred Hertz and quite adequate for my uses.

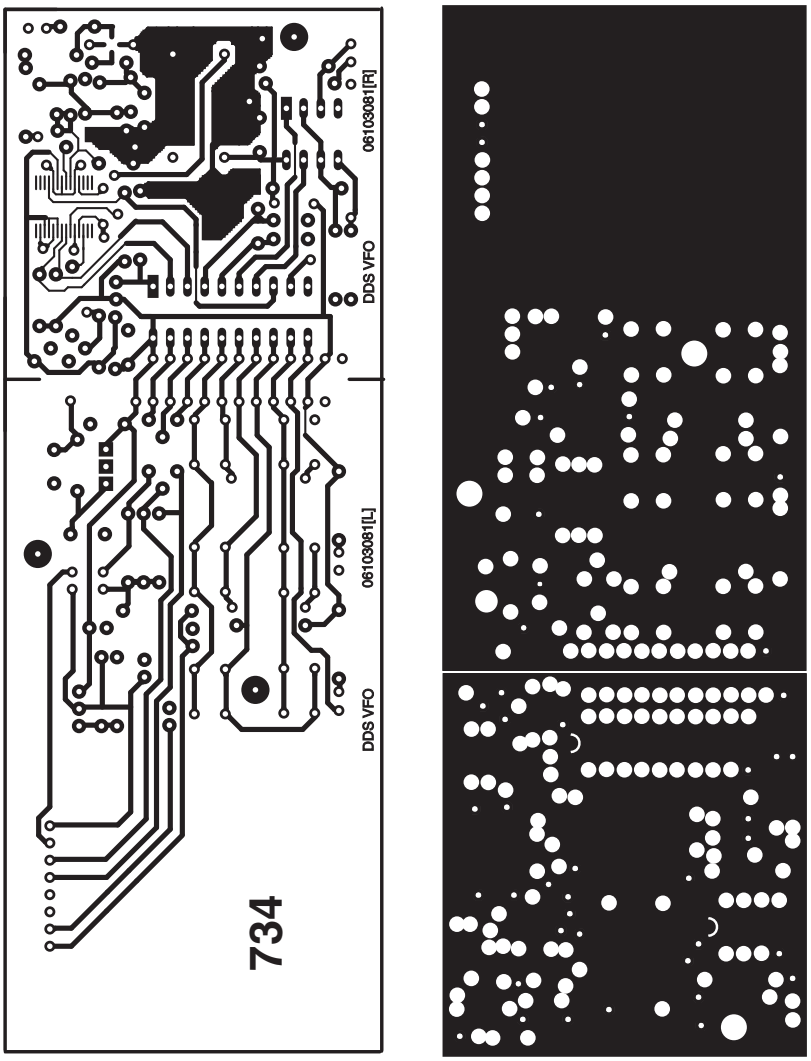
Display module

The Nokia 3310 LCD module requires a 3.3V supply. While some 8051 chips will operate on the same 3V supply, the 80MHz oscillator demands a 5V supply. The decision was therefore made to run both a 5V rail (for the micro and oscillator) and a 3.3V rail for the LCD. It's a slight additional complexity, but makes the design easier to convert to other types of 8051 chips should this prove desirable.

The interface between the AT-89C4051 and the display, necessary due to the different supply rails on these parts, is handled by three 1N4148 isolating diodes. If you are able to purchase some 3.3V clock oscillators (a standard part, but one I couldn't buy locally), you can easily modify the entire VFO for single supply rail operation.

The microprocessor interface for the LCD module uses fewer control lines than suggested in many references. Most suggest the need for five lines, including a reset line from the microprocessor. Careful reading of the datasheet revealed that the display chip select (CS) line can be permanently tied to ground (0V) at the cost of a little more current.

The VFO's MMIC amplifier (IC5) is fairly greedy, drawing around 65mA, so the modest constant 5mA consumed by the always-on LCD turned out to be of little concern. The datasheet also suggested the possibility of using a resistor-capacitor reset arrangement (10kΩ and 4.7µF) and that saved a further I/O pin. As a result, there is an additional delay of a hundred milliseconds or so at power-up, just to be sure the display has reset, but this is of little importance in overall operation.



Figs.10 and 11: here's the full-size artwork for both sides of the PC board; the top (ground plane) is at right. We imagine most constructors will not bother etching a second layer (even if they can) but will simply remove the top-side copper around the holes with a small twist drill (eg, 5mm). It's tedious, but easy enough to do holding the drill in your fingers, putting the tip in the hole and twisting. The smaller holes in the ground plane are for the components which solder to both sides of the board – these should not be opened out.

Tuning in

The main dial knob connects to an optical encoder. This is interfaced to the microprocessor with an LM393 comparator (IC1) to ensure clean rising and falling quadrature signals.

The use of an optical encoder delivers improved long-term reliability and allows users to set up the mechanics of the dial knob to suit individual taste.

Software

The software files will be available via the *EPE* Library site, accessed via **www.epemag.com**. They are also available, with some additional

Parts List – DDS VFO

1 double-sided PC board, code 734, available from the EPE PCB Service, size 150mm × 50mm (see text)
1 digital display ex-Nokia 3310 cellular phone (see text)
1 surplus mechanical (ball-type) mouse for optical encoder parts (containing one LED and two phototransistors – see text)
1 8.866MHz crystal (X1)
6 PC-mount SPST 'keyboard' pushbutton switches

Semiconductors
1 LM393 dual power voltage comparator (IC1)
1 AT89C4051 microcontroller (IC2)
1 80MHz oscillator (IC3)
1 AD9850 (IC4)
1 ERA4 (IC5)
1 7805 5V positive voltage regulator (REG1)
1 LM317LZ voltage regulator (REG2)
3 1N4148 silicon signal diodes (D1-3)
1 yellow LED
1 green LED

Capacitors

1 10µF 16V PC electrolytic	
3 10µF 10V PC electrolytic	
1 4.7µF 10V PC electrolytic	
1 1µF 10V PC electrolytic	
7 100nF polyester	(code 0.1, 100n or 104)
1 150pF polyester	(code 150p or 151)
2 100pF polyester or ceramic	(code 100p or 101)
1 33pF ceramic	(code 33p or 33)
2 22pF ceramic	(code 22p or 22)
1 10pF ceramic	(code 10p or 10)

Inductors
1 390nH (L1) (13T 33SWG ENCU on T25-10 toroidal former)
1 330nH (L2) (12T 33SWG ENCU on T25-10 toroidal former)
4 100µH (RFC1-4)

Resistors (all 0.25W, 1%)

1 22kΩ	12 10kΩ	1 3.9kΩ	1 1kΩ	1 560Ω
1 470Ω	2 330Ω	1 120Ω	1 100Ω	1 56Ω

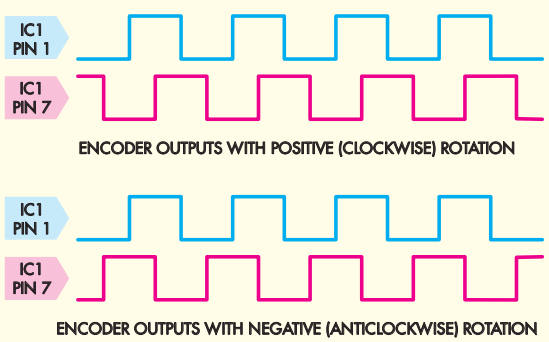


Fig.12: quadrature outputs from an optical encoder are used to tune the DDS.

information, from Andrew's ZL2PD website – see the References panel.

Preprogrammed PICs will also be available from Magenta Electronics – see their advert in this issue for contact details.

Construction

The printed circuit board component layout and full-size copper foil masters for the Digital VFO With LCD Graphics Display are shown in Fig.8 and Fig.10. This board is available from the *EPE PCB Service*, code 734.

The VFO can be built either as a single PC board, measuring about 150 × 50 × 15mm (W × H × D) or in a sandwiched two-PC board configuration measuring 100 × 50 × 25mm (W × H × D). Those wanting a smaller version can convert the current layout to use SMD parts and reduce the dimensions by about 40%.

While the present design uses a double-sided PC board, the top side of the board is left unetched, forming a continuous copper ground. This allows the PC board to be etched in typical home workshops with ease, as if it was a single-sided PC board. That's the method I used for the version pictured.

While I've used standard components as far as possible, construction is not for the faint-hearted. The DDS chip, for example, is a 28-pin SMD, with very close pin spacing. The display connections are also challenging. Time and care allow both to be soldered into place, but it does require a good soldering iron with a fine tip, steady hands, patience and good eyesight.

I'd suggest building the keyboard/display PC board first. Install the jumpers first, the resistors, then the switches, and finally mount the display. The Nokia 3310 display is supplied mounted on a plastic keypad frame assembly, complete with speaker.

Prise out the speaker – it's just pressed into a rubber ring – and trim the surplus plastic away with a sharp knife – being careful not to disturb the plastic around the display itself. This is essential to maintain slight compression on the metallic springs, which press onto the conductive tracks on the LCD glass.

Display wiring

The display is then wired to the pads on the PC board. I was tempted to lay the PC board out to permit the display to be directly mounted on it, but the current method offers a little more flexibility. However, it does require some delicate soldering of wire jumpers between the spring metal connections on the rear of the display and the PC board.

I kept everything in place with a few dabs of hot glue and the display assembly was mounted a few millimetres off the PC board with three further strategic dabs of hot glue. This

sounds crude – but it's unseen and the glue forms a very rigid arrangement, which can be easily adjusted with a little heat from a soldering iron.

The display is extremely light and the resulting mounting is very robust. There is also space beneath the LCD for the addition of backlighting if desired, perhaps using some diffused LEDs, although the current PC board layout does not allow for component wiring.

Don't be tempted to remove the white plastic material from the rear of the LCD. This improves display contrast and aids backlighting. I tried some green LEDs for backlighting and they worked very well, so I may add these to my transceiver project.

An extra pull-up resistor (10kΩ) can be seen in Fig.5 mounted next to the inter-PC board wiring on the top side of the keyboard/display PC board. This was caused by a minor change in pin connections when going from my stripboard and wirewrap prototype to the final PC board version. This resistor has now been added to the PC board layout shown in Figs.8 and 9.

Microprocessor board

Construction of the DDS/microprocessor PC board can start with the installation of the resistors and capacitors. Then proceed to add the jumpers and the various through-PC board connections if your board does not have plated-through holes.

Mount the microprocessor socket (I strongly recommend using a 'machine screw' IC socket for non-plated through PC boards), the LM393 comparator, crystal oscillator and crystal. The LM393 does not need a socket. Complete the board by soldering in the DDS chip and the ERA-4 MMIC.

The optical encoder should be added next. Although you can use a commercial model, I made my optical encoder from parts salvaged from an old PC mechanical-type mouse. It's not a difficult task – there are enough bits inside an old mouse for two such encoders.

It is possible to monitor the two output pins of the LM393 interface to confirm correct quadrature waveforms using an oscilloscope (see Fig.12) while rotating the encoder.

If you test without the microprocessor installed, which is best, you will need to add temporary pull-up resistors to each open-collector comparator

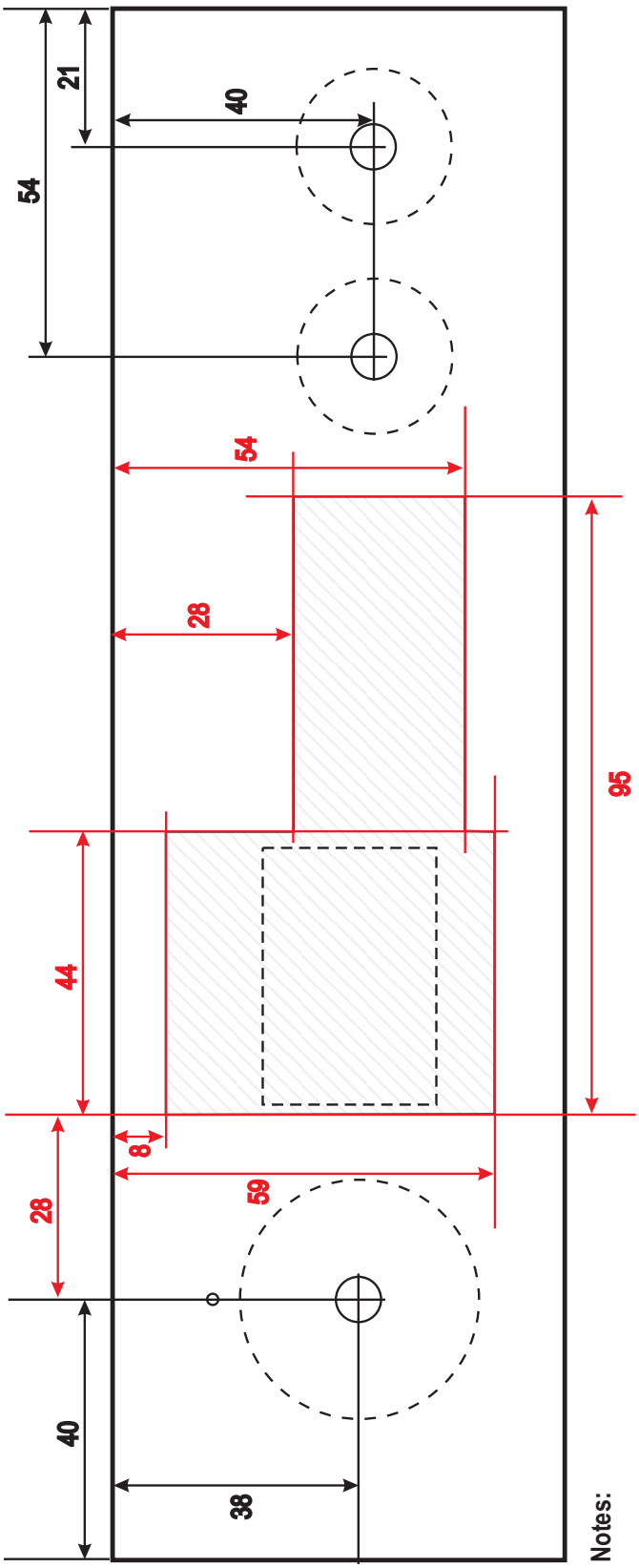


Fig.13: same-sized diagram of the front panel of the author's transceiver (Fig.1) showing where the VFO mounts.

VFO KEY FUNCTIONS	
Step	Selects VFO frequency increment (10Hz, 100Hz or 1kHz steps)
Band	Selects desired band (160m, 80m, 60m, 40m, 30m, 20m, 15m, 12m, 10m)
RIT	Changes dial to RIT (receiver incremental tuning) control, allowing the receiver frequency to be offset by ±5kHz in 10Hz steps
VFO A/B	Selects one of two independent VFO frequency banks
Lock	Locks the VFO frequency to the currently selected DDS output frequency
Tx	Removes the receiver IF and RIT offsets from the VFO output frequency

LINE	FUNCTION
1	Reserved for a 14-character string of text, including the user's callsign
2	Digital display of VFO frequency
3	Used by the VFO cursor which indicates the step size currently in use
4	Analogue dial display
5	RIT frequency (Only shown in RIT mode)
6	Status messages including VFO lock, VFO A/B selection, and Tx mode

Line 1 is the top-most LCD line. Lines in the software are actually numbered from 0 to 5 to match the LCD controller's addressing scheme.

output. Any value from 4.7kΩ to 100kΩ works fine for testing. Remove these once the encoder testing is complete. Fig.12 shows the ideal waveforms. Actual outputs have less perfect shapes, with variable width and timing, but still do the job.

The LCD module and pushbutton control switches are mounted on the solder side of the PC board. This allows the board to be mounted at the ideal distance from the front panel for display visibility and for the buttons to be depressed through a Lexan or similar flexible keypad/panel.

Making the front panel

Because my workshop facilities don't run to Lexan production, I made a workable flexible front panel from transparent plastic stick-on film from the local stationery shop and a laser-printed paper panel overlay.

The film is layered over the paper on both sides, and provides protection for the display while allowing the buttons to be easily pressed under the appropriate keypad label.

This panel will obviously wear out much faster than Lexan, but it's cheap and easy to make and replace.

There are two indicator LEDs on the PC board. The green LED shows when DC is applied to the board and can be used as a power indicator. The yellow LED was used during the software development to measure the time taken by the main software loop. It still does, changing state each time through the loop, flickering in varying degrees of brightness as buttons are pressed, the VFO is tuned and the LCD updated. I located this LED at top dead centre over the main tuning knob. Yes, I confess, it's only there for show, so just omit it if you don't like it.

References

1) The ZL2PD website can be found at www.geocities.com/zl2pd/ This contains all of the source code and assembled hex files.
2) Analog Devices (1999) *A Technical Tutorial on Digital Signal Synthesis* (see www.analog.com).
3) Two websites offering Nokia 3310 LCD displays at time of writing are: www.jelu.se and gsmserver.com, although I have no experience with either source.

The two PC boards are connected together using a total of 12 short wire links. There is a further short wire jumper which is run between the two boards for the +12V supply. This goes to the 120Ω resistor to power the MMIC (see Fig.8).

Operation

With an 80MHz DDS clock, the VFO will operate with minimal spurious outputs up to about 30MHz. In transmit mode, the DDS VFO outputs the frequency displayed on the LCD.

In receive mode, the receiver IF offset is added to the displayed output frequency until the actual DDS output frequency exceeds about 30MHz. At that point, the IF offset is subtracted from the nominal output frequency to keep spurious products to an acceptable minimum.

The VFO keys have the functions set out in the table at the top of the page.

As mentioned earlier, the LCD is addressed as a 6-line display, each eight pixels high and 84 pixels wide. This is determined by the LCD controller chip bonded inside the Nokia 3310 display, a Philips PCD8544 or equivalent.

The DDS VFO software therefore addresses the display using this line-based mode, as shown above.

Also mentioned earlier, the VFO has three tuning speeds, selected by the 'Step' key. Some consideration was given to adding variable-rate tuning to this VFO. This method is used on some commercial transceivers.

As the dial is rotated more quickly, for example, the tuning rate will initially directly match the increased rotation speed. Then, if the tuning rate is sustained, the VFO frequency increment will be automatically increased, resulting in accelerated tuning, with the frequency being incremented at a much faster rate. When the dial rotation is subsequently slowed, this is detected and the tuning rate switches to a slower rate.

Having used it in one of the commercial transceivers I own, I've not found it particularly pleasant to use. Call me old-fashioned, but I prefer the standard fast/slow tuning speed selection used in one of my older commercial transceivers.

I did try a variety of variable rate methods during the development of this design, but none really proved to offer any benefits over the scheme

finally adopted. So, variable-rate tuning is not a standard feature in this VFO.

Construction options

The split PC board layouts used in this design readily permit the use of other keypads and displays. In such cases, only the DDS/microprocessor board needs to be built. The relevant port lines are all available on the edge of this PC board.

With minor changes in software, standard 2-line × 16-character alphanumeric LCD modules may be used, as may many different keypad arrangements and keypads. In most such cases, the software will readily fit in the smaller AT89C2051 (2K Flash ROM) microprocessor, which is 100% pin-compatible with the DDS/microprocessor board layout shown here.

If there is sufficient interest, I will make schematics, connection details and software available on my website for this alternate version. ***EPE***

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PIC Probe *July '09*

Page 15, second column – first paragraph – should read: 'As you do this, also check the colours: red towards the probe, ***green*** in the middle and ***orange*** towards the switch.'

The LED order shown in Fig.2 is correct.

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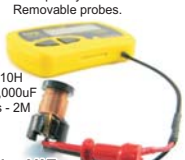

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By JIM ROWE

Emergency 12V Lighting Controller

This easy-to-build project automatically turns on the power for 12V emergency lights within a second or two of a mains power failure. Build it and you won't have to search for candles or your torch in the event of a blackout.

WHAT happens at your place if there's a sudden 'blackout' or mains power failure? It's a familiar story – if it's at night, you're left floundering in the darkness, searching for some candles or your torch. If you do find the torch, it's more than likely that the batteries have gone flat.

This 'emergency light' project means that you should never have to search around in the darkness during a blackout again. As soon as the mains power fails, it automatically turns on the power for some 12V emergency lights within a second or two. It then keeps them operating until either the mains power is restored or its internal 12V sealed lead-acid (SLA) battery is discharged to the safe minimum level.

Basically, the project is designed to be used in conjunction with a small 12V/1A automatic SLA battery charger, such as the Powertech MB-3526 unit sold by Jaycar. This unit normally keeps the internal SLA battery at full charge and we use this project to monitor the charging voltage so that it can determine when there is a mains failure.

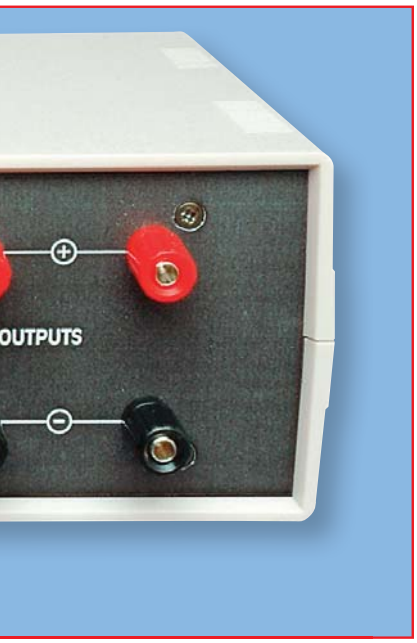
That's how it knows when to switch on your 12V emergency lights.

Running time

The 12V SLA battery specified has a rated capacity of 7.2Ah (ampere-hours), which should be enough to power typical domestic 12V emergency lights for the duration of all but the most prolonged mains failures. For example, it will power a couple of 12V/16W (twin 8W tubes) fluorescent fittings for around two hours, or for a little over one hour if you hook up a 12V/11W single fluoro as well.

How can you work out the time it will run a certain combination of 12V emergency lights? As a rough guide, you need to work out how much current each light fitting draws, then add up the total current. Then if you divide the battery capacity by this total current, the answer will be the approximate running time in hours.

The reason why this gives only a rough guide to running time is that the nominal capacity of a battery is



based on it being discharged over a 20-hour period – ie, at a discharge current rate of C/20, where 'C' is the battery's nominal capacity (in this case 7.2Ah, so C/20 = 360mA).

When you discharge the battery at a higher rate than this, its effective capacity drops somewhat. For example, if you reduce the discharge time to 10 hours, its effective capacity drops to 6.7Ah. If you want to discharge it in five hours, the effective capacity drops to 5.95Ah. And if you want to discharge it in just one hour, its effective capacity drops to 4.0Ah.

