THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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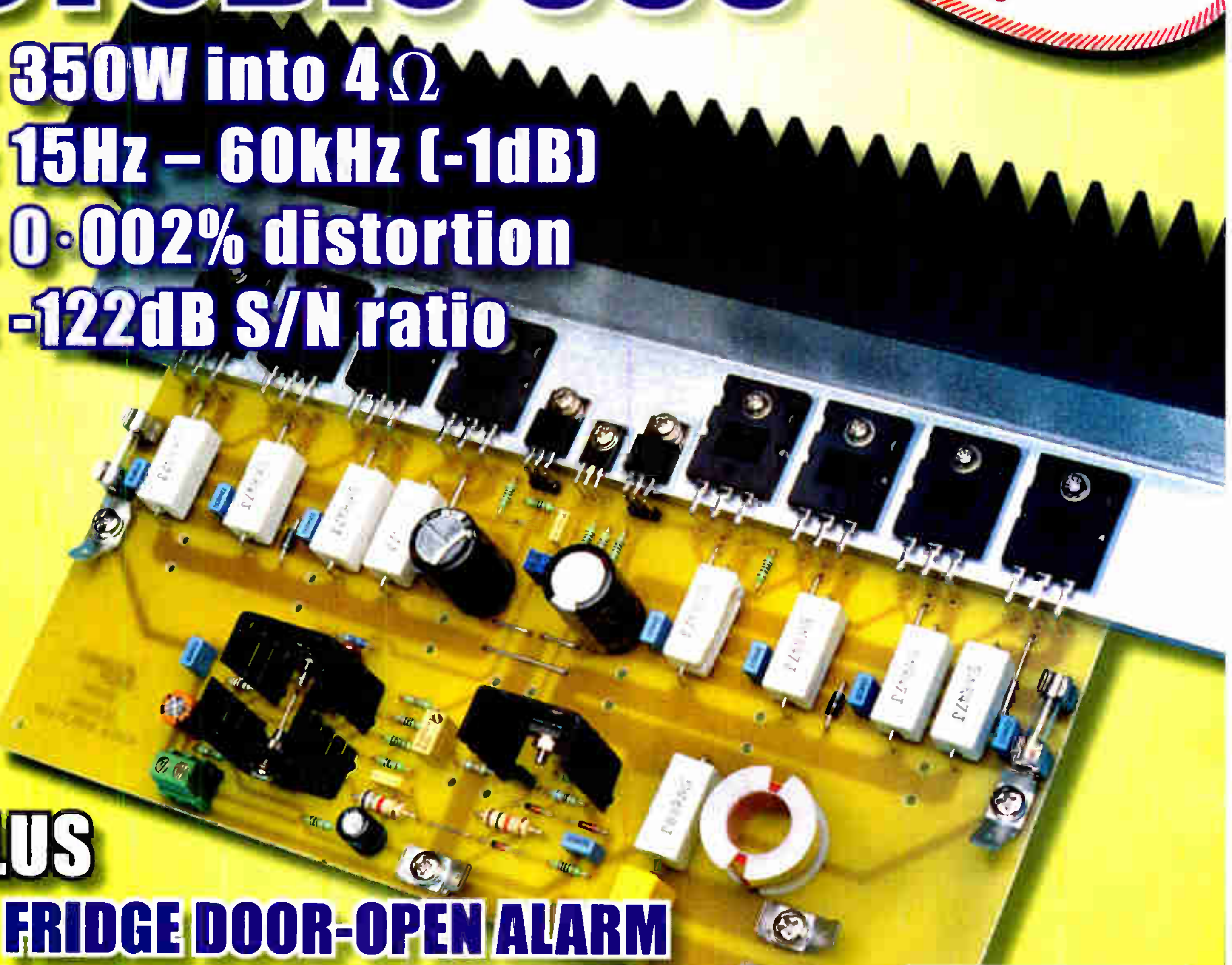

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* FRIDGE DOOR-OPEN ALARM
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OCTOBER 2006 £3.30