So, if you want to run three of the ST-3016 12V/16W fluoro fittings, which each draw around 1.35A, this will result in a total current of 3 x 1.35A = 4.05A. The battery will be able to run these for 4.0/4.05, or just a whisker under one hour.

Similarly, you could run four 12V/11W fluoro fittings, which each draw about 0.9A (giving a total current of 4 x 0.9 = 3.6A) for a little over an hour (4.0/3.6 = 1.11).

In either case, if you just run one lamp, it will probably run for a few hours.

A manual override switch is included, so that you can turn off the 12V lights manually if they're not needed – for example, if there's a blackout during the day.

How it works

Refer to Fig.1 for the circuit details. As you can see, there's not a lot to it. At its heart is the 12V/7.2Ah SLA battery, which is maintained at full charge by the external automatic charger when mains power is present.

The charging current flows through D1 and directly into the battery. Note that D1 is a 1N5822 Schottky diode, which has a low forward voltage drop (typically 390mV for a charging current of 1A), so it doesn't significantly effect the charger's operation.

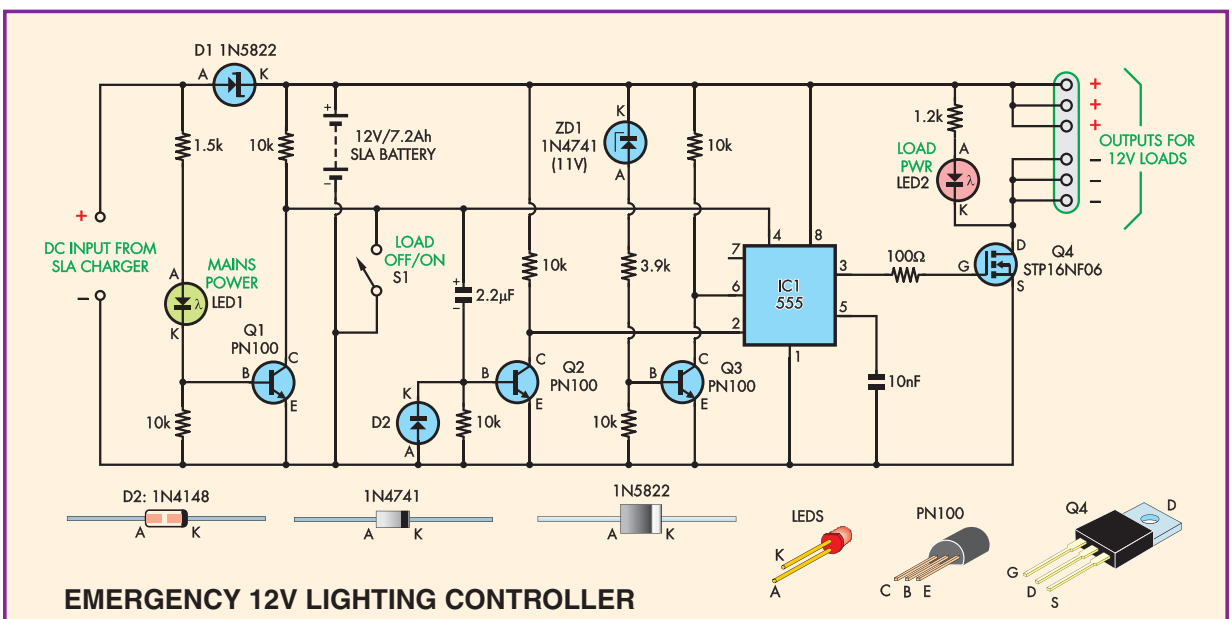
The DC input voltage from the charger is also applied to LED1 via a series 1.5kΩ resistor, with the LED current also flowing through the base-emitter junction of transistor Q1. As a result LED1 turns on whenever mains power is present and Q1 is forward biased as well. This causes Q1 to turn on and pull its collector voltage down to a low level (around 400mV).

The collector of Q1 is connected to the reset input (pin 4) of IC1, a 555 timer IC used here as a dual comparator and flip-flop. So, whenever mains power is present and Q1 is on, IC1 is held in its reset state with its pin 3 output switched low. As a result, the gate (G) of Q4, an *N*-channel power MOSET, is also held low and so Q4 remains off.

Basically, Q4 functions as the switch for the 12V emergency lights. When Q4 is off, the lights are off as well.

Power failure

Now consider what happens when the mains power fails. When this happens, there is no charging voltage from the SLA charger and so diode D1 becomes reverse biased. As a result,



EMERGENCY 12V LIGHTING CONTROLLER

Fig.1: the circuit uses transistors Q1 and Q2 and 555 timer IC1 to detect when the mains fails. When it does, pin 3 of IC1 switches high and Q4 turns on and connects an SLA battery to the emergency lights. Zener diode ZD1 and transistor Q3 trigger IC1 and turn the lights off again to prevent over-discharge if the battery voltage drops below 11.6V.

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The Powertech 12V 1A SLA battery charger (Jaycar MB-3526) is ideal for use with the Lighting Controller.

LED1 turns off and there is no longer any base current for Q1, which turns off as well.

Transistor Q1's collector is now pulled high (ie, to the battery voltage) via a 10kΩ resistor, thus removing the reset signal from IC1 (pin 4). At the same time, the 2.2µF capacitor on the reset line pulls the base of transistor Q2 high. Q2 thus turns on and pulls pin 3 (the 'lower threshold' comparator input) of IC1 low.

The 2.2µF capacitor now charges via a 10kΩ resistor, and as it does so, its charging current (and hence Q2's base current) reduces exponentially. After a very short time, the transistor comes out of saturation and its collector voltage begins to rise.

As soon as this voltage reaches the lower threshold level of IC1 (around 4V), the internal flip-flop is triggered 'on'. This switches IC1's pin 3 output high (ie, to nearly +12V), in turn switching on MOSFET Q4 and turning on the emergency lights and LED2. A 1.2kΩ resistor limits the current through LED2.

In summary then, when the mains power fails, IC1 quickly switches its pin 3 output high and Q4 and the emergency lights turn on.

If necessary, the lights can be turned off manually or prevented from turning on automatically at all, using override switch S1. When this is closed, IC1's pin 4 reset input is pulled low permanently, regardless as to whether or not transistor Q1 is conducting. As a result, IC1 is kept in the reset state and so Q4 and the emergency lights remain off.

Preventing over-discharge

Zener diode ZD1 and transistor Q3 form a simple protection circuit, which prevents the SLA battery from being over-discharged during a prolonged blackout. SLA batteries are not designed for really deep discharging and if that did occur, the battery could suffer permanent damage.

The way this circuit works is very simple. Whenever the battery voltage remains above about 11.6V, Zener diode ZD1 conducts, and so current flows through its 3.9kΩ series resistor and the base-emitter junction of transistor Q3. As a result, Q3 turns on and pulls pin 6 (the upper threshold input of IC1) to less than 0.5V. This input is therefore kept inactive.

However, if the SLA battery voltage drops just below 11.6V, there is no longer sufficient current through ZD1 to keep Q3 turned on. As a result, Q3 turns off and its collector voltage rises to the battery voltage, taking pin 6 of IC1 with it.

As soon pin 6 reaches its upper threshold level of about 8V (12V × 2/3), IC1's internal flip-flop resets and pin 3 switches low. This turns off Q4 and the emergency lights to prevent any further discharging of the battery.

IC1 is now kept in the reset state until the battery voltage rises above 11.6V again, which will normally only happen when the mains power is restored. Of course, once this occurs, Q1 will turn on again and hold IC1 in the reset state, thereby preventing Q4 and the lights from turning on until the mains fails on another occasion.

Construction

Apart from the SLA battery, all of the parts for the Emergency 12V Lighting Controller are installed on a single PC board, coded 733, and measuring 204 × 64mm. This PC board is available from the *EPE PCB Service*.

The board has been designed to mount vertically behind the front panel of a vented plastic instrument case measuring 260 × 190 × 80mm. The case size was chosen so that the SLA battery could also be fitted inside, to protect it from damage. As shown in the photos, the battery is fitted on its side at the rear of the case and is held down by a clamp bracket made from sheet aluminium.

The output cable from the external SLA charger is brought into the case at rear left, via a cable gland. The individual leads then connect to the rear of the PC

Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	6	10kΩ	brown black orange brown	brown black black red brown
❑	1	3.9kΩ	orange white red brown	orange white black brown brown
❑	1	1.5kΩ	brown green red brown	brown green black brown brown
❑	1	1.2kΩ	brown red red brown	brown red black brown brown
❑	1	100Ω	brown black brown brown	brown black black black brown

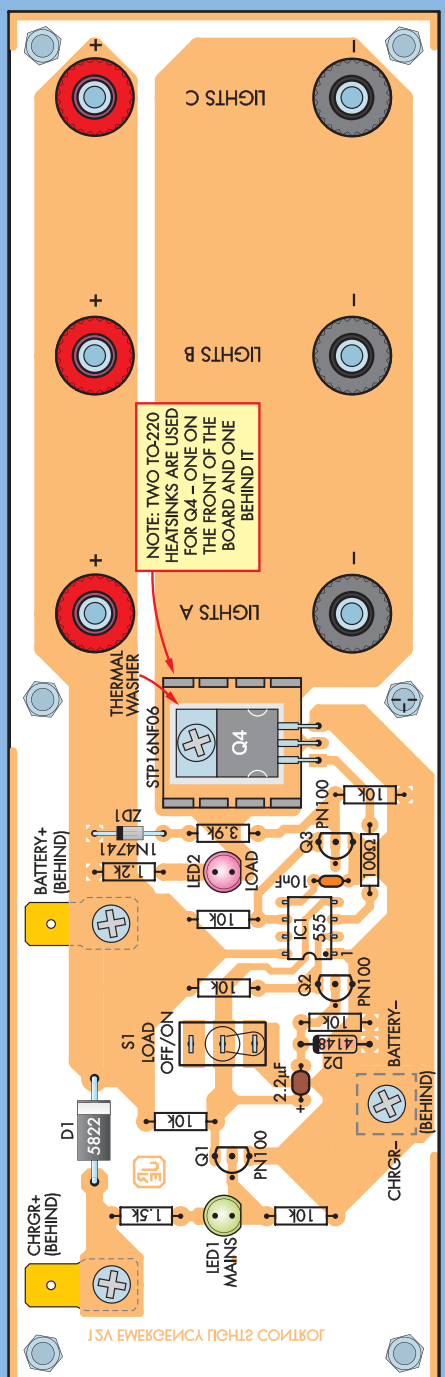
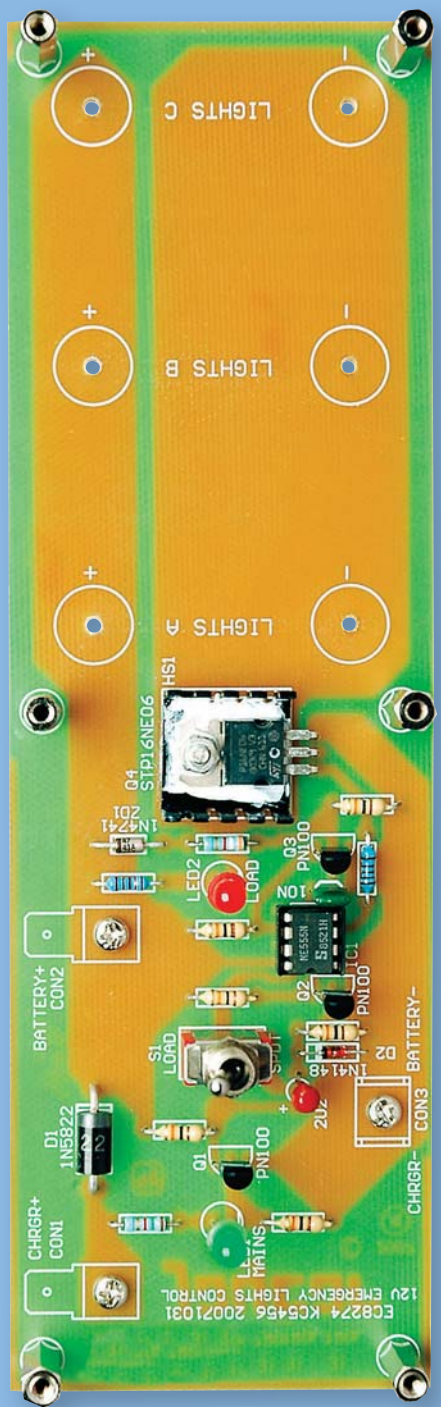


Fig.2: install the parts on the PC board as shown here, but do not initially install the six binding post terminals. The latter are mounted on the front panel first and are only soldered to the PC board after testing is complete – see text. Note that MOSFET Q4 has two heatsinks – one under its tab on the top of the board and one directly behind it on the copper side of the board.



Take care to ensure that all polarised parts (IC, transistors, diodes, LEDs and the tantalum capacitor) are correctly orientated when building the board. The three spade quick-connect terminal lugs (two single-ended, one double-ended) are bolted to the back of the board using M3 × 6mm machine screws, lockwashers and nuts. Note that we used thermal grease to aid heat transfer between Q4's tab and its heatsink, but kits will be supplied with a thermal washer instead.

board via quick-connect spade connectors. Similarly, the connections between the SLA battery and the PC board are made via short lengths of heavy-duty cable, fitted with female quick-connect spade connectors at each end.

The six 12V output terminals (binding posts) for the emergency lights (or some other load) are actually initially mounted on the front panel of the case rather than the PC board. Their terminals are then later soldered directly to the PC board copper when the otherwise completed PC board assembly is attached to the panel via six M3 × 15mm tapped spacers.

Fig.2 shows the parts layout on the PC board. The first step in the assembly

Parts List – Emergency 12V Lighting Controller

1 vented instrument case, size 260 × 190 × 80mm
1 PC board, 733, available from the *EPE PCB Service*, size 204 × 64mm
2 19 × 19mm U-shaped TO-220 heatsinks
1 TO-220 thermal washer, or insulation kit
1 SPDT mini toggle switch (S1)
1 8-pin IC socket
2 single-ended quick-connect spade lugs
1 double-ended quick-connect spade lug
6 female quick-connect spade connectors
6 M3 × 15mm tapped spacers
6 M3 × 6mm countersink head machine screws
10 M3 × 6mm pan-head machine screws
4 M3 nuts and star lockwashers
3 binding posts/banana jack terminals, red
3 binding posts/banana jack terminals, black
1 12V 7.2Ah SLA battery (Jaycar SB-2486)
1 295 × 75mm piece of 18g (1.3mm) aluminium sheet
3 10mm-long self-tapping screws, 4g or 5g
1 cable gland, 3-6.5mm cable size

Semiconductors
1 555 timer IC (IC1)
3 PN100 *NPN* transistors (Q1 to Q3)
1 STP16NF06 *N*-channel 60V/16A MOSFET (Q4)
1 1N4741A 11V 1W Zener diode (ZD1)
1 5mm green LED (LED1)
1 5mm red LED (LED2)
1 1N5822 40V/3A Schottky diode (D1)
1 1N4148 diode (D2)

Capacitors
1 2.2µF tantalum
1 10nF metallised polyester

Resistors (All 0.25W, 1% metal film)
6 10kΩ
1 3.9kΩ
1 1.5kΩ
1 1.2kΩ
1 100Ω

Where To Buy Kits

This project was developed by Jaycar Electronics and they hold the copyright on the design and on the PC board. Complete kits are available from Jaycar Electronics (Cat. KC-5456).

In addition, Jaycar can supply the Powertech MB-3526 automatic SLA charger, along with whatever 12V lighting fixtures you need; eg, the ST-3016 and ST-3006 fluorescent lamps (both rated at 16W).

is to fit the three male spade lug connectors for the charger and battery connections. These all fit on the rear (copper) side of the board and are fastened in place using M3 × 6mm machine screws, star lockwashers and nuts. These must be tightened quite firmly to ensure a reliable connection (you will need a Posidrive screwdriver and a small shifting spanner to hold the nut).

Note that the two single spade lugs are fitted in the upper positions (Charger+ and Battery+), while the double spade lug is fitted in the lower (Charger–/Battery–) position.

Once all three spade lugs have been fitted, you can fit the socket for IC1 (with its notch end towards the left), followed by mini toggle switch S1. The switch mounts vertically, with its connection lugs passing down through matching holes in the board and soldered to the pads underneath.

The resistors can go in next, followed by the capacitors, diodes D1 to D3 and transistors Q1 to Q3. Take care to fit the diodes, transistors and 2.2µF tantalum capacitor with the correct orientation.

Mounting the MOSFET

MOSFET Q4 is next on the list, but first its leads must be bent down through 90° at a point 7mm from its body. That done, it can be fastened to the PC board, along with its thermal washer and two heatsinks. Secure it using an M3 x 6mm machine screw, flat washer and nut.

As shown in Fig.2, the thermal washer goes between Q4's tab and the heatsink on the top of the board. The second heatsink mounts on the back of the PC board (see photo). Make sure that the latter does not short against any of Q4's pads when the assembly is tightened down.

Now complete the board assembly by installing the two 5mm LEDs. These mount vertically, with their longer anode leads towards the top of the board. They should both be fitted with 12mm lead lengths, so that they will later just protrude through matching holes in the front panel when the board is mounted in the case.

A 12mm wide cardboard strip can be used as a spacer when it comes to mounting each LED. Just position it with its bottom edge against the board and push the LED down onto the top edge, with the leads straddling either side of the cardboard spacer.

Once the LEDs are in place, fit the six M3 tapped spacers to the front of the board and secure them using six M3 × 6mm pan head machine screws.

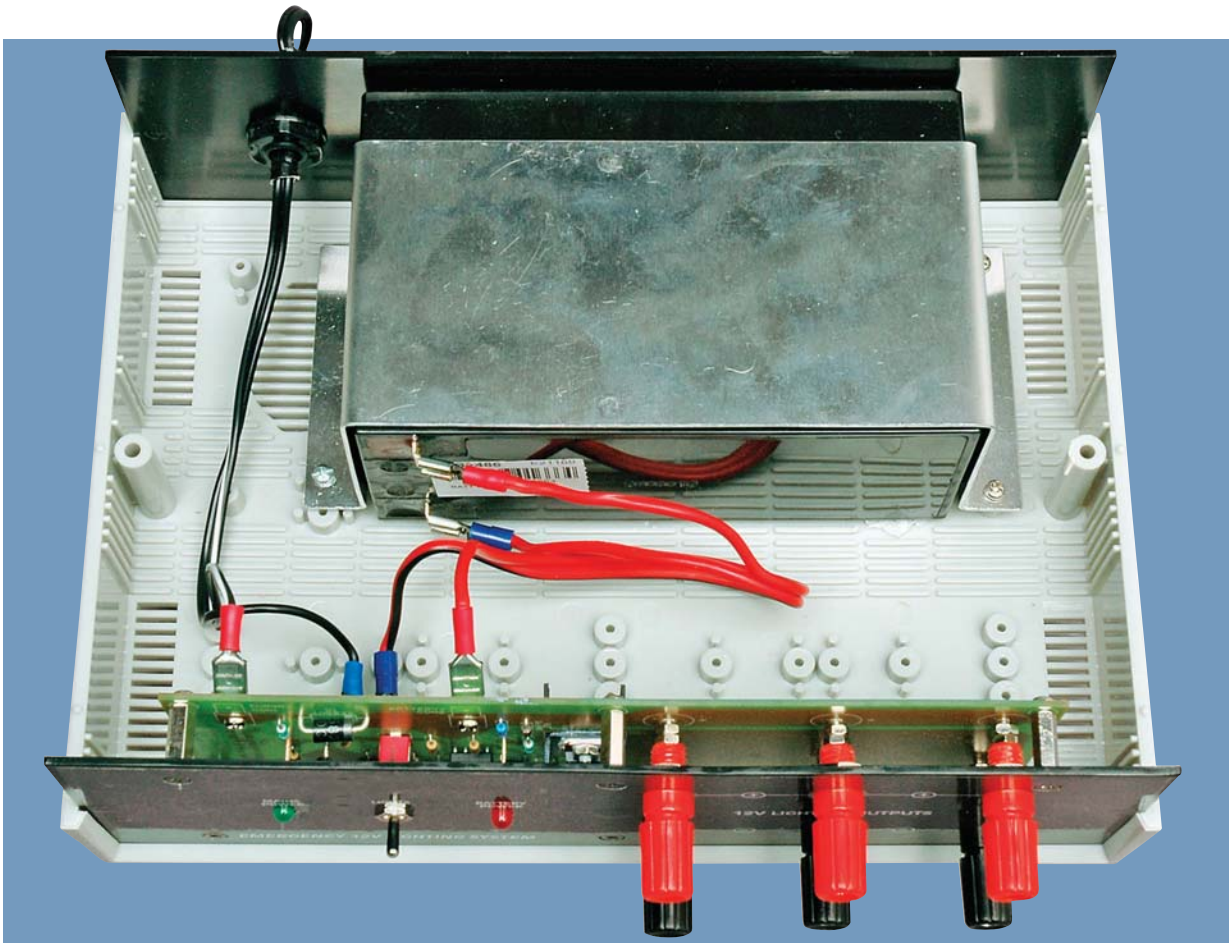
Final assembly

The board assembly is now complete, so the next step is to fit the six binding post terminals into their matching holes in the front panel. The three red positive terminals mount in the upper holes, while the black negative terminals mount in the lower holes. Be sure to tighten up their mounting nuts firmly, so that they don't work loose later.

That done, remove the upper mounting nut from mini toggle switch S1, then offer up the PC board assembly behind the front panel, with the threaded ferrule of S1 and the two LEDs passing through their corresponding holes. At the same time, the solder terminals on the binding post sockets should pass through their corresponding holes in the PC board.

Once everything is correct, fasten the assembly together using six M3 × 6mm countersink-head screws. Tighten these screws down firmly, then refit the outer mounting nut to the front of S1, screwing it down just firmly enough to prevent it from coming loose. A small spanner should then be used to wind the rear nut (and washers) up the ferrule to the rear of the panel, to prevent the panel from bowing down when the front nut is tightened.

Do not solder the terminals of the binding posts yet. That step comes



This is the view inside the completed Emergency 12V Lighting Controller. The battery in the prototype was secured using an aluminium clamp.

later, after the unit has been tested. If you do solder these terminals, you will not be able to access any of the on-board components if something is wrong.

The board/panel assembly can be slipped into the lower half of the case – see photo. That done, you can then turn your attention to making up the mounting clamp bracket for the SLA battery. This is fashioned from a piece of sheet aluminium – see Fig.4.

Note that three 4mm diameter holes need to be drilled in the bracket for the mounting screws; it's easier to drill these holes before you bend it into shape.

Fitting the battery

Before fitting the battery into the case, you'll need to cut away some of the short spacing pillars moulded into the base, so the battery will rest on the bottom (this is necessary in order to provide clearance for the case top). The pillars to be cut away are those in the centre, directly below where the battery sits. **Make sure you don't cut away those at either end, which are used to screw down the battery clamp bracket – see photos.**

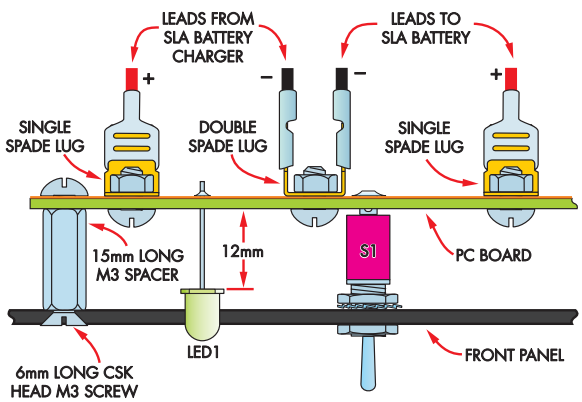
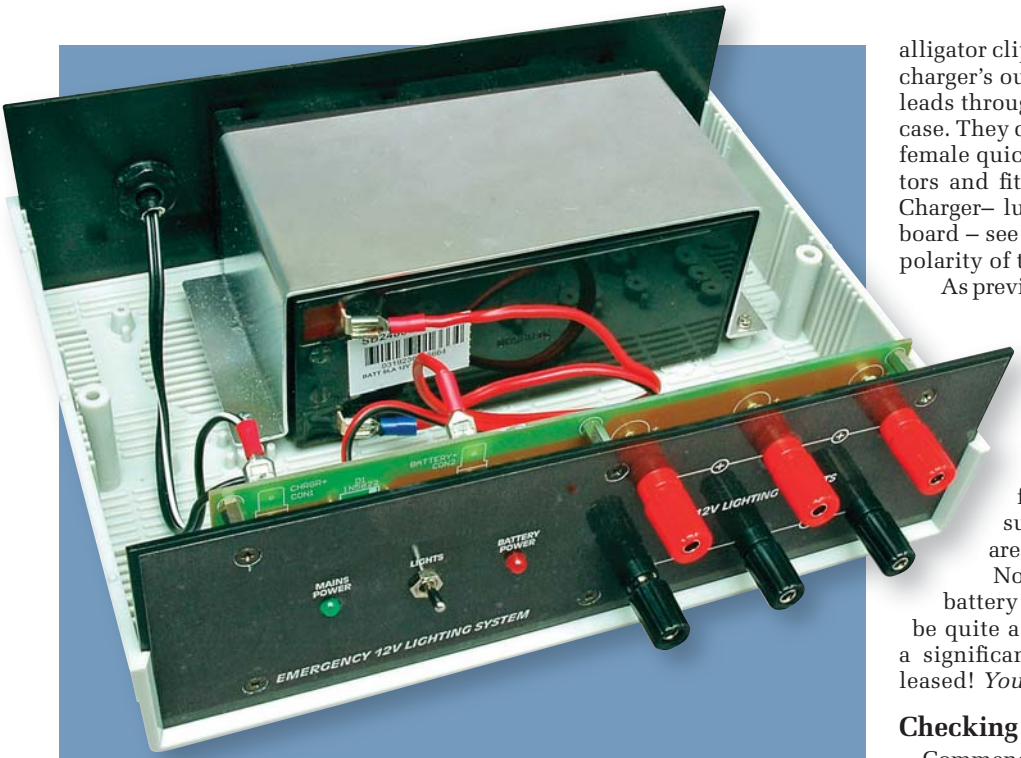
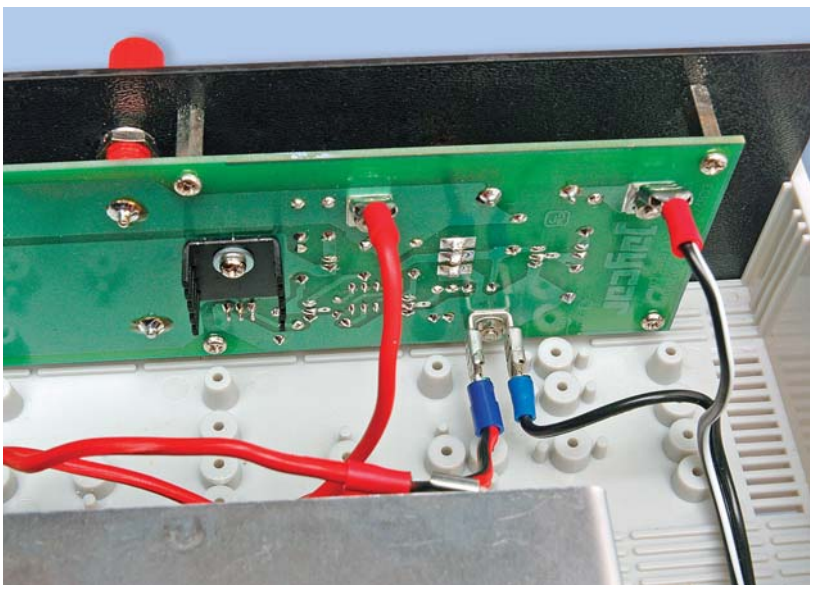


Fig.3: the leads from the battery and the charger are connected to the spade lugs on the back of the PC board using female quick-connect terminals. Note also how switch S1 is secured.



The PC board mounts behind the front panel on six M3 × 15mm tapped spacers, secured at the front using countersink head M3 screws. Note how the charger's leads are secured to the rear panel using a cable gland.



This close-up view shows how the connections from the charger and the SLA battery are run to the PC board, via the quick-connect terminals. Note also the second U-shaped heatsink for Q4 on the back of the board.

You should now be able to place the battery on its side in the case and slide the clamp bracket down over it. Complete the job by fastening the clamp bracket to the bottom of the case bottom using three 10mm-long self-tapping screws.

The next step is to fit the cable gland into the 12.5mm round hole in the rear panel. That done, cut the alligator clips off the ends of the SLA charger's output leads, then pass the leads through the gland and into the case. They can then be fitted with the female quick-connect spade connectors and fitted to the Charger+ and Charger– lugs on the rear of the PC board – see Fig.3. Take care with the polarity of the leads here.

As previously mentioned, the SLA battery is connected to the PC board via short lengths of heavy-duty cable, fitted with female quick-connect spade connectors at each end. Complete the wiring by fitting these, again making sure that the connections are correct.

Note that if you reverse the battery connections, there may be quite a lot of damage done and a significant amount of smoke released! *You have been warned.*

Checking it out

Commence testing by, lightly tack soldering a couple of temporary leads to one pair of output pads on the back of the board (ie, one to a positive output terminal and the other to a negative output terminal). Connect the other ends of these leads to your multimeter and set the meter to the 20V range.

Now plug the SLA charger's mains lead into a power outlet and switch on. This should cause the Lighting Controller's green 'Power' LED (LED1) to light, indicating that the charger is supplying power to the circuit and to the SLA battery.

If the SLA battery has very little charge in it at this stage, this will be indicated by the charger's red LED glowing. In that case, leave things for a while until the battery charges, with its terminal voltage up to at least 12.5V. This will be indicated by the red LED on the charger going out and the green 'trickle' LED turning on instead.

Now make sure that switch S1 is in the 'Lights On' (down) position, then switch the charger off at the mains outlet. Within no more than a second or two, LED1 on the Lighting Controller should go out and LED2 should light instead. This indicates that MOSFET Q4 has turned on and that 12V power from the battery is now available via the output

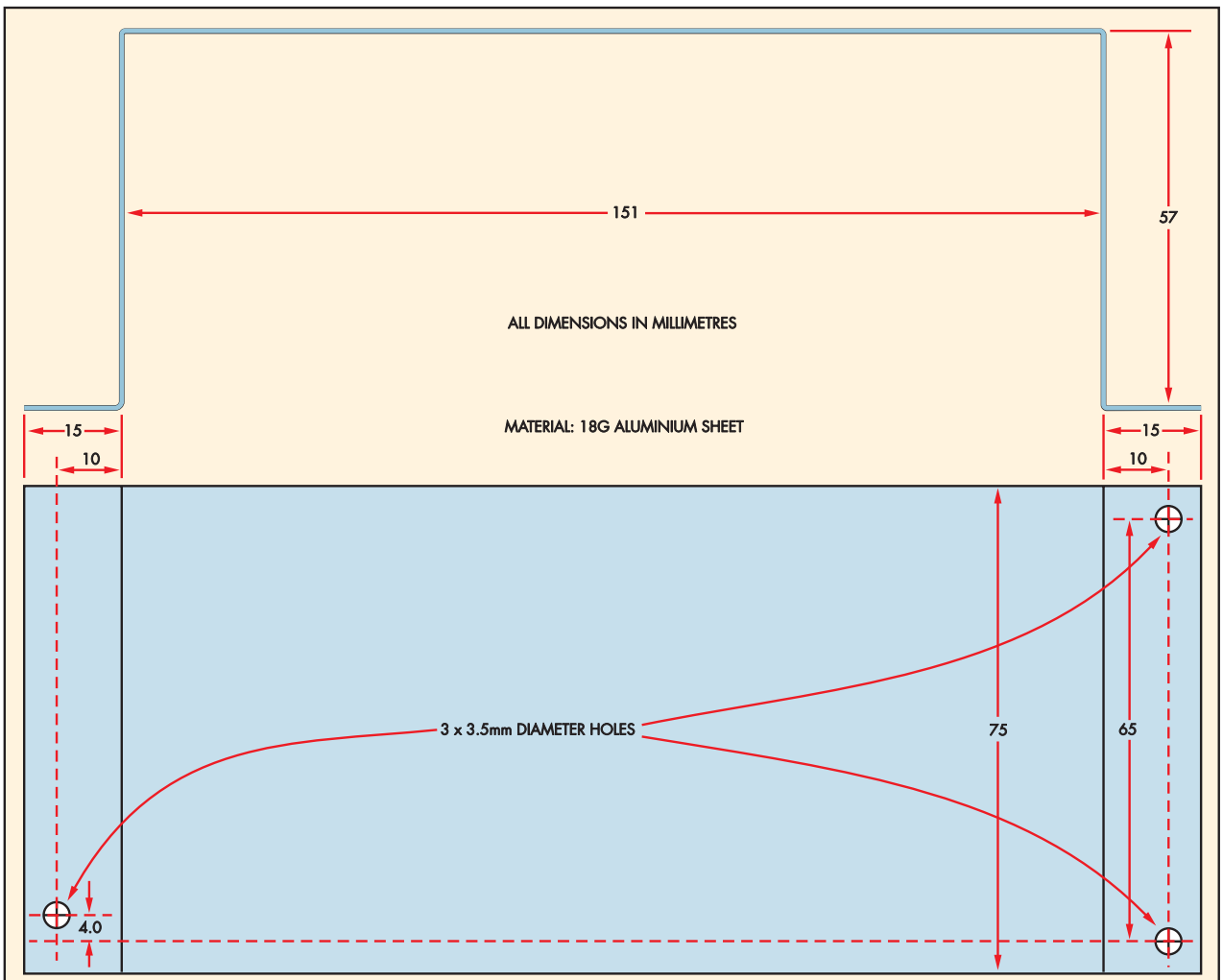


Fig.4: here's how to make up the metal clamp that's used to secure the SLA battery in the case. It's made from 18-gauge aluminium sheet and can be bent up in a vice.

terminals (this should be indicated on your multimeter).

In fact, if you connect a 12V emergency light in place of the meter, it should immediately light.

Assuming it all works, switch off, remove the temporary leads and solder all six binding post terminals. Your Emergency 12V Lighting Controller is now ready for use, so refit the top of the case. **Once that's done, switch the charger back on so that it can complete the job of topping up the battery's charge.**

While it's doing that, you can now start mounting your 12V emergency lights and running the cabling to them. Be sure to mount the lights in locations where they will be useful when the next blackout occurs. ***EPE***

The Emergency Lighting Controller is ideal for use with 12V fluorescent lamp fittings of the type shown here. Both these units are available from Jaycar Electronics (ST-3006 top, ST-3016 bottom), feature twin fluorescent tubes and are rated at 16W.

TEACH-IN 2010

LADDER LOGIC PROGRAMMING FOR THE PIC MICRO

Part 1: Getting Started – Working with Inputs and Outputs

By Walter Ditch

THIS is the first of a series of six articles, which will show you how to program a variety of PIC microcontrollers using an approach known as ladder logic.

Why ladder logic? Well, this is the preferred software development method for a type of computer known as a PLC, or Programmable Logic Controller. PLCs are rugged computers, which are commonly used in industry to control production line operations and processes. They are designed to be easily configured and used by engineers, typically to perform simple logical tasks and sequences.

Ladder logic has historically proved very popular with electrical engineers, since it allows control-oriented software to be created by linking together 'electrical' elements such as inputs, outputs, latches, counters, timers, shift registers and sequencers. As we'll see in this series, the approach is quite intuitive for those from an electrical or electronic background, since the individual programming elements are already well understood. The resulting source code programs also tend to be quite short and easy to interpret.

This first installment of the series concentrates on developing simple PLC-style programs to read inputs and to control outputs. We'll look at the graphical representation of a control-oriented system using a ladder diagram, and its conversion to a source code file.

We'll then work through the detailed steps involved in creating and testing PLC-style applications, using a variety of widely available PIC-based hardware and software. The internal method of operation of the supplied software will also be discussed, enabling you to decide for yourself when and where this approach might be applicable.

Subsequent parts of the series will introduce further software features and applications, including:

- Simple combinational and sequential logic (logic gates and latches)
- Timers and shift registers
- Counters and pulse-width modulated (PWM) outputs
- Sequencers and byte-oriented instructions

A variety of microcontroller-based applications of ladder logic will also be developed, including alarms, motor controllers, robotics, and sequence-based systems.

The software supplied with the series has been placed into the public domain by the author, and so is free for you to use. It currently works with five different PIC micros (16F627/627A, 16F628/628A, 16F648, 16F88 and 16F887), plus the following commonly available hardware/software platforms:

1. Velleman K8048 Programming and Experimentation Board, available from a number of mail order suppliers.
2. PICkitTM 2 Debug Express Board, supplied by Microchipdirect (**www.microchipdirect.com**)
3. Matrix Multimedia Version 3 PICmicro MCU Development Board, available from the *Everyday Practical Electronics* (*EPE*) Readers Services.
4. Proteus VSM electronic circuit simulation software from Labcenter Electronics (**www.labcenter.co.uk**).

Hopefully, you will have access to one of the above and will be able to work along with the series. Seeing really is believing, and the best way to learn is to try the concepts out for yourself. If you do, I guarantee you'll be surprised by the power and simplicity of ladder logic!

Comparing PLCs and microcontrollers

The main differences between a PLC and a microcontroller relate to

size, complexity and, of course, cost. The inputs and outputs circuits of a PLC, for example, are extremely rugged, with digital inputs often being connected via opto-isolators, and digital output types including transistor, thyristor, triac and relay. This allows the PLC to directly control high power devices, such as motors, pneumatic actuators and the like. A typical commercially available PLC is shown in Fig.1.1, with input connections shown at the top and outputs at the bottom.

Fig.1.1. A typical industrial PLC

While the I/O connections of a microcontroller operate at much lower voltage and current than those of a PLC, they are essentially the same from a software point of view. The internal structure of a microcontroller also contains many similar elements to those found inside a PLC, including a central processing unit, program memory (ROM), together with a variety of volatile and non-volatile data memory types. (The content of volatile memory types, such as static RAM, is lost when power is removed, while non-volatile memory, such as EEPROM, is retained.)

The allocation of connections as inputs or outputs is, of course, pre-determined by the PLC manufacturer, since this is a pre-requisite for the connection of specialised interface circuitry. Not so in the microcontroller world, where the assembly language programmer normally has to decide on port directions, plus a variety of other configuration settings, prior to actually getting the microcontroller to do something useful.

This added complexity is avoided here by the pre-configuration of default settings, such as port directions, in the supplied PLC header files. (For example, in the PIC16F627 version, Port A is configured to be an input, while Port B is an output.) You can, of course, change these settings, simply by editing the relevant section of the header file, but the software is designed to work straight out of the box, without any need for configuration – just like a real PLC.

So, having established that PLCs and microcontrollers have a lot in common, let's turn our attention to ladder logic, and find out what it has to offer in terms of software development.

Ladder diagrams and ladder logic

Ladder logic owes its origin to the use of switches and relays to implement combinational and sequential logic functions in electrical control circuits, and it is in part this electrical basis which makes it easy for electrical engineers to understand – even those without a computing background. Consider, for example, a simple electrical circuit consisting of a switch and a lamp, and also its representation using a ladder diagram, as shown in Fig.1.2.

Considering the circuit on the left, closing the switch will clearly cause the lamp to light. The ladder diagram on the right is equivalent, consisting of a pair of vertical power rails, with one or more horizontal 'rungs'. (The ladder-like appearance gives this type of diagram its name.) Closing the normally open switch contacts on the left of the ladder diagram will connect power through the horizontal rung, hence lighting the lamp.

Historically, the output would typically have been a relay coil, thus allowing a relatively low voltage control circuit to switch mains operated power devices. For this reason, PLC inputs are often referred to as contacts, while outputs are called coils. It can be seen from the ladder diagram that an output coil is represented graphically using a pair of curved braces (although a circular output symbol is sometimes seen).

This extremely simple concept is the basis of PLC operation, and in part explains why electrical engineers are so comfortable writing PLC programs.

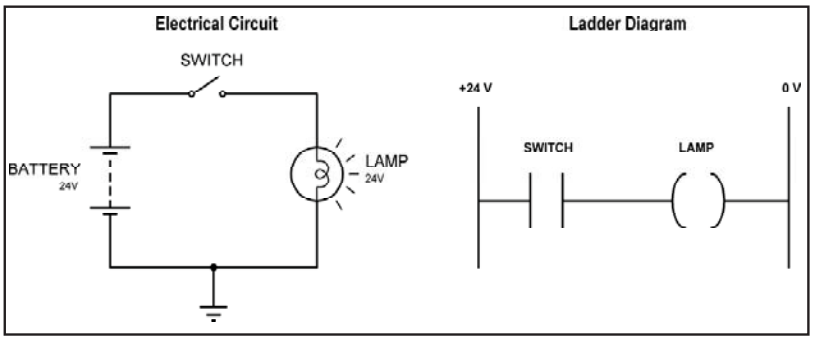


Fig.1.2. A simple switch and lamp circuit (left) and its equivalent ladder diagram (right)

Ladder logic programs are also very concise, with a section of code to (1) read an input and then (2) control a linked output requiring as little as two lines of code. Listing 1.1 shows a possible implementation.

In general, a PLC program is created by converting each input contact

```
    ld      SWITCH          ; Read state of Switch
    out     LAMP            ; Output to Lamp
```

Listing 1.1. A notional section of a PLC program based on the circuit and ladder diagram of Fig.1.2

and output coil of the system's ladder diagram into a series of equivalent program statements. Execution of the program is then a continuously operating sequence of:

- Reading inputs
- Performing logic-based calculations
- Controlling outputs

This repeating process is known as the scan cycle, and is shown graphically for a slightly more complex example in Fig.1.3.

It can be seen that each rung of the ladder diagram is evaluated from left to right, starting at the top rung and working progressively down (Steps 1 and 2 of Fig.1.3). The End of Program statement forces program execution to resume from the beginning of the first rung (Step 3), causing the program to run continuously. This program might be coded using statements such as those given in Listing 1.2.

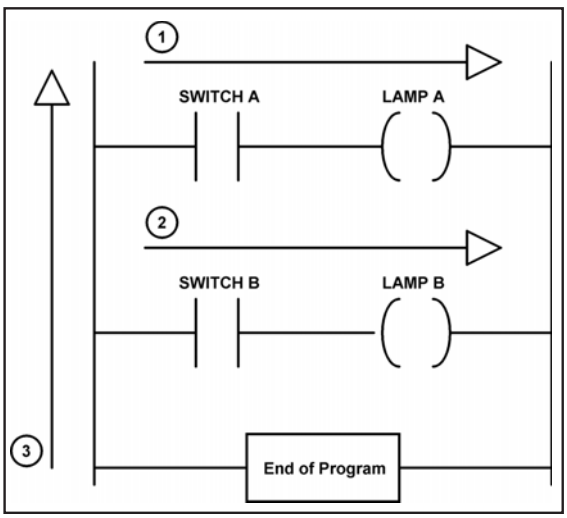


Fig.1.3. The repeating scan cycle of a PLC executing a ladder logic program

A number of conclusions may be immediately drawn from this method of operation:

1. Execution of a PLC program consists of a continuously operating program loop (a repeating scan cycle), even though this is not explicitly shown in the program listing or ladder diagram.

2. The time taken for a single scan cycle will increase in line with the complexity of the program, since the execution time for a single instruction is fixed by the microprocessor clock frequency.

Slightly less obviously:

3. An externally applied input signal will need to be present for a sufficient time to guarantee it being 'seen' by the input phase of the scanning loop.

4. The average time taken to react to a changing input is related to the scanning loop duration.

5. It may take more than one scanning loop for the results of complex calculations to fully propagate through the system. This may lead to the possibility of transient glitches as calculations 'ripple-though'.

In practice, you should find that ladder logic solutions are suitable in the majority of logic-based control scenarios, since the computer is typically operating at much higher speed than the system being controlled.

Now that the basic principles of ladder logic programming have been covered, the next step is to obtain the required software, which will then enable us to create and test an executable program.

```
    ld      SWITCH_A        ; Read state of Switch A
    out     LAMP_A          ; Output to Lamp A

    ld      SWITCH_B        ; Read state of Switch B
    out     LAMP_B          ; Output to Lamp B

    endp                    ; End of PLC program
```

Listing 1.2. A PLC program based on the ladder diagram of Fig.1.3

Obtaining the software

The ladder logic software is designed to work with the MPLAB Integrated Development Environment (IDE), which is freely available for download from the Microchip website (**www.microchip.com**), or on CD-Rom . All that is required is to include a link to the appropriate header file from within the assembly language source file, at which point a variety of PLC-style commands become available for use in your programs.