NEW ELECTRONIC CONSTRUCTION KITS

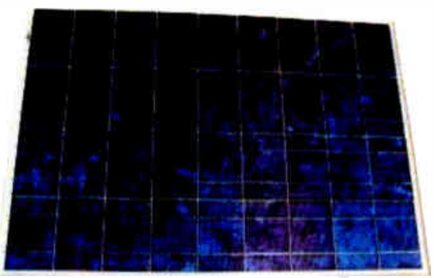
This 30 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides conponents that can be used to make a variety of experiments including Timers and Burglar Alarms. Requires: 3 x AA batteries. £15.00 ref BET1803

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

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

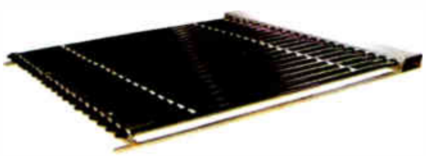
The **75 in 1 electronic kit** includes an nintroduction to electrical and electronic technology. It provides conponents that can be used to make and test a wide variety of experiments including Water Sensors, Logic Circuits and Oscillators. The kit then progresses to the use of an intergrated circuit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

SOLAR PANELS



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

EVACUATED TUBE SOLAR HOT WATER PANELS



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

2kW WIND TURBINE KIT

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

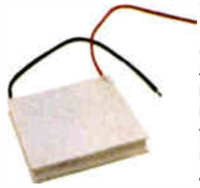
Other sizes available from 200 watts (£299) up to 20kW (£13,999) The 200w system is complete apart from 2x12v batteries and concrete for the tower. These low cost systems can provide substantial amounts of power, even in average wind conditions.

STEAM ENGINE KIT

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

HOT AIR MOTOR (Stirling motor) This is an interesting metal based project for pupils aged 15 plus. The material pack will enable them to make a fully functional hot air motor. All the critical parts (piston, working cylinder, flywheel and coolers) have been pre-made and are ready for use. The detailed plans show all the important stages for the required metal working (Measuring with a vernier, sawing, silver soldering, drilling, marking out,thread making, silver soldering, sawing and filing, etc) At the same time the principles of the hot air motor are described in the wide ranging instructions. Technical data : Working cylinder stroke ø 12 x 10 mm Pressure cylinder stroke ø 13 x 11 mm

Unloaded speed approx. 800 rpm Size: Flywheel dia. 55mm Base 130 x130 mm With sinter smooth bearings and ready shaped cooler. £29.70 ref STEAMKIT2 Silversolder pack £3.50 ref SSK



Thermo **Peltier element**, large Size: 40 x 40 x 4,7 mmTechnical data of the Thermo element:Use as a Peltier element to cool or heat: will provide 33 Watts of heating or cooling, max temp difference between sides of 67ºC, maximum output 15V 3,9 Ampere 150ºC 3,5 Ohm 250 mW/K 22 g, 49 mV/K £14 ref TEL1

Die cast illuminated microscope set in plastic carry case Includes a handy carry case with a 1200x magnification microscope. Contents include test tubes, magnifier glass and probe. Requires 2 x AA batteries (not included). ultra-compact, lightweight, easy to use and comfortable to hold. An ideal microscope for the beginner offering a good magnification range. £25.99 ref MAG1200

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STIRLING ENGINES

HB10 One of our range of Stirling engines The Bohm HB10 Stirling engine is available in both ready built and kit form. The power comes from a small spirit burner, once lit just watch this amazing Stirling engine run. HB10 in kit form is £97.95 or £101.99 built. Many other models in stock. Order online at www.mamodspares.co.uk

Rapidos Mobile networking digital surveillance system. Plugs into USB port on computer, takes 4 cameras, NSTC or PAL, 352*288 res, 1-30 f/s MPEG4 & MJPEG, motion detection, pre and post recording, watermark, date, time and location markings, alarm notice via FAX, FTP or email, Modes- continuous record, motion detection record, sheduled record, time lapse record, dynamic IP, can send live images to your mobile phone. £109 ref RAPIDOS

HEAT PUMPS

A heat pump is a system that uses a refrigeration-style compressor to transfer heat from outside to inside, in order to heat offices or homes. Heat pumps can take heat from the air, water or ground. Ground source heat pumps are very efficient – in fact you will get 3-4 units of heat for every unit of electricity supplied to the heat-pump. Basic component parts of a GSHP:

1 A heat pump packaged unit: Water-Water type. (approx. the size of a small fridge) containing two cold water connections and two heated water connections.