As mentioned earlier, versions of the software are available for the following commonly used PIC microcontrollers:

- PIC16F627/PIC16F627A (header file '16F627.PLC')
- PIC16F628/PIC16F628A (header file '16F628.PLC')
- PIC16F648 (header file '16F648.PLC')
- PIC16F88 (header files '16F88_L.PLC' and '16F88_H.PLC' offer low voltage and high voltage program versions respectively)
- PIC16F887 (header file '16F887.PLC')

In practice, the first four of these are all 18-pin ICs, differing mainly in the quantity of flash-based program memory, static RAM, or EEPROM-based non-volatile data memory. The PIC16F887 is a 44-pin IC, having enhanced input/output capabilities. These features are summarised in Table 1.1.

Inclusion of the appropriate header file will cause a number of default settings to be chosen, such as port directions, oscillator type and so on. These settings have been tested with a number of hardware configurations, and are intended to simplify the configuration process as far as possible. (You should of course review these settings to ensure compatibility with your own requirements.) Default options are summarised in Table 1.2.

A number of required files are available in a compressed ZIP file, which may be obtained from the the Library > Project Code section of the *Everyday Practical Electronics* website (**www.epemag.com**). The contents of the ZIP file are given in Table 1.3.

Device	Program (kWords)	RAM (bytes)	EEPROM (bytes)	Max I/O (bits)	Other Features
PIC16F627	1	224	128	16	2 comparators
PIC16F628	2	224	128	16	2 comparators
PIC16F648	4	256	256	16	2 comparators
PIC16F88	4	368	256	16	2 comparators 7-channel ADC
PIC16F887	8	368	256	35	2 comparators 14-channel ADC

Table 1.1. Major features of supported PIC microcontrollers

Device	Inputs	Outputs	Other Features
PIC16F627 / 628 / 648	Port A (5 bits)	Port B (8 bits)	Comparators disabled, pull-ups disabled 4MHz external crystal oscillator selected Timer 0 configured for use by PLC software MCLR enabled, Watchdog timer enabled
PIC16F88	Port A (5 bits)	Port B (8 bits)	Comparators disabled, pull-ups disabled 4MHz external crystal oscillator selected Timer 0 configured for use by PLC software MCLR enabled, Watchdog timer enabled ADC disabled
PIC16F887	Port A (8 bits) Port B (8 bits) Port E (4 bits)	Port C (8 bits) Port D (8 bits)	Comparators disabled, pull-ups disabled 4MHz internal oscillator selected Timer 0 configured for use by PLC software MCLR disabled, Watchdog timer enabled ADC disabled

Table 1.2. Default PIC software configuration options

Filename	Description
16F627.PLC	PLC header file for the PIC16F627/627A microcontroller
16F628.PLC	PLC header file for the PIC16F628/628A microcontroller
16F648.PLC	PLC header file for the PIC16F648A microcontroller
16F88_L.PLC	PLC header file for the PIC16F88 microcontroller – low voltage programming enabled on pin RB3
16F88_H.PLC	PLC header file for the PIC16F88 microcontroller – high voltage programming enabled, pin RB3 available for general I/O
16F887.PLC	PLC header file for the PIC16F887 microcontroller
PIC16F627.DSN	Proteus VSM simulation – PIC16F627A based Digital I/O Board
PIC16F88.DSN	Proteus VSM simulation – PIC16F88 based Digital I/O Board
PIC16F887.DSN	Proteus VSM simulation – PIC16F887A based Digital I/O Board
Lst1_3.asm	Source code file for Listing 1.3
Lst1_4.asm	Source code file for Listing 1.4
Lst1_5.asm	Source code file for Listing 1.5
Lst1_6.asm	Source code file for Listing 1.6

Table 1.3. File contents of 'PLC1.zip'

```
    include "16F887.PLC"  ; Defines PLC instructions

    ld      PORTB, 0      ; Read Port B bit 0
    out     PORTD, 0      ; Output to Port D bit 0

    endp                  ; End of PLC program
```

Listing 1.3. Reading a switch and outputting to an LED (Lst1_3.asm)

Assembling and executing simple PLC-style programs

In this section you will see just how easy it is to create and assemble simple programs and then run them on a variety of different PIC-based systems. I recommend that you try these activities out for yourself, if at all possible.

Begin by extracting the entire contents of the ZIP file to a convenient folder and then use the MPLAB IDE's **File > Open** menu option to display the file 'Lst1_3.asm', the content of which is given in Listing 1.3.

Our first program is functionally identical to the code snippet previously seen in Listing 1.1, but based on the PIC16F887 microcontroller. It is suitable for use either with the PICkit 2 Debug Express board, or with Proteus VSM electronic simulation software. (Note that the PICkit 2 board has a single input switch, labelled SW1, which is connected to the least significant bit of Port B, plus eight LEDs connected to Port D – which explains the choice of inputs and outputs in Listing 1.3.

Having displayed the source (.asm) file in MPLAB, the next step is to assemble it, in order to create a machine code (.hex) file, which can later be downloaded and programmed. The first step is to choose the required microcontroller type by selecting the **Configure > Select Device** menu option, and then selecting the **PIC16F887** from the Device drop-down list. Next click on the blue title bar of the source code file to ensure it is highlighted and then assemble the file by selecting the **Project > Quickbuild Lst1_3.asm** menu option. If everything has gone to plan you should see a flurry of activity as the file is assembled, culminating in a 'Build Succeeded' message, displayed in the Build tab of the Output window. The MPLAB IDE has now done its job and a Lst1_3.hex file will have been created in the same directory as the source code file, ready to be programmed.

Syntax	Function	Ladder Diagram Symbol
`ld REGISTER, BIT[0-7]`	Read an I/O bit	PORTA, 1
`ld_not REGISTER, BIT[0-7]`	Read an I/O bit (inverted)	PORTA, 1
`out REGISTER, BIT[0-7]`	Send to output bit	PORTB, 0
`out_not REGISTER, BIT[0-7]`	Send to output bit (inverted)	PORTB, 2

Table 1.4. Bit input/output commands

under the VDD PICkit 2 label at the upper right.

Pressing Switch 1 will now cause the LED connected to RD0 to toggle on and off. However, you may note that the LED actually goes out when the switch is pressed, which is the opposite of what you might have expected. Examining the schematic diagram supplied with the PICkit 2 documentation solves the mystery, revealing that SW1 normally reads as a logic-1, providing a logic-0 when

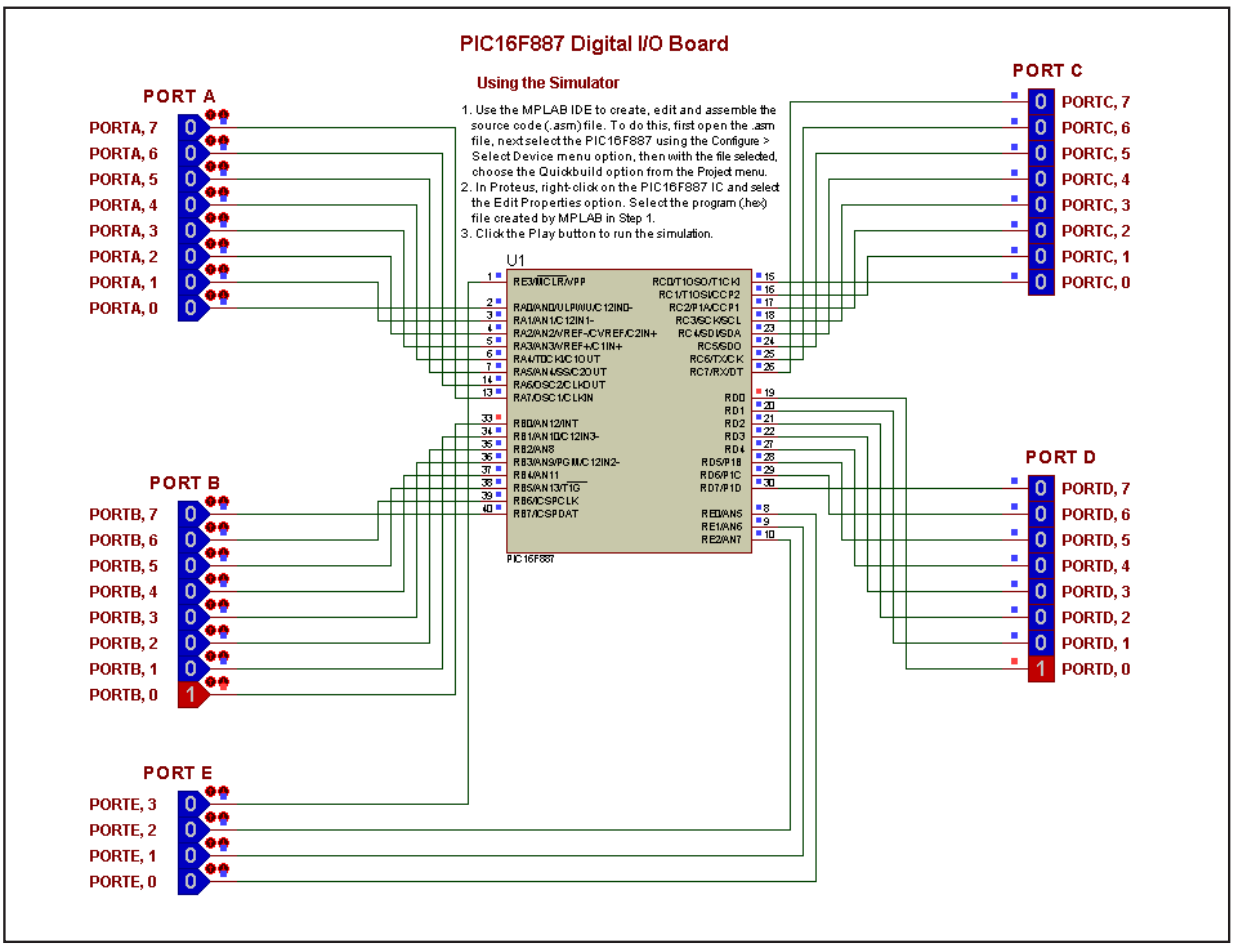


Fig.1.4. A Proteus VSM simulation of the PIC16F887 microcontroller

What happens next depends on how you intend to actually run the program. If you are using the PICKit 2 board then the next step is to run the PICkit 2 programmer application, then use the **File > Import Hex** menu option to open the machine code (.hex) file created earlier. Next, click the **Write** button to program the PIC16F887 microcontroller. You should see a green Programming Successful message in the programmer window at this stage. Finally, apply power to the board by clicking the **On** checkbox situated just

pressed. The required logic of our program may be easily restored by replacing the 'ld' instruction with its negative logic 'ld_not' equivalent, as given in Table 1.4.

From Table 1.4, we can also see that a negative logic output command

(out_not) is available. Thus, we can create a logical inversion either by using 'ld_not' followed by 'out', or 'ld' followed by 'out_not'. If you are using the PICkit 2 board, then you can use this information to modify the program of Listing 1.3 so that pressing the switch causes the LED to come on, rather than go out.

If you are lucky enough to have the full version of Proteus VSM, Version 7.0 or later, then this may be used to simulate the operation of the program of Listing 1.3. Begin by using Proteus to open the supplied PIC16F887.DSN file, which will appear as shown in Fig.1.4.

Controlling multiple inputs and outputs

To take a slightly more complex example, suppose we wanted to control several inputs and outputs. This could be achieved as illustrated by Listing 1.4, shown for a PIC16F627-based system.

Assuming you have a suitable PIC programmer and experimentation board, such as the Velleman K8048, the first step is to use the MPLAB IDE to create a machine code file (remembering of course to set the device type to either the PIC16F627 or PIC16F627A, as appropriate). Next, connect the programmer to your PC via the supplied serial cable and then download and execute the program. When the program is executed, pressing a switch connected to the first two bits of Port A should cause the corresponding bit of Port B to be activated, as shown in Fig.1.5.

If you have access to the Proteus VSM software then you use this to load the 'PIC16F627.DSN' simulation and then follow the procedure described earlier to load and execute the program of Listing 1.4.

Surprisingly, it is also possible to develop similarly complex programs for the PICkit 2 Debug Express board, despite the fact that the PCB is limited to a single physical input switch! The trick in this case is to use the PICkit 2 Logic Tool application to control up to three additional digital input signals via the In Circuit Serial Programming (ICSP) interface, which links the 'black box' to the PIC16F887 PCB. When not being used to download programs, the Logic tool allows inputs RE3, RB7 and RB6 to be controlled by activating pins 1, 4 and 5 of the ICSP interface respectively.

```
include "16F627.PLC"  ; Defines PLC instructions

ld      PORTA, 0      ; Read Port A bit 0
out     PORTB, 0      ; Output to Port B bit 0

ld      PORTA, 1      ; Read Port A bit 1
out     PORTB, 1      ; Output to Port B bit 1

endp                  ; End of PLC program
```

Listing 1.4. Reading and controlling multiple inputs and outputs (Lst1_4.asm)

Our machine code program created earlier must be logically attached to the PIC16F887, prior to running the simulation. To do this, right-click on component U1 and select the **Edit Properties** option from the context menu to display the Edit Component dialog. From here, you can click the yellow folder icon and browse to find the 'Lst1_3.hex' file created earlier. Close the dialog and then click the Play button at the lower left of the Proteus window to run the simulation. You'll then be able to click on the input connected to bit 0 of Port B, which should cause the corresponding bit of Port D to change (as illustrated by Fig.1.4).

```
include "16F887.PLC"  ; Defines PLC instructions

ld      PORTE, 3      ; Read Port E bit 3 (ICSP pin 1)
out     PORTD, 3      ; Output to Port D bit 3

ld      PORTB, 7      ; Read Port B bit 7 (ICSP pin 4)
out     PORTD, 2      ; Output to Port D bit 2

ld      PORTB, 6      ; Read Port B bit 6 (ICSP pin 5)
out     PORTD, 1      ; Output to Port D bit 1

ld_not  PORTB, 0      ; Read Port B bit 0 inverted (SW1)
out     PORTD, 0      ; Output to Port D bit 0

endp                  ; End of PLC program
```

Listing 1.5. Controlling up to four inputs using the PICkit 2 Debug Express (Lst1_5.asm)

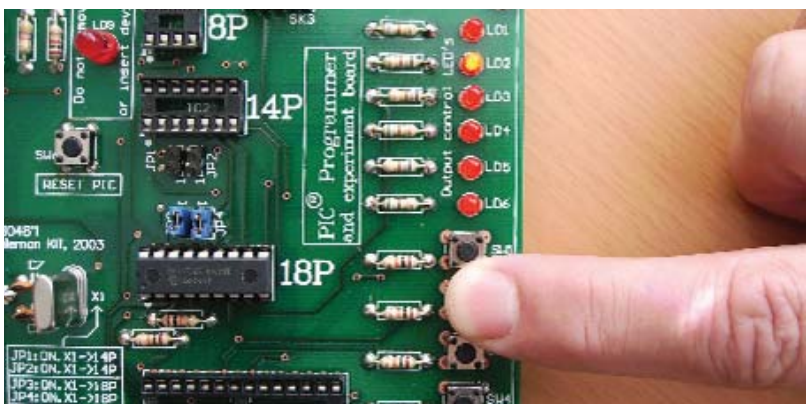


Fig.1.5. The output produced by Listing 1.4, running on a Velleman K8048 board

To see this in action for yourself, begin by assembling the program of Listing 1.5, and then download the resulting machine code file to the PIC16F887 in the normal way.

Next, enable power to the PCB by clicking the **On** check-box and then select the **Tools > Logic Tool** option from the pull-down menu, which will display the PICkit 2 Logic Tool dialog of Fig.1.6.

Ensure the Mode option is set to **Logic I/O** by clicking the button at the upper right, and then click the **Enable**

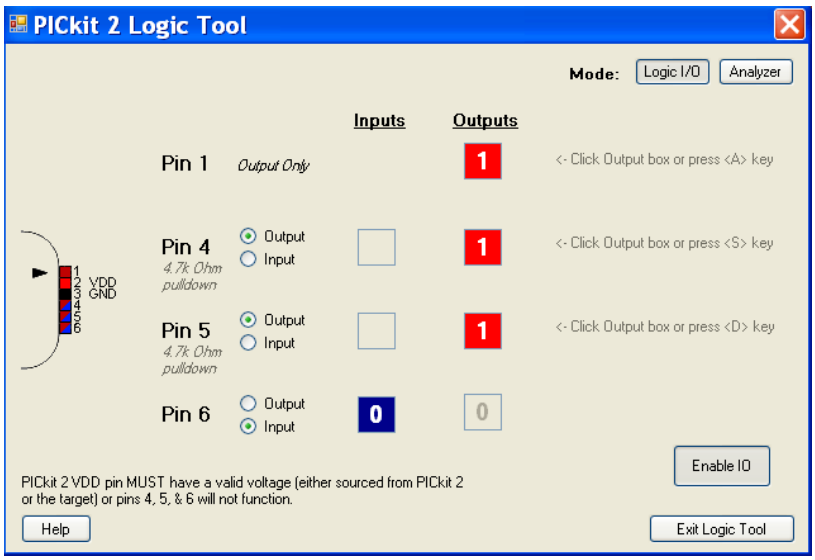


Fig.1.6. Controlling digital inputs via the PICkit 2 Logic Tool dialog

IO button to allow logic levels to be directly observed or controlled. Next, set pins 4 and 5 to be outputs, at which point you should be able to control the state of the LEDs connected to outputs RD0-RD3, with the program of Listing 1.5 running. (Note that Pin 6 in Fig.1.5 is identified on the schematic diagram as an Auxiliary signal. This pin is not connected to the PIC16F887 IC, by default, and so is not used here.)

Using the PICmicro MCU development board

The final piece of hardware to look at in this installment is the Version 3 PICmicro MCU Development board, as shown in Fig.1.7.

This comprehensive board is available from the *EPE* Readers' Services, and is supplied as standard with a PIC16F88 microcontroller, although a wide variety of other PICs are also supported.

The board brings out the inputs of Port A and the outputs of Port B via switches and LEDs at the lower left and lower right respectively. A 16MHz crystal oscillator is supplied in a socket at the lower right, which is four times faster than the 4MHz default used by the PLC software. If you are planning to do serious work with the PLC software, I'd recommend replacing this with a 4MHz crystal – which will ensure that time-dependent programs covered in later parts of the series run at the correct speed. (Incidentally, the PLC header file is configured to automatically enable an internal RC oscillator at 4MHz in the event that the external oscillator fails to start.)

A USB cable is supplied as standard, although the board can also accommodate an external DC supply (shown at the upper left of Fig.1.7). If the board is powered from the USB cable, then the PIC must be programmed using 'low voltage programming', which makes use of Port B, bit 3 (RB3). To use LVP with the PIC16F88, the upper (RB3) jumper to the left of the LCD display must be positioned to the left, as shown in the image. (Be sure to do this with the power removed, and be very careful which jumper you enable, to avoid damaging the PIC microcontroller.)

Two versions of the header file are provided, supporting low voltage or high voltage programming ('PIC16F88_L.PLC' and 'PIC16F88_H.PLC' respectively). Listing 1.6 shows a suitable test program, which also demonstrates the use of active-low inputs and outputs, as originally seen in Table 1.4.

The program is first assembled in the normal way, by using the MPLAB IDE. A supplied PIC programming application (PPP) is then used to first open the assembled Hex file and then transfer it via the USB cable to the PIC micro. The program will then run automatically.

A Proteus simulation of the 16F88 microcontroller (PIC16F88.DSN) is also provided, for those readers with access to this powerful software. Operation is the same as that described earlier – see Fig.1.4 and associated text for details.

Troubleshooting tips

While operation should be mostly trouble free, the following troubleshooting tips will help you to resolve any issues as quickly as possible:

1. The MPASM assembler used by the MPLAB IDE is case sensitive and it is a requirement that all PLC *commands* should be entered in lower case, and any *parameters* in upper case. The first step is therefore to carefully check the listing for typographical errors.

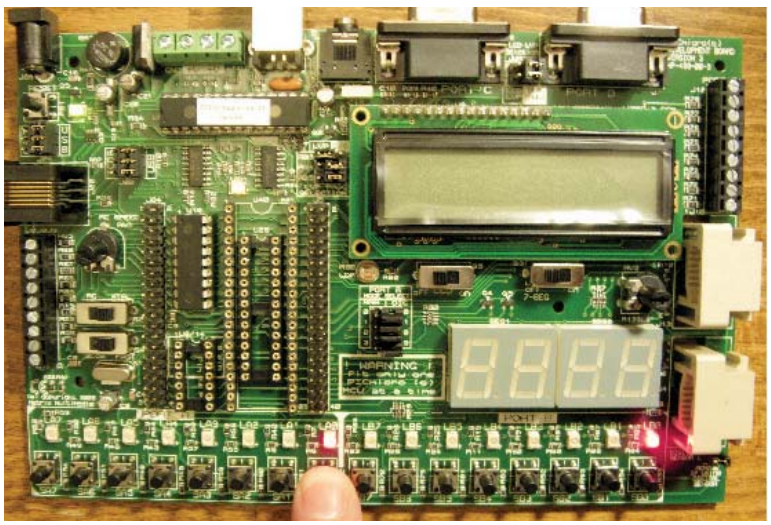


Fig.1.7. Running a simple bit input/output program on the PICmicro MCU development board

```
include "16F88_L.PLC" ; Defines PLC instructions
                      ; (Low voltage programming version
                      ; with RB3 used as the LVP pin)

ld      PORTA, 0      ; Read Port A bit 0
out     PORTB, 2      ; Output to Port B bit 2

ld_not  PORTA, 1      ; Read Port A bit 1 (inverted)
out     PORTB, 5      ; Output to Port B bit 5

ld      PORTA, 2      ; Read Port A bit 2
out_not PORTB, 6      ; Output to Port B bit 6 (inverted)

ld_not  PORTA, 3      ; Read Port A bit 3 (inverted)
out_not PORTB, 7      ; Output to Port B bit 7 (inverted)

endp                  ; End of PLC program
```

Listing 1.6. Controlling normal and inverted signals with the PIC16F88 (Lst1_6.asm)

2. Ensure that the relevant include file is in the same directory as the assembler source file, otherwise the assembler may be unable to locate it.