2. The heat source which is usually a closed loop of plastic pipe containing water with glycol or common salt to prevent the water from freezing. This pipe is buried in the ground in vertical bore holes or horizontal trenches. The trenches take either straight pipe or coiled (Slinky) pipe, buried about 1.5 to 2m below the surface. A large area is needed for this.

3. The heat distribution system. This is either underfloor heating pipes or conventional radiators of large area connected via normal water pipes.

4. Electrical input and controls. The system will be require an electrical input energy, single phase is perfectly adequate for smaller systems. A specialised controller will be incorporated to provide temperature and timing functions of the system.

This type of installation offers many advantages.

a) The water-water heat pump unit is a sealed and reliable self contained unit.

b) There are no corrosion or degradation issues with buried plastic pipes.

c) The system will continue to provide the same output even during extremely cold spells.

d) The installation is fairly invisible. i.e. no tanks or outside unit to see.

e) No regular maintenance required.

Some tips

The efficiency of any system will be greatly improved if the heated water is kept as low as possible. For this reason, underfloor heating is preferred to radiators. It is vital to ensure that the underfloor layout is designed to use low water temperatures. i.e. plenty of pipe and high flow-rates. If radiators are to be used, they must be large enough. Double the normal sizing (as used with a boiler) is a good starting point.

5Kw (output) ground to air heat pump £1,099 ref HP5
9kw (output) ground to water heat pump £1,999 ref HP9

ISSN 0262 3617

PROJECTS . . . THEORY . . .
NEWS . . . COMMENT . . .
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EPE EVERYDAY PRACTICAL ELECTRONICS

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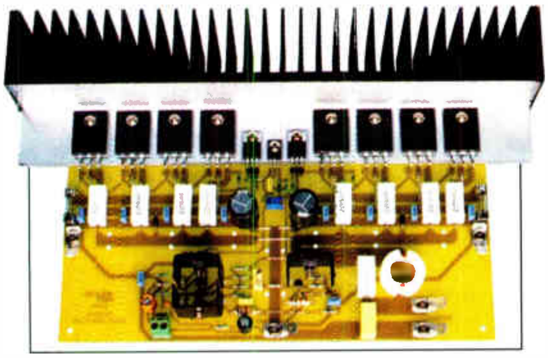
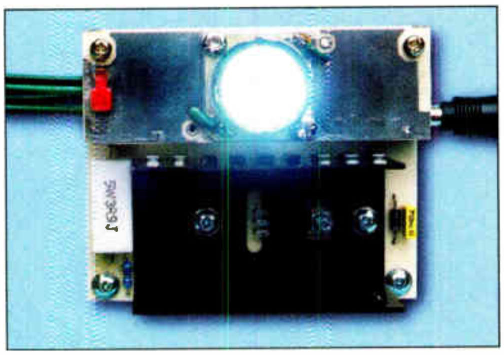
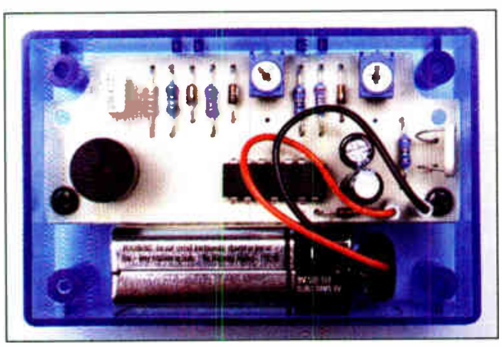






Projects and Circuits

Series and Features

Regulars and Services

Our November 2006 issue will be published on Thursday, 12 October 2006. See page 72 for details

Hot New Kits This Summer!

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

EPE Ultrasonic Wind Speed Meter

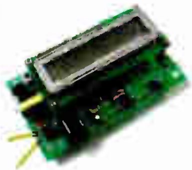
Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

Specifications

- Units of display: metres per second, feet per second, kilometres per hour and miles per hour
- Resolution: Nearest tenth of a metre
- Range: Zero to 50mph approx.