3. When using the MPLAB IDE, check that you have selected the correct microcontroller type, prior to attempting to assemble the source code file.

4. The assembler creates a number of other files which may contain useful diagnostic information. In particular, an error (.err) file is created with details of any errors, and a listing (.lst) file will contain full details of the source code, the machine code generated, plus any errors.

5. Try to keep filenames and file pathnames short. Some versions of the MPASM assembler will give an error if the filename portion of the source file name is longer than eight characters. You may also get an error if the full pathname is longer than 62 characters.

6. Consider temporarily commenting out lines which you suspect may be causing an error. You can do this by adding a semicolon to the start of the line. It may also be useful to temporarily add additional lines to your program, purely for debugging purposes.

7. For users of Proteus, the Watch window may provide useful debugging information. (We'll look at this Proteus feature later in the series.)

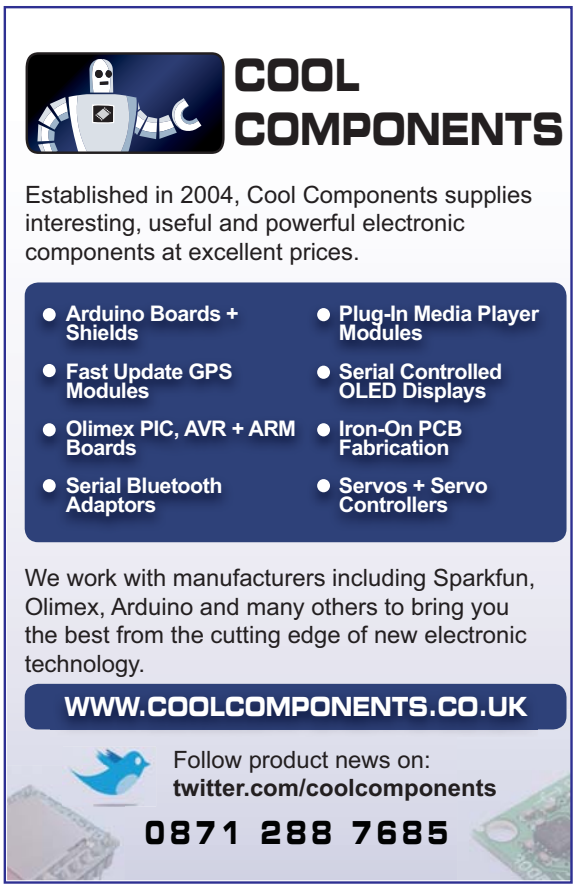
Final thoughts

In this first article we've focused on reading and controlling individual inputs and outputs. Bear in mind that this is only a small portion of the available command set, and we'll be progressively introducing additional features of the software in the remaining five parts of the series.

We've also demonstrated that the software can be used with a variety of PIC microcontrollers, with commonly available programmer and experimentation boards, and even with electronic circuit simulation software.

The next installment will begin by using ladder logic elements to construct simple combinational logic circuits based on Boolean operators such as AND, OR, and EOR (exclusive-OR). We'll then move on to consider the development of simple sequential logic systems, including latches, and also the creation of variable frequency pulsed outputs.

We'll then use these concepts to develop a simple and extendable alarm circuit, using just a few lines of code, and suitable as the basis of either a car alarm or burglar alarm. Features will include multiple input sensors, a latched alarm status output, and a pulsed armed/disarmed LED.



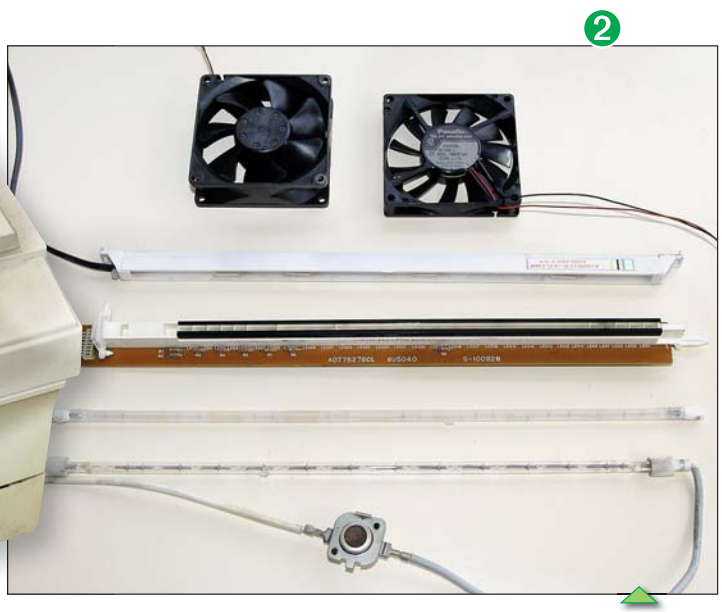
Recycle It!

BY JULIAN EDGAR

There's lots of good bits inside junked photocopiers

If you haven't noticed, these days you can pick up used photocopiers for a pittance. Nope, not pretend little desktop photocopiers, but the full-size office monsters that weight 40kg or more.
Some are working, some aren't – but when you pay less than a tenner, all are excellent salvage value! So what bits and pieces can you get out of a typical photocopier?

The quality and number of useful components depends a lot on the specific photocopier. Unfortunately, there's no way of knowing exactly what you've got until you pull it apart. Some have as many five DC brushless fans – but some have only two. Some photocopiers have large stepper motors, while others use synchronous AC motors, which are much less useful.
So, although the salvaged components might be well worth £50 (or much more), because of the uncertainty, it's wise to not spend more than £10 to £15. The photocopier pictured here was bought by tender for just £10.



Inside all photocopiers you'll find lights and fans. The lights – high voltage, high power incandescent filament bulbs – are used to both illuminate the material to be copied and also act as a heater to cook the toner as the photocopied sheets are on their way out of the machine. The latter light often includes an over-temperature switch mounted nearby.

In addition, you'll sometimes find rows of mains-powered neon lamps and/or rows of low-voltage LEDs. Fans consist primarily of conventional PC-type fans (although often running on 24V – but they'll work down to 12V without problems) but sometimes – if you get lucky – you'll find a bunch of squirrel-cage fans of the sort that move a lot of air very quietly. These are usually AC mains-powered, but a few work on 24V DC.

You can also be sure of finding an excellent quality lens (typical focal length = 180mm) and a number of mirrors. The lenses are razor sharp and make ideal hand magnifying glasses – they're also large and bright and some are coated for better light transmission.

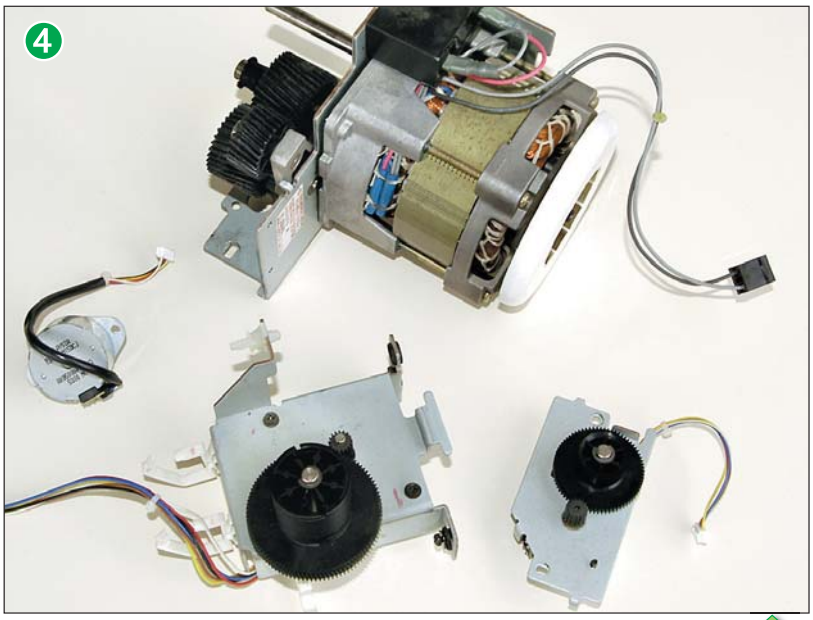
The mirrors are front-faced and their length corresponds to the width of the photocopy area. Typically, they're 10mm to 20mm wide, so they're long and narrow. To be honest I haven't found a lot of use for them (except, oddly enough, winding high powered resistors on them!), but if you're into lasers or other optical systems and need very low-cost, high-quality mirrors, they should do the job quite nicely!

Rat It Before You Chuck It!

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

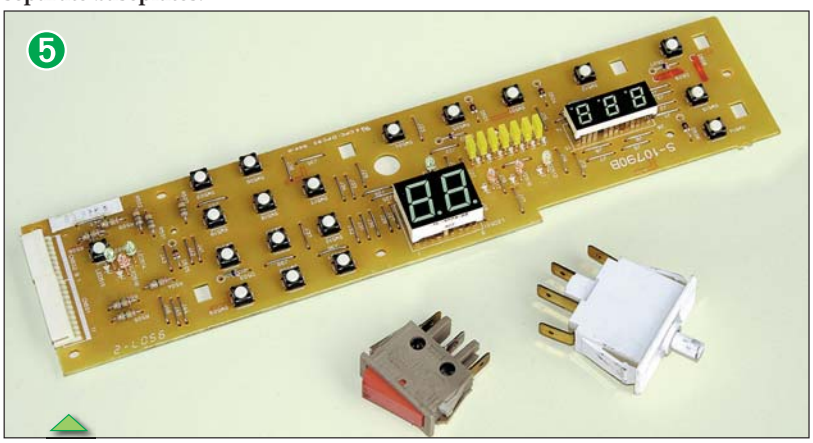
And you can contribute as well. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you salvage the high-quality bearings from VCR heads.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

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



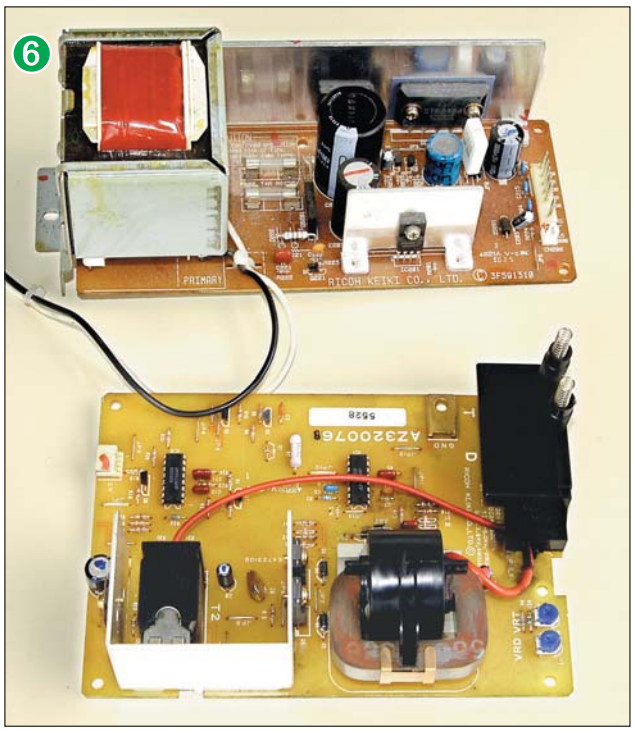
Even if the photocopier's main transport system is powered by an AC motor, there will still be a few low-voltage stepper motors inside. For example, if the copier uses a document feeder, there'll be a stepper buried in that part of the machine. However, occasionally you may stumble across 'gold' – huge stepper motors (as big as a man's fist) with built-in reduction gearboxes. These are highly prized (and if you don't want them, you can make a good profit 'eBaying' them). They can be used to drive robots or 3-axis milling machines, or they can be driven backwards as really 'grunty' alternators.

Alternatively, you may find an AC motor with a built-in reduction gearbox. The one pictured here has an output shaft speed of just 53 RPM, making it ideal for spinning an advertising sign or the like. Note, most of the extensive gear-train you'll find inside a copier cannot be extracted whole – not unless you keep the complete chassis intact. Instead, look for sub-gear assemblies that mount on separate baseplates.



There are two completely different classes of switches inside photocopiers. The most numerous are the tiny tactile PC-mounted pushbutton types which are located behind the membrane keypad. By using a heatgun directed at the solder side of the PC board and a pair of pointed-nosed pliers to pull them out, a lot can be salvaged in a very short time.

There will also be another pair of switches with very different current ratings to the pushbuttons – the main on/off switch (normally on the back of the photocopier) and a pushbutton switch that goes open-circuit when the top-half of the copier is pivoted up for repair or toner replacement. The latter two switches are definitely worth salvaging – they are heavy-duty, with typical ratings of 16A at 250V AC.



Think 'photocopiers' and you're probably immediately thinking of high-voltage power supplies. After all, photocopiers use kilovolts inside! However, while the power supplies are able to be salvaged (most copiers have at least two HV power supplies), there aren't too many practical uses for a power supply with an output of just 290μA at 5kV! In addition, there's usually a conventional linear power supply, typically providing 5.2V at 0.4A and 1.6A at 24V.

If you decide to strip these rather than use them whole, you'll find a range of medium and small aluminium heatsinks that are easily removed. Make sure that any high-voltage capacitors are completely discharged before touching them.

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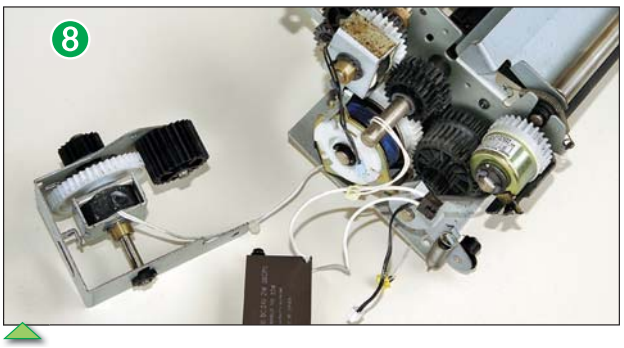
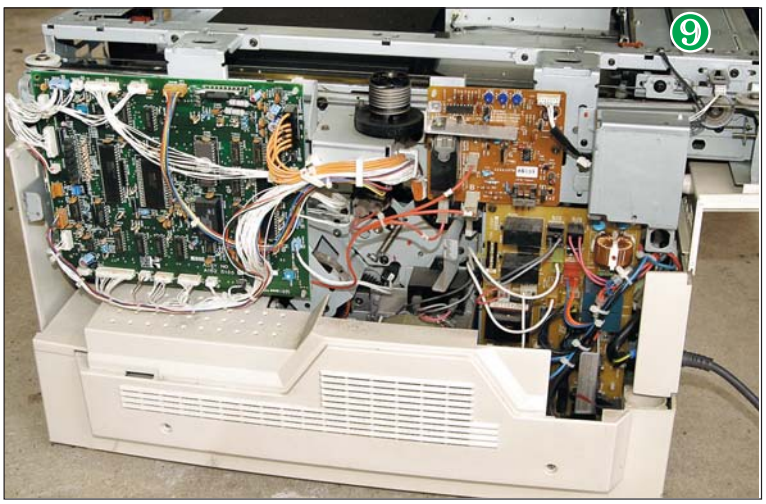
When you're pulling apart a photocopier, there are a few precautions to keep in mind. First, disassemble the copier outside while wearing old clothes – inevitably, toner will get everywhere. Second, some copiers use torsion bar springs to counterbalance the weight of the open top-half. These springs are very powerful and if you undo their retaining screws while they're under tension, they can fly out and possibly cause injury. Other copiers use small 'gas' struts – another excellent salvage part. Finally, the high-voltage power supplies have on-board capacitors that could give a nasty bite – they should be OK if the copier hasn't been powered-up recently, but keep it in mind or you could get a nasty shock. *EPE*

There's also a whole lot of hardware that's worth scrounging. The fold-down lid often uses snap-action two-position hinges, there are hundreds of machine screws, many springs, pulleys, cables and toothed belts, and a bunch of cogs and gears.

There's also something potentially even more useful – painted or plated sheet metal brackets and panels. These are ideal if you need to construct custom brackets, make a new faceplate panel or similar. And don't forget the glass: it's usually very easy to remove (do it first so there's less chance of breaking it!).



This list of parts hasn't been exhaustive – I haven't mentioned the LED displays, the electro-mechanical counter, the electric clutches, bearings or shafts. There are usually plenty of good bits to salvage. But even if you don't keep a lot of stuff, pulling apart a photocopier is a fun exercise in itself. It's fascinating to see how the engineers have fitted a complex machine into a compact package.



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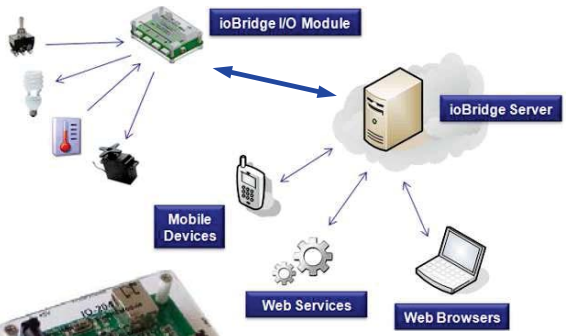

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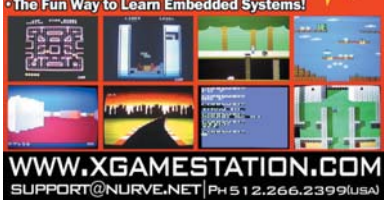

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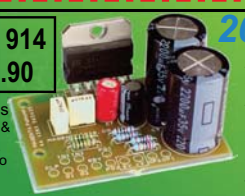

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Max's Cool Beans

By Max The Magnificent

FOR the last few months I've been working with a team of high-profile industry experts to create a radically new website that will allow folks to create, deploy, and access technology-based information. "Why is this so different from anything we've seen before?" I hear you cry. Well, I shall elucidate... but first let me set the scene...

Timelines

I left England and moved to America almost 20 years ago as I pen these words (eeeek... where does the time go?). Upon my arrival, I subscribed to all of the usual suspects with regard to engineering-related publications. These included *EE Times*, *EDN* (*Electronic Design News*), and so forth. This was prior to the Internet taking the world by storm, so all of these magazines were delivered the old-fashioned way – as physical printed documents that landed on the desk with a resounding 'thud'.

In those days of yore, almost every engineer in the office subscribed independently. On the day a magazine was delivered, the receptionist's desk would be buried under a mountain of the little rascals (the magazines, not the engineers). None of the recipients really thought about the costs involved in all of this, because these magazine subscriptions were free to qualified engineers ... everything was paid for by advertising.

Nothing really seemed under threat in the early days of the Internet (circa the mid 1990s), but 'the times they were a-changing!' Consider *EE Times*, for example, which was (and still is) a weekly publication. Prior to the Internet, this magazine had 'heft,' being roughly the size and weight of one of the larger sunday newspapers. As web-based information delivery started to make inroads, however, advertisers began to switch their attention to this new form of media, and technical publications like *EE Times* ilk grew steadily thinner and thinner. Today? Well, let's just say that the print versions of *EE Times*, *EDN*, and all of their cousins are but shadows of their former selves.

The fact is that the majority of today's engineers now have little interest in print publications; instead, they prefer to glean any required information on-the-fly from the Internet. In addition to searching for specific information using Google, it is also possible to access web-based versions of the various magazines. Sad to relate, however, these 'old-school' media houses have fallen behind the curve. They remain based on the concept of an editorial staff gathering and creating information that is subsequently 'fed to the masses.'

The data flow on these traditional sites is almost overwhelmingly unidirectional. At best, you may be able to rate an article ('from 1 to 5 stars') and offer comments on it. This is no longer sufficient. People now wish to have direct contact with the authors of articles, and also to have the ability to create and contribute their own content in the form of blogs, articles, reviews, and *Ingenuity Unlimited*-type items (circuit diagrams, design techniques, snippets of code) and so forth.

Furthermore, the most significant Internet phenomenon of recent years is that of social networking. The general public is enamoured with sites like Facebook, Twitter, and YouTube, while professionals also make use of sites like LinkedIn and Plaxo. Although these environments are interesting in their own right, they really don't help folks who wish to create and access technical content.

TechBites

All of this explains why I and my colleagues have been working furiously to create a new website called TechBites (**www.TechBites.com**), which offers a unique mix of social networking combined with technology content creation and delivery.

This really is rather cool. Anyone can access any of the articles on the site without having to register. It's only if you wish to comment on articles or rate articles or join discussions or communicate with other users that you have to become a member. Membership is free, and requires only your name and email address, plus you have to choose a user name and password so you can manage your account in the future.

Once you've become a member, you are automatically provided with your own profile page that you can share with your friends. Now, in addition to reading other members' blogs and articles, you can create your own. When you do create an article, in addition to it appearing on your profile page, it also appears on the appropriate site-wide content page.

But wait, there's more, because we also have the concept of 'communities' of folks interested in the same technological areas. For example, there's a PIC microcontroller community, a video community, a chip design community, and so forth. Anyone can join any community and, when you create a blog or an article, you can 'tag' it as being associated with one or more communities, in which case it will automatically appear on those community pages.

Furthermore, anyone can create and lead their own community (I'm running the FPGA and chip design communities). I could waffle on about this for hours, but it would be better if you were to bounce across to *TechBites.com* and take a look for yourself. If you do join, be sure to visit my profile. If you click the 'be my friend' link on my profile, you'll appear on my map and we can send messages to each other. I've never bothered to create a Facebook or Twitter account, so all of this is new to me too, but it's actually rather fun ... why don't you try it and see...

Check out 'The Cool Beans Blog' at www.epemag.com

Catch up with Max and his up-to-date topical discussions

Time Domain Response

RECENTLY, *Circuit Surgery* has provided an extended response to ***Paul Goodson's*** question on 'Filter Circuits' posted on the *EPE Chatzone* (**chatzones.co.uk**). These articles prompted some further questions, and last month we took a more in-depth look at the concept of poles and zeros. This month, we have another question relating to the first filters article. ***Nagi Saad*** emailed us to ask:

Regarding the Filters Circuits Design of July '09 (Part 1). What is the importance of the 'time domain response' (Fig 4) for filter design? When is it necessary to examine it by applying a step input signal?