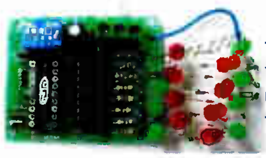
Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see website for full details). Power: 9Vdc (PP3 battery). Main PCB: 50x83mm.
Kit Order Code: 3168KT - **£36.95**

Audio DTMF Decoder and Display



Detects DTMF tones via an onboard electret microphone or direct from the phone lines through an audio transformer. The numbers are displayed on a 16 character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based. Supply: 9-12V DC (Order Code PSU445). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£20.95**
Assembled Order Code: AS3153 - **£29.95**

EPE PIC Controlled LED Flasher



This versatile PIC based LED or filament bulb flasher can be used to flash from 1 to 176 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 super bright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher, EPE Magazine Dec 02. See website for full details. Board Supply: 9-12Vdc. LED supply: 9-45Vdc (depending on number of LED used). PCB: 43x54mm.
Kit Order Code: 3169KT - **£11.95**

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

FM Bugs & Transmitters

Our extensive range goes from discreet surveillance bugs to powerful FM broadcast transmitters. Here are a few examples. All can be received on a standard FM radio and have adjustable transmitting frequency.

MMTX' Micro-Miniature 9V FM Room Bug

Our best selling bug! Good performance. Just 25x15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band. Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT - **£8.95**
Assembled Order Code: AS3051 - **£14.95**

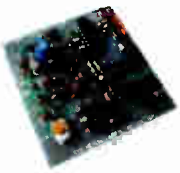
HPTX' High Power FM Room Bug

Our most powerful room bug. Very impressive performance. Clear and stable output signal thanks to the extra circuitry employed. Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip supplied). 70x15mm.
Kit Order Code: 3032KT - **£9.95**
Assembled Order Code: AS3032 - **£17.95**

MTTX' Miniature Telephone Transmitter

Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire - uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20x45mm.
Kit Order Code: 3016KT - **£7.95**
Assembled Order Code: AS3016 - **£13.95**

Wide Band Synthesised FM Transmitter



PLL based crystal-locked wide band FM transmitter delivering a high quality, stable 10mW output. Accepts both MIC audio signal (10mV) and LINE input (1v p-p) for example hi-fi, CD, audio mixer (like our kit 1052) or computer sound card. Supply: 9-15Vdc.
Kit Order Code: 3172KT - **£19.95**
Assembled Order Code: AS3172 - **£32.95**

3 Watt FM Transmitter

Small, powerful FM transmitter. Audio pre-amp stage and three RF stages deliver 3 watts of RF power. Use with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45x145mm.
Kit Order Code: 1028KT - **£23.95**
Assembled Order Code: AS1028 - **£31.95**

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Also available - 30-in-1 **£15.95**, 130-in-1 **£37.95** & 300-in-1 **£59.95** (details on website)

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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.

Precision Digital Multitester (4.5 Digit)

A highly featured, high-precision digital multimeter with a large 4.5 digit LCD display. High accuracy (0.05%). Auto-zeroing, polarity selection and over-range indication. Supplied complete with shrouded test leads, shock-proof rubber holster, built-in probe holder and stand. Supplied fully assembled with holster, battery and presentation box. Features include:
Capacitance • Audio Frequency • Data Hold • hFE / Diode Test • Auto Power Off

Technical Specifications

DC voltage: 200mV-1000V • AC voltage: 2V-700V • DC current: 2mA-20A • AC current: 20mA-20A • Resistance: 200Ω-200MΩ • Capacitance: 2nF-20uF • Frequency: 20kHz • Max display: 19999

Order Code: MM463 - Was £44.95 **Now on sale at just £29.95!**

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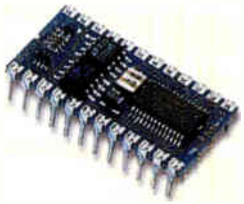


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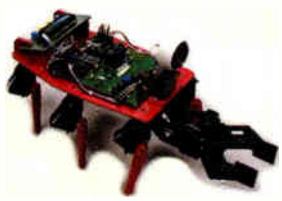
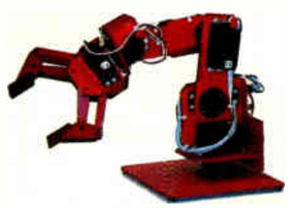