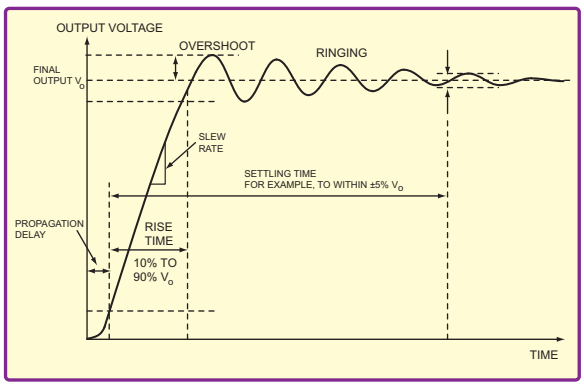

Fig.1. Time domain response

A step in time

A more detailed version of the figure to which the question refers is repeated here in Fig.1. This graph shows a generic step response of a filter. This is typical of the output produced when the circuit is subjected to an idealised step input change (eg, an instantaneous change from 0V to 1V at the input at time zero). This is referred to as a 'time domain response' because we are looking at the behaviour of the filter in time, rather than how its response varies with frequency (which would be the obvious first thing to consider for a filter).

Other types of time domain response you may encounter are the 'impulse response' (which we will discuss shortly) and the 'ramp response' which, as the name suggests, is a response to an input voltage ramping up linearly.

These three types of time response are available from the Filter Free design software from Nuhertz (**www.nuhertz.com**), which we discussed in the Aug '09 issue (Part 2 of the initial three-part series on filters).

The step response probably provides the most direct intuitive information relating to practical circuit design. The impulse response is very important in the theory and mathematics of filter circuits.

To illustrate a number of typical step responses Fig.2 to Fig.5 show the step responses for the four types of common filter discussed in the Aug '09 article. These are all third-order low-pass filters with cutoff frequencies of 1kHz, having Butterworth, Bessel and two types of Chebyshev characteristics. All of these graphs were generated using Filter Free and represent idealised responses – they are not simulations of actual circuits

From the graphs, we see that Bessel filters provide little or no overshoot and ringing compared with the other types. The most significant overshoot and ringing is produced by the Chebyshev filters, which also provide the steepest cutoff in their frequency responses (see earlier article). The Butterwoth filter is in between the Bessel and Chebyshev types, both in terms of ringing and overshoot and steepness of cutoff.

There are both practical and theoretical reasons why the step response of a filter is important. From the theoretical perspective, the step response is the output produced by an input change from 0 to 1 at time zero. The input is assumed to be zero for infinite time before this and 1 for infinite time after the step.

For linear filters (which applies to all the op-amp based filters we have been considering), the step response fully describes the filter; that is, there is a direct and specific mathematical relationship between the frequency response and the step response. If you know one of these you can determine the other.

Impulsive response

The impulse response, which we mentioned earlier, also fully defines a

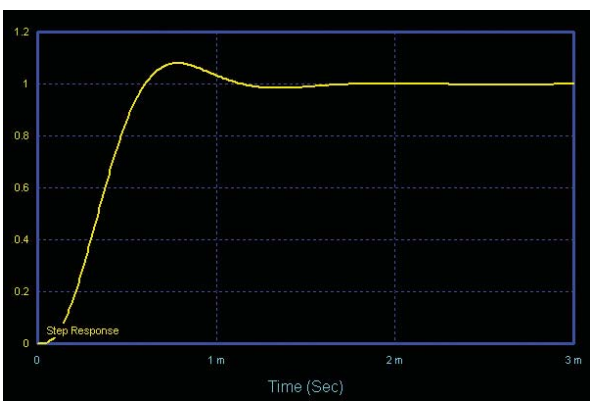

Fig.2. Butterworth third-order 1kHz low-pass filter step response

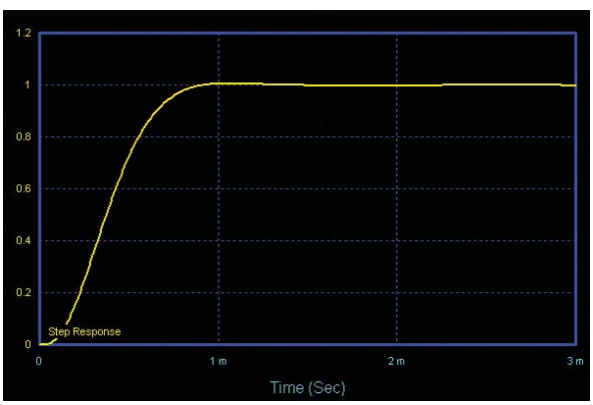

Fig.3. Bessel third-order low-pass 1kHz filter step response

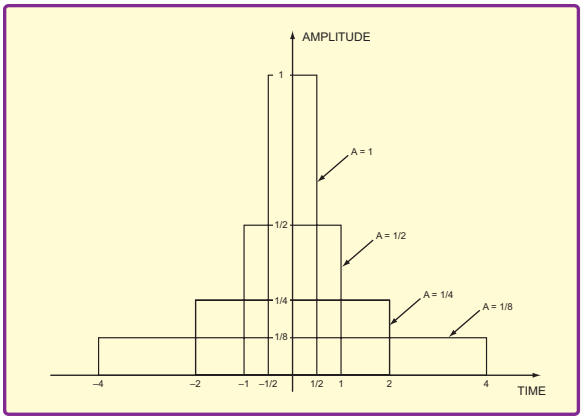

Fig.6. Visualising the impulse. As A gets larger the pulse gets shorter and taller, but retains the same area underneath it on the graph.

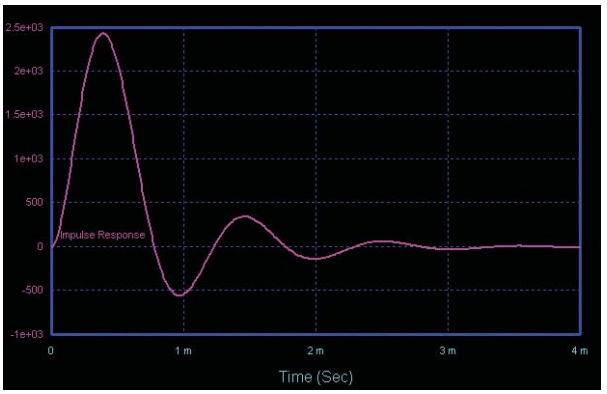

Fig.7. Type-I Chebyshev third-order low-pass 1kHz filter impulse response

linear filter. The 'impulse' is an infinitely short pulse, with infinite amplitude, but with finite energy. This is obviously a very abstract idea, but we can also think of a physical approximation of the impulse such as a quick hammer hit.

For example, consider a resonate object such as a bell. If it is given a sharp tap it will emit a fading sound at its resonant frequency. Electrical systems behave in a similar manner if a sharp voltage or current spike is applied. The impulse is the 'mathematically perfect' version of such a sharp tap, and is important because applying an impulse to a system reveals its characteristics.

You can imagine an impulse by considering a pulse of amplitude A and a duration of 1/A. Thus, the area under the pulse drawn on a graph is A × 1/A which is 1, whatever the value of A. The area under the pulse relates to its energy, which is constant with the scheme just described, whatever value A is used. As the value of A becomes very large (tends to infinity) the pulse becomes an ever-closer approximation to the impulse function. This is illustrated in Fig.6.

An example impulse response (filter output) is shown in Fig.7. This is for the same Chebyshev filter as the step response in Fig.4. Again, we used Filter Free to plot this graph.

Parameters

Returning to Fig.1, the parameters and features shown on that graph: propagation delay, rise time, slew rate, settling time, ringing and overshoot may have an impact on any practical circuit using a filter.

Propagation delay is the time from an input step occurring until an output response is seen from the filter. This is related to the phase shift characteristics of the filter. The propagation delay of low-frequency low-pass filters will usually be larger than those with higher cutoff frequencies.

Rise time is the time taken for the filter output to go from 10% to 90% of its final value in response to the step input. This is related to the *slew rate*, which is the slope (volts per second rate of change) of the rising edge of the filter's output. If the slew rate of the op amps used in a filter circuit is poor, the output voltage may not be able to change as fast as predicted by the step response. In such a situation, the filter's characteristics would not be as designed, due to the limitations imposed by the op amp, and the time taken for the filter to respond to a step change may be longer than required by the application.

Overshoot

It's common for a filter's output voltage to go higher than the final value just after the initial rising edge of a step change. This is known as 'overshoot'. The overshoot is often followed by a decaying oscillation known as 'ringing'. Some filters exhibit little or no overshoot or ringing; for example, see the Bessel filter response in Fig.3.

Overshoot or ringing may be a problem in some applications. For example the voltage reached by the overshoot may trigger a circuit to do something unwanted; however, more commonly it is the time taken for the overshoot and ringing to die away, that is the *settling time*, which is the important issue. This, together with the propagation delay, determines the total time it takes for the filter's output to respond to a step input change.

An abrupt change

Obviously, the step response characteristics will be more important in situations where large abrupt changes are applied to the filter. For example, if a relatively low frequency square wave (eg, less than one tenth of the cutoff frequency) is applied to a low-pass filter then the output pulses will resemble the step response.

For the filters with the step responses shown in Fig.2 to Fig.5, we can assume that at about 5ms after a step input, the output has settled very close to its final value (only 3ms is shown on the graphs). So, a square wave input to these filters with 5ms pulses (a period of 10ms, a frequency of 100Hz) will produce output

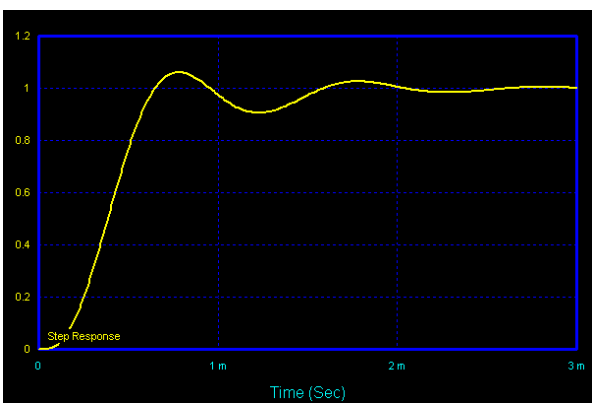

Fig.4. Type-I Chebyshev third-order low-pass 1kHz filter step response

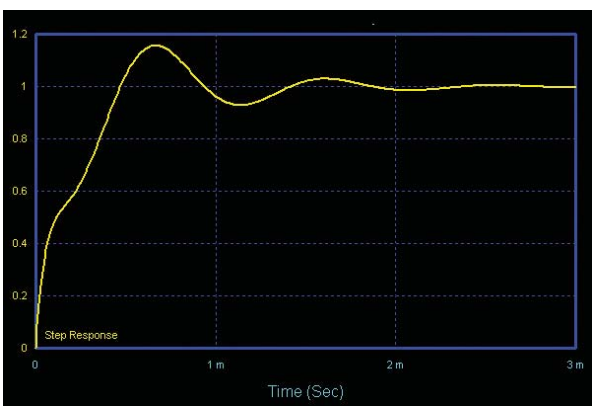

Fig.5. Type-II Chebyshev third-order low-pass 1kHz filter step response

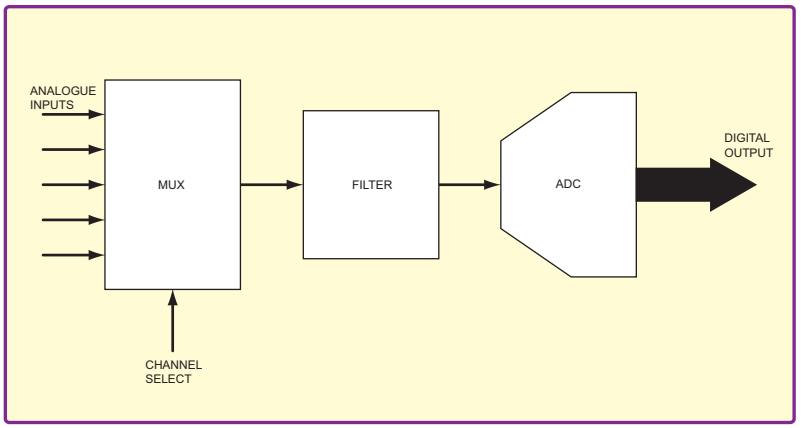

Fig.8. Typical application in which filter step response is important

pulses resembling the step response curves. From a mathematical perspective, the response to a step and a slow square wave are not the same, but if the square wave pulse is equal to, or longer than, the settling time the difference will not be significant in practical terms.

Applying slow square waves to filters may provide an obvious example of the step response, but in itself may not relate very directly to real applications. An example of a common circuit where step inputs are applied to filters is shown in Fig.8.

Here, an analogue multiplexer is used to select one of several analogue inputs for conversion to digital by an ADC (which may be stand-alone or part of a microcontroller such as a PIC). Typically, these analogue inputs might be from various sensors. The filter removes noise from the measured signals and prevents aliasing in the ADC.

Different levels

Although the individual input signals may change smoothly they will all be at different levels and so switching multiplexer channels will cause a step change at the filters's input. If the analogue-to-digital conversion takes place too soon after the multiplexer has switched, the filter may not have had sufficient time to respond (propagation delay and settling time) before the measurement is made. This will compromise the accuracy of the system. If the measurement is inadvertently made during an overshoot then a very significant error may result.

Settling time is not rigidly defined – it depends on the accuracy required (settle to 1%, 0.1%, etc.). In this example, the required settling accuracy (and hence time) depends on the ADC. For an 8-bit ADC, one bit represents about 0.4% of the input range, for 12 bits about 0.02% and for 16 bits it is around 0.0015%. If the filter does not settle to within ± ½ bit within the required measurement time the resolution of the ADC is wasted.

Compromise

As is common in all engineering design, filtering in the circuit of Fig.8 requires a compromise. A filter with a steep cutoff will reduce noise more effectively and provide better anti-aliasing for the ADC, but may have a time domain response which is too slow or has too much overshoot or ringing. Using a 'softer' filter such as a Bessel rather than the steeper cutoff type such as Chebyshev may provide the best overall performance in this type of circuit.

Application note 3203 from Maxim Integrated Products provides another possible solution to this problem in which a filter's characteristics are changed under 'step' conditions in order to speed up the circuit's response. Filters with 'adaptive' responses like this are not 'linear', making mathematical analysis much more difficult.

The Maxim circuit uses a window comparator to monitor the difference between the filter's input and output. When this is greater than ±50mV, the filter's cutoff frequency increases by ten times, resulting in fast step response. When the system output changes to within 50mV of the system input, the cutoff frequency is returned back to its standard value.

Their example circuit uses a MAX7409 fifth-order, low-pass, switched-capacitor filter IC. See **www.maxim-ic.com/appnotes.cfm/an_pk/3203** for more details.

Summary

We have now spent several months discussing filter circuits, but we believe that this is justifiable because filters are so important in electronic systems. The vast number of filter types and circuits (which prompted Paul's initial question), combined with the advanced mathematics, which often accompanies discussion of filters in books and websites, can make the topic somewhat daunting. However, armed with some understanding of the basic concepts and knowledge of a few practicalities, including the impact of non-ideal components and filter performance – and after installing some free filter design software – it is possible to design useful filters without knowing any advanced mathematics.

We hope that the original three articles and the follow-up questions from Sam Zack and Nagi Saad have provided useful insights into this topic, but we would be happy to receive further questions if you have them.

TL-500

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Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

THE subject of producing front panel overlays and labels is one that has been covered in *EPE* from time to time over the years, and there has been a steady trend away from traditional methods in favour of more high-tech approaches. Instead of using rub-on transfers, stencils, and simple photographic techniques, it is now computers, printers, and labelling machines that are the order of the day. To some extent, this change has been forced by changes in the commercial world, where the advantages of high-tech methods has resulted in a steady decline in the demand for traditional tools and materials.

While it would be an exaggeration to say that none of the traditional methods are usable any more, some of them are well and truly obsolete. The rest are difficult to use due to the limited availability of the materials and tools required.

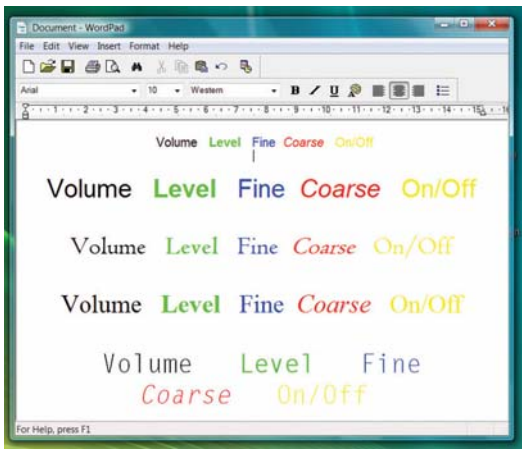

Fig.1. Even a very basic word processor such as WordPad can be used to produce labels using a variety of fonts, sizes, colours, and styles. One slight drawback is that there is no way of setting a background colour

It is still possible to use the once highly popular rub-on transfer lettering, but most of the manufacturers have ceased production and suitable transfers are unlikely to be found in the local shops. Buying them online is usually the only option. Anyway, here we will only consider the high-tech approaches, which offer the hobbyist the same advantages that they provide in the commercial world.

Professional touch

The decline of traditional methods in favour of high-tech labels and panels is not surprising. It used to be difficult and time consuming to produce really professional looking results. The materials involved were often quite expensive, and mistakes could be costly. Less expensive methods such as rub-on transfers could provide quite good results at relatively low cost, but tended to lack durability.

Using a high-tech approach it is much quicker and easier to produce great looking results, and it is possible to make high quality panels that genuinely rival those found on top quality ready-made equipment. The processes involved are not totally skill-free, but they can be mastered by most people after a little practice. Because the processes involved are generally much easier using a high-tech approach, it is possible to go much further and produce dials, symbols, etc., that could not be tackled using traditional methods.

Cost comparisons are difficult because the old and new methods are so different. Assuming that you have access to a computer and a suitable printer, the high-tech approach is unlikely to be more expensive. It is fair to say that both methods can be very cheap or quite costly, depending on the exact methods used and the quality of the finished product.

Of course, the situation is different if you do not have access to suitable computing equipment. Even with the relatively low cost of modern computer hardware, producing panels using a computer is unlikely to be a practical proposition if you have to buy the equipment specifically for this purpose.

A Word in the hand

In order to produce panels and labels it is clearly necessary to have suitable software so that the required design can be prepared for printing. Producing simple labels should present no significant problems, since any word processor program should be capable of producing lettering in a variety of fonts, styles, sizes, and colours.

Even WordPad, the word processor that is part of every standard Windows installation, can handle this type of thing (Fig.1). One slight limitation with WordPad is that there seems to be no way of setting a background colour, so you are limited to white. Of course, coloured paper can be used, but bear in mind that doing so will produce massive colour shifts in the printed lettering when using any colour other than black.

It is not essential to use a computer and printer if individual labels rather than complete panel overlays are required. The upmarket electronic labelling machines are quite expensive, but the small handheld units (Fig.2) are available for about £15 to £20, and can sometimes be obtained for around £10 in sales.

They use a simple but effective system of thermal printing that provides reasonably high quality lettering. Results are certainly in a different league to those obtained from the simple mechanical labelling machines that use an embossing technique to produce the labels.

The tape supplied with the labeller usually gives something like black lettering on a white or transparent background, but it is possible to obtain replacement tapes that have alternative colour combinations. Some labellers can use tapes of two or three different widths, but in the current context it is usually small lettering that is needed, and the narrowest (3.5mm and 6mm) tapes are likely to be the most useful.

Obviously, it is the normal plastic tapes that are required in this application, and not the iron-on fabric type! The self-adhesive labels produced are quite durable, and these machines probably represent the quickest and easiest way of producing good quality panel labels.

Graphics software

In order to produce really fancy lettering, or a complete panel, it is necessary to have some form of graphics design software. Paint and photo-editing programs are usable in this application, but in practice tend to be less capable and harder to use than CAD (computer aided design) and illustration software. CAD programs are primarily intended for technical drawings, such as circuit diagrams and house plans. Their ability to produce designs accurately to scale makes them well suited to panel designs, and modern CAD programs usually have facilities for adding text in various fonts, styles, sizes and colours.

Illustration software is the type used by most professionals when producing panel designs for commercial equipment. Illustration programs enable drawings to be made accurately to scale, but also provide great scope for designers to 'do their own thing'. There are usually facilities to fill shapes and lettering with complex patterns and graduated colours, together with tools for distorting objects and drawing freehand.

With practically any design you can dream up made possible, it is easy to get carried away with this type of software. You can end up with a design that uses numerous clever effects and seems very good at first, but actually looks out of place on the finished item of equipment. Clever

effects are all well and good in the right context, but are likely to look out of place on the more staid projects such as items of test equipment. It is also easy to end up with a design that most users will find confusing rather than helpful.

A down-to-earth approach generally gives the best result. Try to produce panel designs that are well matched to their projects.

Cheap or free

Illustration and CAD software tends to be aimed at professional users, and this is reflected in the prices you have to pay. A CAD program such as AutoCAD costs thousands of pounds, and an illustration program, such as CorelDRAW or Adobe Illustrator, can cost a few hundred pounds. A lower cost alternative has to be found if you only need the software to produce a front panel design from time to time.

Fig.2. The smaller electronic labelling machines probably represent the simplest way of producing good quality panel legends. Tapes offering various combinations of text and background colour are available

Fortunately, there are some good low cost and free alternatives. While these will not give the full range of features available from expensive illustration or CAD software, they should still be more than adequate for producing good quality front panel designs. In general, they are slightly less straightforward to use than the commercial alternatives, but it should not take long to learn the basics, which are all that is required for producing most panel designs.

Renaissance

After dwindling somewhat, the range of free drawing programs has undergone something of a renaissance. A careful search of the Internet should locate several useful CAD and illustration programs that are available as free downloads.

Some of the old favourites are still available, including a free version of DrawPlus (DrawPlus SE), which has been featured in a least one previous article in this series. It is an illustration program from the British company Serif. This download is available from **www.freeserifsoftware.com** and not the main Serif site (www.serif.com).

Inkscape is probably the most powerful illustration program that is available as a free download, and it is produced as part of the Open Source Project. Versions for computers running under Windows, Linux, and Mac OS X are available. At around 34 megabytes, it will download in less than a minute using a good broadband connection, and it is a practical proposition using a 56k dial-up connection. No minimum hardware requirements are specified, but it seems to work quite well with panel designs and other fairly simple drawings when running on an old PC with a very basic specification.