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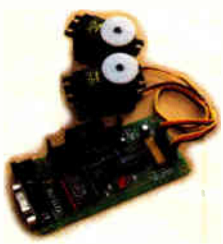
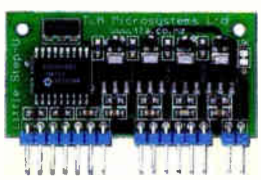


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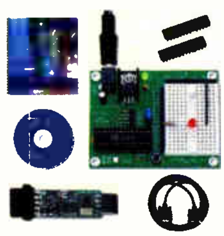

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One Door Closes . . .

Our *Teach-In 2006* series ended last month but if you are quick you can still enter the final On-Line Test, and if you obtain a score of 85% or more your name will go forward to the *Teach-In* prize draw. Prizes have been donated by Rapid Electronics – the first prize is an extensive tool kit worth £275, there are also 21 runner-up prizes. Entries to the prize draw will close at noon on 10 November, but the On-Line Test will remain for some time yet.

The *Teach-In* series has proved to be very popular and we are therefore planning to publish the whole series in book form. Plans for this are still being progressed but we are hoping to include an extra feature on using SPICE circuit simulation software and provide a free cover-mounted CDROM, with the software and interactive Teach-In Tests on it. More on this in a few months time.

.....Another Opens

With *Teach-In* completed we now have room for a short series entitled *Using C*. This has been specially written for us – with hobbyists and students in mind – by Mike Hibbett of *PIC N'Mix* fame (amongst other things). The series will start next month by looking at why you might want to use C, the choice of compilers, and go on to cover such topics as how embedded C programs are structured, how to build them, special features/issues/problems, using Assembly in line with C and linking Assembly modules into C. The series will conclude with an example project using Microchip USB code to build a USB LCD display and simple keyboard for a PC.

Don't miss Part 1 next month, the November issue is on sale on October 12.

Price

Please note that our cover price and subscription fees will have to be increased with effect from next month, so now is the time to subscribe to *EPE* to avoid the price rise (and get your copies for just £2.75 each) for another year – or two if you want to save even more. See page 61 for subscription details or visit our web site at **www.epemag.co.uk**

Mike Kenward

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We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.**

PROJECTS AND CIRCUITS

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 than 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.**

COMPONENT SUPPLIES

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

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

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We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

News . . .

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

SKY'S BROADBAND

Barry Fox reports that Sky has upset the applecart with a radical new approach to broadband pricing

ANYONE who subscribes to any Sky Pay TV package *whether the basic £15 a month or top price HDTV* can now get a free broadband connection. "It's a landmark day", says James Murdoch, Sky's Chief Executive (and son of Rupert Murdoch). "Too many people have being paying too much for broadband for too long".

"The services which have recently been launched, promising cheaper broadband, are tied up with all kinds of catches and conditions" says Brian Sullivan, Sky's Director of Product Strategy and Management, and the man who launched Sky+ and Sky HD. "We asked our satellite customers what they wanted and they said something simple as well as cheap".

Everyone signing up with Sky broadband gets a wireless router free; and everyone gets MacAfee security software and updates free. The Base package is free after a £40 activation fee, which covers the £40 cost of BT's charge to Sky for connection.

However, the free service is capped at 2Mbps speed and 2GB per month. The Mid package gives 8Mbps with 40GB per month and costs £5 per month after £20 activation. The Max package gives speeds up to 16Mbps for £10 per month with unlimited download and free activation. (Non-TV subscribers can pay £17 pm for 8Mbps.) Home installation of the router by an engineer is free for the Max package. Others can self-install or pay £50 for an engineer to call.

Saving £200

Murdoch and Sullivan presented figures which show savings averaging around £200 a year over the competition. "We estimate customers can save £1bn over 18 months or two years. That's money that would be going into the pockets of BT and others", says Murdoch.

The move follows Sky's purchase of Internet Service Provider Easynet; 28% of UK households are now covered by changes already made to BT exchanges and 50% will be ready by Christmas. Murdoch explains why Sky is investing £500m in the project over three years. The new Sky HD box is the first hybrid device, with MPEG-4 capability and Ethernet connectivity as well as satellite reception. "All future Sky receivers will be hybrid. In 2007 there will be software that lets subscribers plug a broadband connection into their satellite receivers. We can then offer video on demand and gaming. Sky is already the largest legal video download service in Europe".