The screen layout used is the standard one for this type of software (Fig.3), with the usual menu bar at the top. The toolbar down the left-hand side of the screen provides access to the drawing and editing tools that are used most frequently. These are used to draw shapes and text on the screen, to zoom in and out, to apply fancy fills to text and other objects, to draw freehand, and so on. The menu bar and the toolbar beneath it are used for the basic file and editing tasks and setting the text defaults.

The normal first step is to draw the outline of the front panel using the rectangular shape tool. Any holes or other cutouts in the panel are then added. There are rulers above and to the left of the drawing area that are useful when drawing accurately to scale, and an optional grid can be brought up on the screen.

There is a Snap facility that constrains objects so that they can only be drawn on the grid. This provides a quick and easy way of getting everything drawn and aligned very accurately.

All objects, including text have an outline (stroke) and a fill colour. The bottom section of the screen gives quick access to a wide range of colours, and also to dialogue boxes that permit fancy fills such as patterned and graduated types to be added. It is possible to effectively get rid of outlines by setting a width of zero, and fills can be removed by using the 'None' option.

Having completing the scale drawing of the panel and adding any required fills or other effects, it is time to add the text. It is possible to use any font installed on the computer, with a full range of sizes and colours. The full range of stroke and fill facilities are available for text, so it is possible to add clever effects. In Fig.3 a graduated fill has been used for the line of large text near the bottom of the dummy panel design.

When adding text it is probably a good idea to switch off the Snap facility and position things 'by eye'. With text it is sometimes the case that the mathematically correct position actually looks slightly out of kilter. In these situations it is better to use your judgement, and go with what looks right.

Finally

When designing a panel using a computer it is very easy to overlook the practicalities and produce a great looking design that is useless in the real world. This can be avoided by making careful measurements to ensure that there is sufficient room for the actual controls, knobs, sockets, lights, displays, or whatever. On the front side of the panel, ensure that the labels will not be partially hidden under control knobs.

Double-check everything, and try to avoid the classic mistake of omitting a control or socket! Remember that there will be controls and other components on the rear of the panel, and that the layout must leave sufficient space for them. It is a good idea to include drilling marks in the design. It can then be printed on ordinary paper, temporarily glued to the front panel, and used as a drilling guide.

Modern graphics programs, including the better free ones, are quite complex. Be prepared to take some time to learn the range of facilities available from whatever drawing program you select. Some time spent reading through the tutorials and producing some dummy panel designs will make life much easier when you start work on the genuine article.

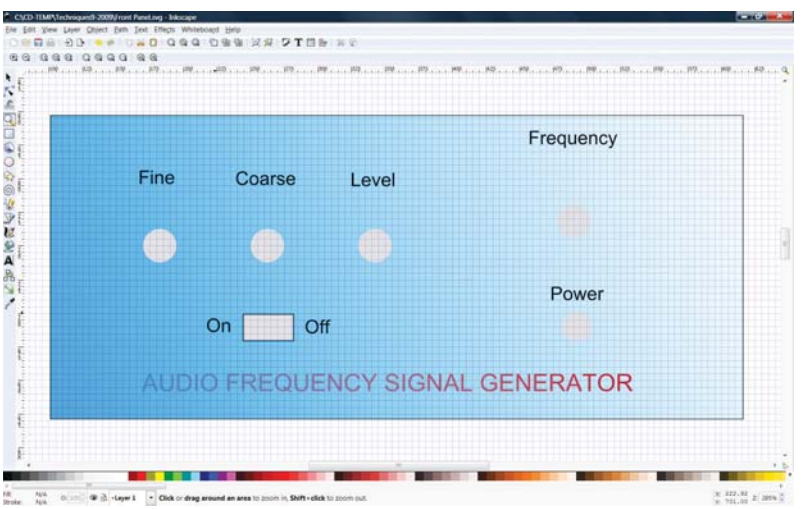

Fig.3. Inkscape uses a standard Windows screen layout with a menu bar and toolbars at the top. The toolbar down the left side of the screen gives access to the facilities that are likely to be used quite frequently

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Real Time Operating Systems – Part 2

We continue this month with an exploration of real time operating systems that can (or might be able to) run on some of the PIC range of microcontrollers. Having covered the terminology around RTOSs last month, we can now take a look under the hood at several freely available versions that can be downloaded from the Internet. We shall be looking at:

Microchip's PIC16 OS (AN585)
FreeRTOS
eCos
Salvo
ucLinux
Contiki

This isn't an exhaustive list of OSs, and there are a few other RTOSs of interest available, but this list covers an interesting range of offerings. The website of each one (listed in the References section at the end of this article) provides a wealth of information and you will find many tutorials and introductions to how small operating systems are designed and used.

Don't forget that many of the terms used to describe operating system features can be looked up on the Internet – Wikipedia has some excellent pages covering all aspects of operating system design. So, if you missed last month's article, or have found a term used that you do not recognise, turn to your favorite Internet search engine.

We will pick one of these operating systems for our example project next month, and will cover installation, setup and use. We haven't decided which OS to use yet; this article is being written over a number of days as we evaluate each operating system, so at this point your guess is as good as ours!

Let's dive in, in no particular order.

Salvo

Salvo is produced by Pumpkin Inc, based in the US. It's a commercial product, but the company provides a freely downloadable 'Lite' version that is fully functional, and appears quite useable. It's limited to just three tasks within the system, so it's really only useful as a learning aid. The user manual is very detailed and they provide some clear, easy-to-follow examples and tutorials.

The limitations mean that we won't be using this OS in our example next month – after all, one of the main reasons for using an OS is to support the development of large, complex applications – but it is worth taking a look at, reading the user manual and examining the tutorials. Studying a diverse range of OS designs is interesting, as it shows the different ways in which an OS can be designed, and it's always nice to see a different 'angle' on how it's done.

Salvo uses a form of 'cooperative multitasking', which means that the currently executing task will continue to run until it gives up its processing time to the OS, usually by calling an OS delay routine, or waiting for a message from another task. This is the simplest type of operating system design, but has the downside that if you have a section of code that takes a long time to execute then all other tasks will have to wait until the current task finishes. That's not always a problem, but it does mean you have to think harder about your design, and sometimes make a compromise or two.

The OS is supplied as a library file that you include into your application build script. It's designed for applications written in C, and fits easily into the Hi-Tech or Microchip compilers. If combined with the Hitech C compiler, it will work with some of the tiniest PICs available – including the PIC12F. That's quite an achievement!

If you are using the Microchip C compiler, however, the smallest PIC processor supported is the PIC18F. This is due to the limitation of the Microchip compiler itself, and not the Salvo operating system. Microchip, in their wisdom, have decided that it is not worth bothering with supporting the C language with these smaller parts, which is a bit of a shame.

Microchip's AN585

Microchip have produced their own simple OS, aimed at the PIC16 family processors. It's over ten years old now and quite dated, but once again it makes interesting reading. Unlike all the other examples, this OS is written completely in assembler, and targeted at the PIC16C64.

Although antiquated, the principles are still interesting and the code is portable to other processors (with some considerable effort.) The design is covered in a 13-page application note AN585, and the full source code is provided as a download.

The source code shows why writing an OS in assembly language is not a great idea. The code is very difficult to read, and not easy to adjust to different use. So we won't say anything more about it, other than to suggest reading the application note.

ucLinux

Many people will be familiar with Linux, the free server and desktop PC operating system first developed by Linus Torvalds in 1991, and now supported by an army of volunteer software developers. Linux is a huge system and completely unsuitable for small microcontrollers, but ucLinux has been developed as a cut down version suitable for microcontrollers that don't have memory management hardware built in.

Memory management is a feature of the larger processors, such as the Pentium and AMD chips, but rarely found in microcontrollers and certainly not in Microchip devices. Memory management allows the processor to isolate each process within its own virtual memory address space, and to use hard disk storage to extend the amount of virtual memory available to the whole system.

ucLinux supports many of the hundreds of free programs and device drivers developed for Linux (including a TCP/IP stack) and so it's no surprise that it is very popular. Many consumer electronic products are based on ucLinux, and the chances are you have something in your home running it – a broadband router, set top box or PVR to name a few. One of the big attractions is that it is completely free – there are no royalty payments or license fees to pay – but from an engineering perspective it's simply the most suitable embedded operating system available.

ucLinux is not a true realtime OS, and cannot respond to interrupts or other events with a defined response time, but in most commercial applications that's not an issue. If your router drops a data packet, or your TV skips a frame, it's no real loss. One couldn't say the same of the control of an aircraft elevator during take off, but those designs are in another league to ours.

Now you might think this is going to be an ideal choice for us, but sadly it's not to be. ucLinux is a fully featured, high specification OS, and makes significant demands on the underlying hardware. Not processor speed, oddly enough; you can run ucLinux on a 16MHz processor, and Microchip processors run at up to 80MHz.

Unfortunately, however, the OS requires a large amount of memory, by small microcontroller standards. A few MBytes of RAM, and about the same of Flash at least. We are looking for an OS that can comfortably sit within a few hundred KBytes of Flash and tens of KBytes of RAM, while still leaving enough space for our own application. So, we must look elsewhere. If you find yourself playing with an ARM micrcontroller, however, it's worth considering.

eCos

Some people consider eCos to be a variant of Linux, but in fact it's very different. Like Linux, it's completely free, although produced under a license that allows you

to use it in conjunction with your own software without requiring you to release that software under an identical license. Linux is released under the GPL, which forces you to release any software that you compile with the Linux kernel (or it's associated GNU libraries) under the same terms, a restriction that can be difficult for commercial companies to accept.

eCos is effectively a runtime system that you link in with your application, somewhat like a library. It implements a single process with the ability to create multiple threads, and like ucLinux does not support memory management – all threads run in the same address space. However, it does provide a rich runtime environment, allowing you to make use of Unix like library and system features, just as ucLinux does.

At the moment, there is no support for any of the Microchip processors, but work is underway for providing a port to the PIC32. Once this is available, it will certainly be worth taking a look. Bear in mind, however, that eCos is a very complex RTOS and is really only suited to experienced software engineers.

Contiki

The previous two operating systems have been relatively 'high end' systems, aimed more at the larger microcontrollers than our humble PIC. Contiki, on the other hand, has been designed with smaller processors in mind, and can operate with just 2KB of RAM and 40KB of Flash.

It started off as a university research project for tiny wireless sensors, and the list of processors that it currently operates on reflects this aim. Unfortunately, the Microchip processors are yet to be supported, which is rather strange, as many other similar types of processor, such as the MSP430, are included. It's a very well designed OS and very clearly documented. There are several network protocol stacks available for it and many wireless device drivers.

Due to it's bias towards small wireless sensors, it is ideal for low power applications and will be perfect for a battery-powered PIC project. Some work has been done informally on supporting Microchip processes; once again, it's a case of waiting and watching.

FreeRTOS

So we come to the final operating system that we will look at this month. FreeRTOS has been designed as a general purpose real time operating system for embedded systems using very small microcontrollers. The OS can fit in 4KBytes of Flash, which will fit easily inside a Microchip processor. The PIC18, PIC24, dsPIC30 and PIC32 parts are already supported too, using the freely available Microchip C compiler.

FreeRTOS can be configured to operate either preemptive or cooperative multitasking. The OS is written in the C language and is contained in just four source files, with a further two files provided for the device-specific code, mostly written in assembly language.

It's probably one of the simplest OSs to understand, and yet provides all the RTOS features that one needs. Just enough, so you are not overwhelmed with complex, confusing features. Despite this, the OS is deployed in many commercial products, and a version of it has been certified for use in safety critical systems – so this is no toy OS.

Although FreeRTOS has evolved into a commercial product, SafeRTOS, FreeRTOS is still an actively supported project in it's own right and remains frequently updated – when we last looked, an update was released ten days earlier. The development team are very supportive and returned emails within a few minutes of our contacting them, and there is a very active user community on their web forum. There are online tutorials, a video that can be downloaded, and books available for sale.

Conclusion

As you might guess, it's the FreeRTOS operating system that we will be playing with next month. While there are other interesting and more powerful free OS's out there, they don't yet support any of the Microchip processors. Their documentation does make for interesting reading, however, and may help fill in the gaps of your understanding of how an embedded OS works.

For now, we are off to find an interesting problem to test FreeRTOS with!

References

Microchip PIC16 Application Note: AN585

FreeRTOS:	**www.freertos.org**
eCos:	**ecos.sourceware.org**
Salvo:	**www.pumpkininc.com**
ucLinux:	**www.uclinux.org**
Contiki:	**www.sics.se/contiki**
PicoOS:	**picoos.sourceforge.net**

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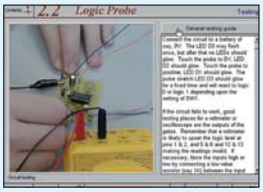
ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS



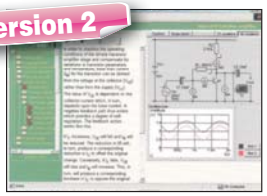
Logic Probe testing

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

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

ELECTRONIC CIRCUITS & COMPONENTS V2.0

Version 2

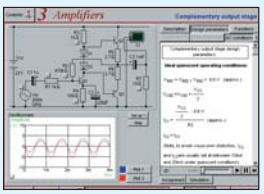


Circuit simulation screen

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

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

ANALOGUE ELECTRONICS



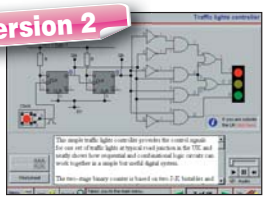
Complimentary output stage

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

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

DIGITAL ELECTRONICS V2.0

Version 2

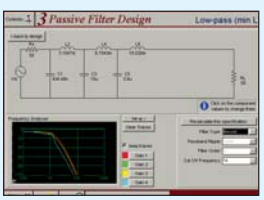


Virtual laboratory - Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

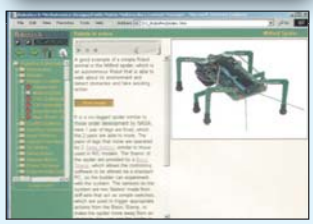
ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student	**£44**	**inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99**	**plus VAT**
Institutional 10 user (Network Licence)	**£249**	**plus VAT**
Site licence	**£499**	**plus VAT**

(UK and EU customers add VAT at 15% to 'plus VAT' prices)

PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

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

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)

£155 including VAT and postage, supplied with USB cable and programming software

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

SOFTWARE

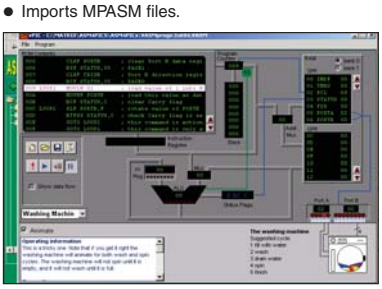
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

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

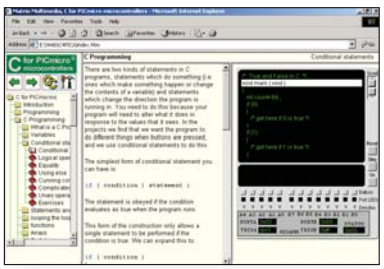


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

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

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



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space. Flowcode will run on XP or later operating systems

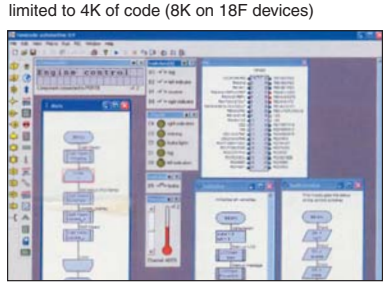
FLOWCODE FOR PICmicro V3

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

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols ● Full on-screen simulation allows debugging and speeds up the development process.

● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 18, 28 and 40-pin devices ● New features in Version 3 include 16-bit arithmetic, strings and string manipulation, improved graphical user interface and printing, support for 18 series devices, pulse width modulation, I2C, new ADC component etc. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

Hobbyist/Student	£44	inc VAT
Institutional (Schools/HE/FE/Industry)	£99	plus VAT
Institutional/Professional 10 user (Network Licence)	£300	plus VAT
Site licence	£599	plus VAT
Flowcode 10 user (Network Licence)	£350	plus VAT
Flowcode 50 user (Network Licence)	£699	plus VAT

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SPECIAL PACKAGE OFFER

TINA Pro V7 (Basic) + Flowcode V3 (Hobbyist/Student)

TINA Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode Circuit Simulation, Testing and PCB Design

£50.00 inc. VAT and p&p

TINA Design Suite is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

Enter any circuit (up to 100 nodes) within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments. Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create, and print documents directly inside TINA or cut and paste your results into your favourite word- procesing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.

***Flowcode V3** (Hobbyist/Student) – For details on Flowcode, see the previous page.*

This offer gives you two seperate CD-ROMs in DVD style cases – the software will need registering (FREE) with Designsoft (TINA) and Matrix Multimedia (Flowcode), details are given within the packages.

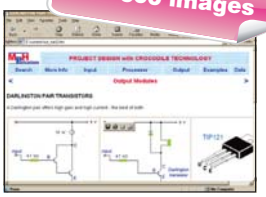
Get TINA + Flowcode for a total of just £50, including VAT and postage.

PROJECT DESIGN WITH CROCODILE TECHNOLOGY

An Interactive Guide to Circuit Design

An interactive CD-ROM to guide you through the process of circuit design. Choose from an extensive range of input, process and output modules, including CMOS Logic, Op-Amps, PIC/PICAXE, Remote Control Modules (IR and Radio), Transistors, Thyristors, Relays and much more.
Click Data for a complete guide to the pin layouts of i.c.s, transistors etc. Click More Information for detailed background information with many animated diagrams.
Nearly all the circuits can be instantly simulated in Crocodile Technology (not included on the CD-ROM) and you can customise the designs as required.*

Over 150 pages
Over 600 images



WHAT'S INCLUDED

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Runs in Microsoft Internet Explorer

All circuits can be viewed, but can only be simulated if your computer has Crocodile Technoloy version 410 or later. A free trial version of Crocodile Technology can be downloaded from: **www.crocodile-clips.com. Animated diagrams run without Crocodile Technology.*

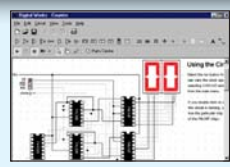
Single User £39.00 inc. VAT.

Multiple Educational Users (under 500 students) £59.00 plus VAT. Over 500 students £79.00 plus VAT.

(UK and EU customers add VAT at 15% to "plus VAT" prices)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME/XP, mouse, sound card, web browser.

DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.

Hobbyist/Student £44 inc. VAT.
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ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 jpg images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Now contains Irfan View image software for Windows, with quick-start notes included.

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☐ **Flowcode V3 for PICmicro**
☐ **Digital Works 3.0**

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Note: The software on each version is the same, only the licence for use varies.

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Ratters And Rotters

TechnoTalk

Mark Nelson

What should we do when electronic products reach the end of their useful life? Binning them is not environmentally friendly and other disposal solutions are downright criminal. It's all rather problematic, as Mark Nelson explains.

ONE of the endearing features of this magazine is its support for 'ratting', the recycling of electronic and electrical gadgets that otherwise would be consigned to the dustbin. Enlightened ratters display great ingenuity in extracting useful components from apparent junk, a skill set that should earn praise from ecologists and indeed from all thrifty folk.

Of course, I aspire to be a ratter as well, although I suspect I'm more of a pack rat. On this score Wikipedia warns that pack rats are people who engage in compulsive hoarding, in reference to the rat's apparent fondness for material objects.

Rather worryingly, the article also shows photographs of the homes of compulsive hoarders and ends by stating that hoarding unnecessary possessions may be referred to as syllogomania or disposophobia. As this looks rather serious, I think it's time to move on rapidly, especially as the dividing line between hoarding and thoughtful provision for possible future need is probably quite easy to cross!

Rotters versus ratters

Praiseworthy as the recycling movement most definitely is, it also attracts less desirable creatures (and I don't mean the rats that may be found at recycling establishments). These absolute rotters are the criminals who are abusing the European Union (EU) directive on the reuse of unwanted electrical and electronic equipment. Organised crime has moved into this field on both sides of the Atlantic, putting both the environment and human health at risk. But how can this happen when we have crystal-clear compliance schemes? And how can low-cost recycling be a problem?

Let's examine the facts. Despite the downturn in the economy, there's plenty of money to be made from recycling electrical and electronic waste. Gold-plated connectors, copper wire from transformers and steel from equipment cases are well worth extracting if the recovery process is cheap enough. Unfortunately, the cheapest method is shipping the waste to countries with low labour costs, where the equipment is stripped and then burnt.

'In Africa, China and India, young children are used to recover tiny amounts of metal,' stated an article in *The Guardian* a couple of months ago. This quoted American environmental activist Ted Smith as saying: "Chips are removed from circuit boards over open fires and give off lead fumes in the process. Children are digging out carbon black from toner cartridges. Other components are put into acid baths in sweat shops.

In lots of parts of the world, the reclamation takes place by the side of ditches and rivers and poisonous chemicals leach into the environment. In China, children are already being found with high levels of chemicals in their blood."

Ugly picture

Needless to say, environmentally-hostile recovery processes of this kind do not take place in Britain, but therein lies the crisis. Exporting the problem elsewhere is ethically criminal and a really ugly picture of what's happening on a massive scale, according to Ted Smith. He claims that between 50 and 80 per cent of all of electrical waste material collected in the USA makes its way abroad, as well as significant amounts from the UK and Europe.

Although exporting waste electrical and electronic equipment (WEEE) is prohibited by the EU's WEEE Directive (and by the Electronic Waste Recycling Act of California), criminals are flouting this legislation by declaring their scrap as functional apparatus. This is then exported for 'reuse' in developing countries, where in fact it is broken up for the materials worth recovering.

In this way it leaves the country illegally by the container load, often camouflaged by outer layers of working (but unsalable) equipment surrounding the scrap stuff. Earlier this year, police and Environment Agency (EA) officials raided two industrial sites in Essex, where they found some 360 shipping containers full of electrical and computer equipment destined for west Africa. Also discovered during the raid were other signs of organised crime: £80,000 worth of vodka and cigarettes, illicit import documentation and other stolen goods.

Since its clampdown initiative started last year, the Agency has made 10 arrests of suspected organised criminals involved in the illegal export of WEEE, stating that it is becoming an increasing problem, with materials being stripped down under appalling conditions. According to intelligence manager Trevor Parish, the EA is determined to crack down on the "big, the bad and the nasty".

Are you a criminal too?