Movie subscribers can download selected features free by broadband to their PCs. Sky's ace is that UK laws now oblige any broadband supplier to provide a MAC (Migration Authorisation Code) which lets a subscriber change service provider easily once their basic contract has expired.

ARE YOU CO SURE?

If you have a Carbon Monoxide (CO) concern and need to know more, Lascar Electronics' EL-USB-CO carbon monoxide data logger could help in determining the nature of the problem.

Carbon monoxide is a poisonous gas which is both odourless and colourless. It is produced by equipment/machinery that isn't working correctly and can be found anywhere from construction sites and furnace rooms to office blocks and homes. Lascar's EL-USB-CO data logger monitors and records CO levels in an environment over a period of time. This can help the user to determine where and when peak levels of CO occur, allowing corrective action to be carried out to remedy the problem.

The EL-USB-CO stores over 32,000 readings and can record CO levels from 0 to 1000 ppm. Setup of the data logger is completed using the supplied EL-USB software, with the EL-USB-CO plugging directly into the USB port of a PC. Here the user can assign the logger a name, choose a sample rate (from a choice of once every: 10 secs, 30 secs, 1 min, 5 mins), as well as determining a high-alarm level. Once setup is complete the EL-USB-CO should be left in the environment where the study is to take place.

The EL-USB-CO is available for purchase at £49.00 from the Lascar website (**www.lascarelectronics.com**). If you have any queries regarding a potential application or would like to discuss the EL-USB-CO further please contact the Lascar sales team on +44 01794 884567 or by email: sales@lascar.co.uk.

ROBOTIC FISH

When recently visiting the London Aquarium, this News editor was fascinated by the display of robotic fish which they have – they are so realistic.

They have been created by Jindong Liu and a team of scientists from the University of Essex, and are the world's first autonomously controlled robotic fish. The three robotic fish are equipped with sensors that allow them to navigate around the tank and learn about their environment. Ultimately, many kinds of sensor will be applied, such as camera and sonar.

Although robotic fish are nothing new, these ones are very lifelike. The way they move when they encounter obstacles or the tank floor, is remarkably similar to that of real fish.

Professor Huosheng Hu, who headed the team of robotics engineers, says that they mimic normal swimming and sharp turning, and that people get confused and think they are real fish.

The team spent three years working with staff at the London Aquarium learning about how different species of fish move and applied their knowledge to the robots, which have been designed to look like carp. Each one is around 50cm (20 inches) long and has shiny scales, and even barbels, like a real carp. The aim is to get the fish to swim as fast as tuna, one of the world's fastest swimming fish species. Members of the Department of Computer Science at the University are aiming to produce a one metre long autonomous robot fish.