Ultra-ecologists might argue 'you are a criminal' if you have ever put spent batteries or 'dead' gadgets in the dustbin, particularly when you consider that every year British households throw away around one million tonnes of WEEE, including some 1.5 million PCs alone. This figure is set to grow as more and more electrical goods have inbuilt obsolescence, and prices make it more economical for consumers to throw goods away rather than repair them.

Although we have a tolerably good record of recycling large kitchen appliances, many other items are not treated or recycled, but instead get buried in landfill sites, wasting resources and putting a major strain on the environment. For this reason, an increasing number of products are marked with the crossed-out wheelie bin symbol, which means 'don't bin this'. You'll find this marking on an increasing range of electrical goods, such as televisions, batteries, phones, fridges, household gadgets and even light bulbs.

Is it a crime then to dump these items in the bin? Not if you are a householder, but this doesn't absolve you from disposing of this equipment responsibly. The government's initiative has created a network of collection points for WEEE and you should find it easier to recycle your old equipment using separate bins at local authority civic amenity sites and new take-back facilities provided by retailers.

It's the law

While slipping a worn-out computer keyboard in the bin won't land you in jail, the law is completly different for traders. Retailers, distributors and manufacturers have a specific legal obligation to dispose of these goods responsibly. Shops that sell electrical goods must either offer to take back waste themselves or else take part in a distributor take-back scheme (and tell you how to participate).

Since July 2007, retailers have been obliged to take back defunct products at no charge when you make a like-for-like purchase (for example, take back your old television when you buy a new one), no matter where you bought the item originally. Holding them to this might be tricky but this is what the regulations say.

You can find out more at two websites: **www.environment-agency.gov.uk/weee** and **http://myzerowaste.com/**, or alternatively call the Environment Agency helpline 08708 506506.

Many of the gadgets we might junk need not be binned in fact, at least not if they are in working order. Computers and mobile phones, even outdated ones, have a value for recycling or export to third-world countries and will be collected free. Take a look at the websites: **www.envirophone.com** and **www.computeraid.org**. Another very worthy organisation is Freecycle, which is an ingenious network of local websites on which you can advertise unwanted goods and have them removed for nothing (**http://www.freecycle.org/groups/unitedkingdom/**).

READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer 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

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000µF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

★ LETTER OF THE MONTH ★

TV modification

Dear EPE

I picked up a copy of *EPE* quite by chance a couple of weeks ago when I was getting the Saturday newspaper. I hadn't realised that a magazine like yours was still published, thinking that the likes of *Everyday Electronics*, *Practical Wireless*, *Practical Electronics* and *Electronics Today International*, which I grew up with, had long been dislodged by the various computing and gaming titles.

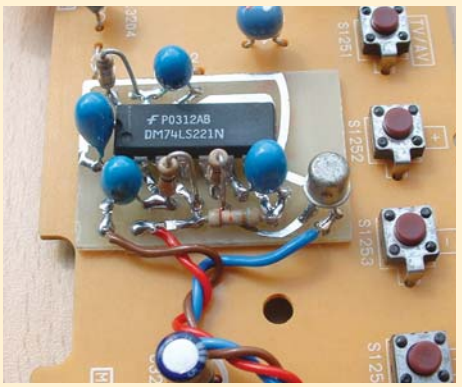
From the mid-70s until a few years ago, I had subscribed to *Television* magazine (I stopped when a change of editor sent it spinning off course) so your magazine could fill a gap in my reading – although there isn't really much of a gap, as I don't seem to have enough time to read my *Which?* and *Computing Which?* magazines, despite being retired (or possibly on a career break).

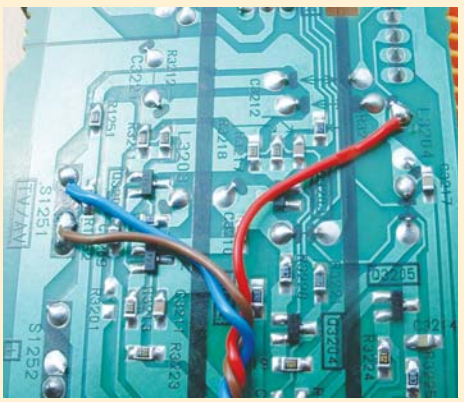
I left Imperial College in 1979 with a 2.2 in electronics and spent eight years working at BBC TV Centre and Lime Grove, West London in engineering operations and maintenance, before moving to Channel 4 in 1987, from which I took voluntary redundancy in 2006. As well as working on the full range of professional broadcast equipment, I designed and built my own electronics projects and modified or repaired a wide range of consumer products.

As an example, I've just modified our Panasonic TV (which uses the very common Euro 4 chassis) so that when it powers-up, or comes out of standby, it automatically selects its AV1 input, since we now watch using our Freeview PVR, rather than the TV's analogue tuner. I've attached some photos (including some of other projects) in case you think this might be suitable for an *Ingenuity Unlimited* item; I could easily write a supporting text referencing the way the TV selects its inputs and mention other possible uses. A 'dos-and-don'ts' article on general repair/construction methods (based on 35 years' experience) is another possibility ('Why desoldering braid beats a solder-sucker').

Anyway, congratulations on a high quality publication – it has a clean, fresh feel with much better graphics and photographs than I remember from those earlier titles!

Steve Burgess, by email





We're always pleased to be 'rediscovered', and while many of our former competitors have fallen by the wayside, I am pleased to report that EPE *is flourishing. Your professional history and TV projects sound fascinating, and I would certainly encourage you to consider writing for us on the topics you suggested.*

Mac and Linux interfacing

Dear EPE

I found *EPE* in the local newsagent recently and was very pleased to find a magazine that focuses on practical electronic projects. I was further pleased to read your editorial in the June 2009 issue, where you indicate that you want to support projects on Macintosh and Linux as well as Windows.

I have worked with interfaces for Macintosh computers for many years when building robots for research. Often, I had to find my own solutions to interface problems. To make these solutions available to others, I developed a website on 'Input, Output and Embedded Systems for Macintosh', **www.uow.edu.au/~phillip/MacInOut/index.html**.

We have found the website a useful way of documenting our projects and often refer to it when designing a new interface.

Also, at *WWDC'09* in San Francisco in June, Paul Holden presented a session (Session 507) on 'Creating iPhone Apps that communicate with accessories'. An accessory is a piece of hardware that is external to your phone. It can be connected through Bluetooth or through the USB and UART in the dock connector. Accessories are supported by the EA-Framework in the iPhone 3 SDK. Information is available for developers on the developer website **http://developer.apple.com**.

iPhone and session videos can be purchased through the iTunes store **http://developer.apple.com/products/videos.html**.

I look forward to some practical electronic projects for both the Mac and the iPhone in future editions of *EPE*.

Dr Phillip McKerrow, Australia, by email

Thanks for your warm comments Phillip, and the links to your fascinating website – perhaps we can find a way to persuade you to get the Mac ball rolling with an interface project!

Net Work

Alan Winstanley

Google, the dominant search engine, continues to roll out more features, mainly because it can. The fuss about Google Street View peeping over the garden fence has subsided, and it is only a matter of time before the integration of the panoramic photo-realistic imagery is complete, with villages and even tiny hamlets falling under the withering gaze of Google's photo cars.

The shock of having one's 'neck of the woods' available on Google for all to see may unbalance the sensibilities of some, but it is not as though the whole world is suddenly looking through the window, though it may feel that way at first. In the US, fire departments use Google Street View to see how large a building is, to help assess what sort of firefighting equipment or ladders they will need when called out on duty.

Doing more business

The search aspect of Google now includes links, maps and graphics for local enterprises, powered through Google Local Business Center. A Google account is needed to utilise it. I feel it is important that businesses check out this service and 'claim' their business in Google Maps, setting up descriptions of their firm (with a healthy sprinkling of keywords) along with a thumbnail graphic or two, so that when your firm's website is flagged up in keyword search results, your own 'business card' can be shown, with no chance of your links being hijacked by rivals.

During the registration process, Google sends you an automated phone-based PIN number: type this into your online account page to validate the setup. Then continue to enter descriptions about your business, including opening hours, brand names, photos and more, and Google will update its database in a few hours.

As mobile bandwidth improves and phone handsets become more accessible, there is an increasing drive towards using mobile search. It will become routine to 'Google' on a mobile phone for, say, the nearest pizza shop or brideswear boutique: Google Maps will show the way. Couple this with mobile step-by-step satellite navigation such as Tom Tom, and you have a fully automated way of steering customers right to your door. All businesses should become familiar with Google Local Business Center and register their business straight away. For more information, see **www.google.com/local/add**

Meanwhile, Microsoft continues to pick up the pace with Bing, its answer to Google that I mentioned briefly in last month's column. Bing has some attractive features that makes it more appealing to use, and it has now added Visual Search as a means of displaying results in thumbnail pictures rather than wading through lists of hyperlinks. Bing is gaining some ground on Google and is set to become a major rival in a maturing search engine world.

Safe and F-Secure

My Carbonite online backup recently expired, so I decided to brandish my credit card for another year. I was charged $220 for a $55 renewal, which did not enhance my confidence in Carbonite's renewals process, and a month passed before I had sight of my cash once again. (You can read more of this saga in my *Net Work* column at *EPE Online*.) Carbonite is also starting to show some technical black holes, including the discovery that it cannot back up some key directories manually, the backup of USB external hard drives has still not been addressed, and it cannot access network drives either. Carbonite's exclusion list also contains the Windows Application Data folder, as well as **.exe** and **.dll** files.

Apart from online backups, I take local backups to a Netgear SAN drive using my preferred choice of Vision Backup Pro from **www.vwsolutions.com** which, unlike Carbonite, takes my networked drives in its stride. Carbonite Pro was touted last year as addressing network backup needs, with costs tiered by a storage amount which can be shared among an unrestricted number of networked PCs. You can download a beta tryout at **www.carbonitepro.com**.

For the past thirty days, I have also been faced with daily nagware popups on my laptop and PCs reminding me that my F-Secure Anti Virus was due to expire: it's that time of year when I consider what's on offer in the world of anti-virus software. F-Secure 2010 from **www.f-secure.com** has received a total makeover, maintaining an attractive and appealing front-end without bombarding the user with too many choices. It is unobtrusive and slick, though the initial cost is about £58 for three PCs; thereafter the annual renewal/upgrade cost is just £19.95 for three licences. A hot rival contender is Kaspersky (**www.kasperksy.com**) which is £39.99 for three anti-virus licences per year, while others to consider are produced by Symantec, McAfee, Panda and Avast. You can often download free trials, but it is very unwise to try running several anti-virus products in tandem, as they will often uninstall any existing products beforehand.

For home and non-commercial use, probably the best choice is the free AVG Anti Virus from **http://free.avg.com/download**. If you have an old Windows 98 machine, then antivirus protection is fast becoming a problem because Avast will stop supporting Windows 98 at the end of this year, and none of the major brands seem to support Windows 98 any longer.

F-Secure Anti-Virus 2010 has had a complete overhaul, but remains unobtrusive and easy to use

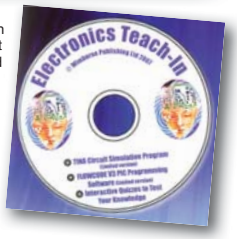
Online bonus

I hope regular *Net Work* readers are following the bonus material on *EPE Online* – simply visit **www.epemag3.com** and click the *Net-Work* link along the top menu. You can view the extra content, with various hyperlinks already made for you to click through. In the September online column, I described problems renewing my Carbonite subscription, how to access your router settings and also outlined my chequered history of taking backups, suggesting a simpler but very robust backup program that I have now adopted.

You can email me at **alan@epemag.demon.co.uk**. It's great to receive your feedback, but due to the volume of mail I don't always manage to reply personally.

DIRECT BOOK SERVICE

Electronics Teach-In CD-ROM



Mike Tooley

A broad-based introduction to electronics – find out how circuits work and what goes on inside them. The CD-ROM contains the whole *Teach-In 2006* series (originally published in *EPE*) in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the Teach-In series.

The interactive Review tests will help you to check your knowledge at the end of each part of *Electronics Teach-In*. You can take these tests as many times as you like, improving your score with each attempt.

The final test covers all aspects of *Electronics Teach-In* and will provide you with a means of checking your overall knowledge of electronics. Once again, you can take the test as many times as you like.

CD-ROM **Order code ETI – CD-ROM** **£8.50**

CIRCUITS AND DESIGN

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** **£5.45**

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** **£5.49**

MICROCONTROLLER COOKBOOK
Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages **Order code NE26** **£25.99**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS AND CDROMS SEE THE SHOP ON OUR UK WEBSITE

www.epemag.com

All prices include UK postage

2

COMPUTING AND ROBOTICS

WINDOWS XP EXPLAINED
N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and home editions.

The book was written with the non-expert, busy person in mind. it explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, notepad and paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; how to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows set-up, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

264 pages **Order code BP514** **£7.99**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages + Large Format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Covers the Vision command system

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages **Order code BP902** **£14.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages **Order code NE36** **£20.99**

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION
John Crisp

If you are, or soon will be, involved in the use of microprocessors and microcontrollers, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors and micrcontrollers. Assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern micros.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** **£22.00**

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.

192 pages + CD-ROM **Order code BP542** **£8.99**

ROBOT BUILDERS COOKBOOK
Owen Bishop

This is a project book and guide for anyone who wants to build and design robots that work first time.

With this book you can get up and running quickly, building fun and intriguing robots from step-by-step instructions. Through hands-on project work, Owen introduces the programming, electronics and mechanics involved in practical robot design-and-build. The use of the PIC microcontroller throughout provides a painless introduction to programming – harnessing the power of a highly popular microcontroller used by students, hobbyists and design engineers worldwide.

Ideal for first-time robot builders, advanced builders wanting to know more about programming robots, and students tackling microcontroller-based practical work and labs.

The book's companion website at http://books.elsevier.com/companions/9780750665568 contains: downloadable files of all the programs and subroutines; program listings for the Quester and the Gantry robots that are too long to be included in the book.

366 pages **Order code NE46** **£21.99**

NEWNES INTERFACING COMPANION
Tony Fischer-Cripps

A uniquely concise and practical guide to the hardware, applications and design issues involved in computer interfacing and the use of transducers and instrumentation. Newnes Interfacing Companion presents the essential information needed to design a PC-based interfacing system from the selection of suitable transducers, to collection of data, and the appropriate signal processing and conditioning.

Contents: Part 1 – Transducers; Measurement systems; Temperature; Light; Position and motion; Force, pressure and flow. Part 2 – Interfacing; Number systems; Computer architecture; Assembly language; Interfacing; A to D and D to A conversions; Data communications; Programmable logic controllers; Data acquisition project. Part 3 – Signal processing; Transfer function; Active filters; Instrumentation amplifier; Noise; Digital signal processing.

295 pages **Order code NE38** **£35.99**

PROJECT BUILDING

ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different.
The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages **Order code BP371** **£5.45**

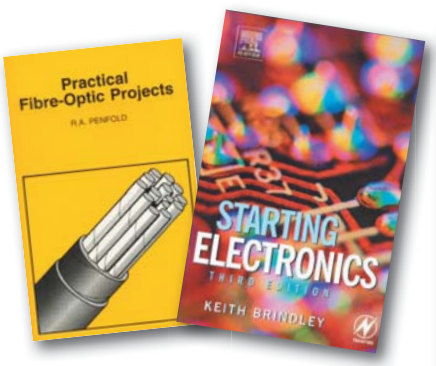
BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.
A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.
Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£23.99**

THEORY AND REFERENCE

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£5.49**



STARTING ELECTRONICS
Third Edition
Keith brindley
A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.
A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.
Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

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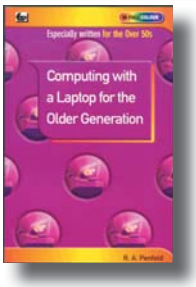

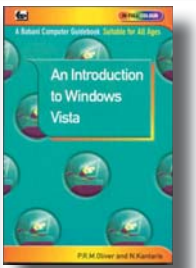

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

STARTING ELECTRONICS, THIRD EDITION
Keith Brindley
A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.
A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.
Breadboarding layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

288 pages **Order code NE42** **£12.99**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold
Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.
There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.
Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages **Order code PC115** **£5.45**

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Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

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PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. Tel: 01202 873872; Fax 01202 874562; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

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

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

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Magnetic Cartridge Preamplifier	681	£7.45
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★ Spectacular Bike Wheel POV Display (double-sided)	711 (set of 3)	£23.73
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★ Solar Water Heating System Controller		
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AUGUST '09		
★Fast Charger For NiMH Batteries	720	£6.66
★Rolling Code Keyless Entry System		
– Main Board	721	£7.29
– Transmitter (2off)	722 (2off)	£6.18
SEPTEMBER '09		
PIC Programmer SOIC Converter	723	£5.07
★ Random Mains Timer	724	£9.51
OCTOBER '09		
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– Main (pair)	731 } set	£9.99
– PSU	732 }	
Emergency 12V Lighting Controller	733	£7.20
★Digital VFO With LCD Graphics Display (doubled sided)	734	£13.00

EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards can also be downloaded from our website (**www.epemag.com**); **go to the 'Library' section.**

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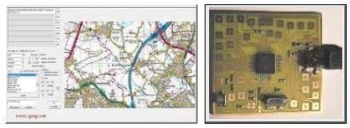

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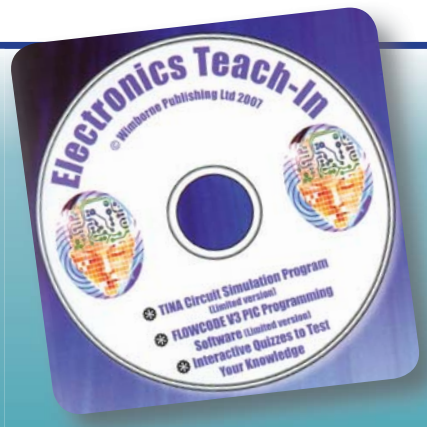

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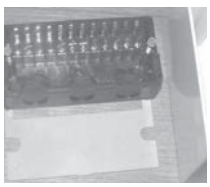

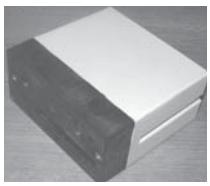

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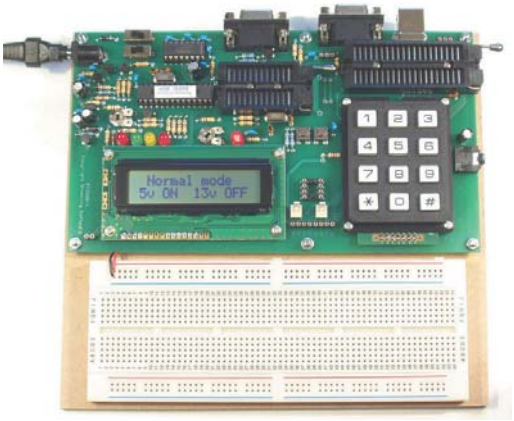
Learn About Microcontrollers



P928 PIC Training Course £164

The best place to begin learning about microcontrollers is the PIC16F627A. This is very simple to use, costs just £1.60, yet is packed full of features including 16 input/output lines, internal oscillator, comparator, serial port, and with two software changes is a drop in replacement for the PIC16F84.

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Experimenting with PIC Microcontrollers

This book introduces PIC programming by jumping straight in with four easy experiments. The first is explained over seven pages assuming no starting knowledge of PICs. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's Fur Elise. Then there are two projects to work through, using a PIC as a sinewave generator, and monitoring the power taken by domestic appliances. Then we adapt the experiments to use the PIC16F877 family, PIC16F84 and PIC18F2321. In the space of 24 experiments, two projects and 56 exercises we work through from absolute beginner to experienced engineer level using the most up to date PICs.

Experimenting with PIC C

The second book starts with an easy to understand explanation of how to write simple PIC programmes in C. Then we begin with four easy experiments to learn about loops. We use the 8/16 bit timers, write text and variables to the LCD, use the keypad, produce a siren sound, a freezer thaw warning device, measure temperatures, drive white LEDs, control motors, switch mains voltages, and experiment with serial communication.

Web site:- www.brunningsoftware.co.uk

PH28 Training Course £189

PIC training and Visual C# training combined into one course. This is the same as the P928 course with an extra book teaching about serial communication.

The first two books and the programmer module are the same as the P928. The third book starts with very simple PC to PIC experiments. We use PC assembler to flash the LEDs on the programmer module and write text to the LCD. Then we learn to use Visual C# on the PC. Flash the LEDs, write text to the LCD, gradually creating more complex routines until a full digital storage oscilloscope is created. (Postage & ins UK £10, Europe £20, rest of world £34).

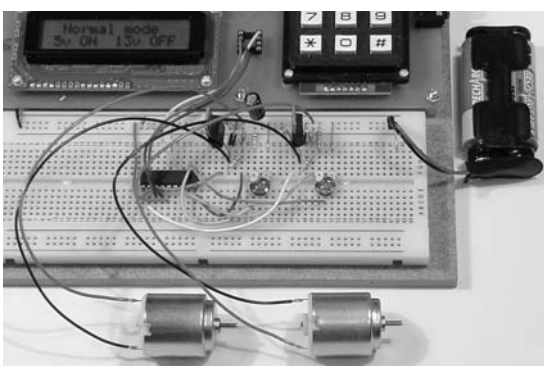
P31 Training Course £90

For £90 you get a modular programmer consisting of USB interface PCB + programmer PCB + PIC16F627A experimental PCB, LCD module, plugboard, USB lead, CD of software, and the book Experimenting with PIC Microcontroller (as supplied with the P928 course). The 24 experiments and two projects can be worked through just the same as with the P928 course. Optional extras include an experimental PCB for use with the PIC16F870 and PIC18F2321, and the second and third books of the P928/PH28 course. The software is the same as supplied with the P928 course and the books are the same except for using the P31 programmer and experimental PCBs. Start with the low cost P31 course and expand the course over time to achieve the same training as the P928/PH28 course. (Postage & ins UK £6, Europe £12, rest of world £18).

Ordering Information

Our P928 course is supplied with a USB adaptor and USB lead as standard but can be supplied with a COM port lead if required. All software referred to in this advertisement will operate within Windows XP, NT, 2000, Vista etc.

Telephone with Visa, MasterCard or Switch, or send cheque/PO.



White LED and Motors

Our PIC training system uses a very practical approach. Towards the end of the second book circuits need to be built on the plugboard. The 5 volt supply which is already wired to the plugboard has a current limit setting which ensures that even the most severe wiring errors will not be a fire hazard and are very unlikely to damage PICs or other ICs.

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