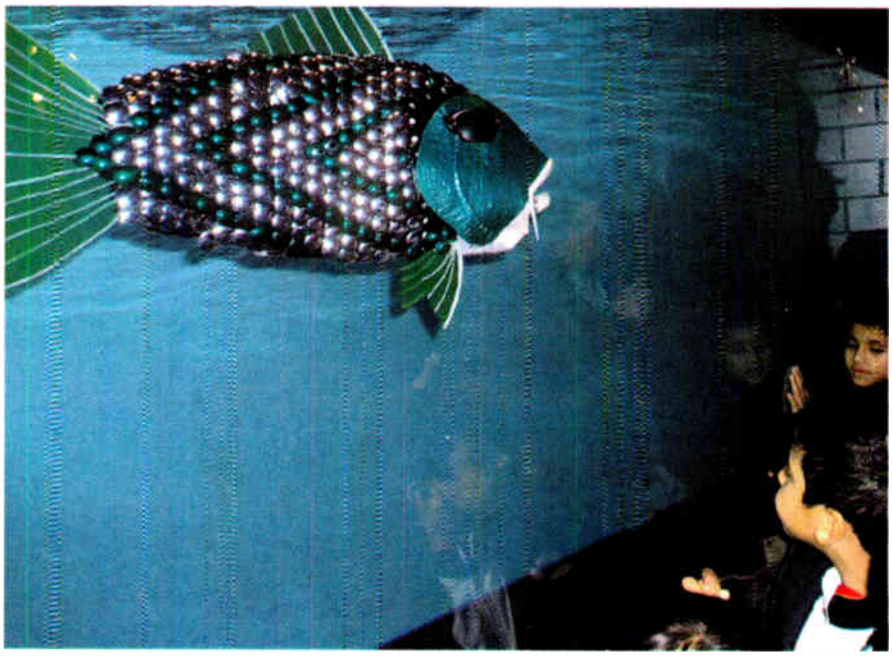

Photo coutesy of Jindong Lui

At the moment the fish are limited to five hours of swimming before their batteries run out.

Professor Hu is reported as saying they want the fish to have the ability to look for their own charging station, just like a real fish looking for food. Later models may be used for underwater exploration for such things as detecting oil pipe leaks or covert surveillance.

The fish are on display at the London Aquarium (close to the London Eye Big Wheel).

We are grateful to Jindong Liu for permission to use the photograph. He is a PhD Student under the supervision of Prof Huosheng Hu and may be contacted at the Department of Computer Science, University of Essex, Wivenhoe Park, Colchester, Essex CO4 3SQ. Tel: +44 1206 872150 (Lab). Fax: +44 01206 872788. Web: **http://privatewww.essex.ac.uk /~jliua**. Also browse the web via **www.google.co.uk**, searching on 'robotic fish'.

New PIC16F Micros

Microchip announces two new 20-pin PIC microcontrollers. The PIC16F631 provides a cost-effective migration from 8- and 14-pin devices, while the PIC16F677 offers affordable hardware I^2C and SPI capability. The devices are a compatible extension of the PIC16F685/687/689/690 series.

Both new microcontrollers feature nanoWatt technology to minimise power consumption – including a Precision Internal Oscillator (operating from 31kHz up to 8MHz), an ultra-low-power Wakeup function, an Enhanced low-power Watchdog Timer and an Enhanced low-power 16-bit Timer with Gate Control.

The key features of both devices include: up to 3.5 Kbytes of Flash Program memory; up to 128 bytes of RAM; two comparators with Set-Reset latch mode; 0.6V internal bandgap reference; in-circuit serial programming technology; brownout reset with software-control option; up to 18 I/O pins.

In addition, the PIC16F677 features 12-channel, 10-bit ADC plus SPI and I^2C support with Address Mask option.

The new devices are supported by Microchip's suite of development tools, including the free MPLAB IDE (Integrated Development Environment), the low-cost PICkit 2 starter kit, and the MPLAB ICD 2 (In-Circuit Debugger).

For more information on the availability of the PIC16F631 and PIC16F677 microcontrollers, in RoHS-compliant 20-pin PDIP, SOIC, SSOP and QFN packages, visit Microchip's Web site at **www.microchip.com**.

Miniature FM Transmitter

MK Consultants has introduced a new high power FM transmitter that delivers class leading long-range performance for a miniature narrow band module. The GT2HP-UHF operates at the UK license-free frequency of 458.85MHz and has a power output of 250mW. The module can be paired with the MK Consultants GR2 receiver.

The small size and high power output performance of the GT2HP-UHF make it ideal for use in the growing number of portable electronics products that require reliable, long range, wireless communications capability. The new module is able to work effectively over ranges of several kilometres in long range switching and telemetry applications such as wireless security, remote controls, paging systems and asset tracking.

The new transmitter uses the latest narrow band crystal technology and can achieve data rates of up to 9600 bits/s. The module requires a nominal DC supply of 5V and has a channel spacing of 25kHz. Although initially available with an operating frequency of 458.85MHz for the UK market, the GT2HP-UHF can be supplied with other frequencies if required.

Due to their high RF sensitivity, GR2 receiver modules are able to operate over long ranges complementing the performance of the GT2HP-UHF transmitter. A switchable data rate filter gives either 2400 baud with –119dBm sensitivity, or 9600 baud with –114dBm sensitivity. The receivers are housed in fully shielded SIL packages measuring 48mm × 17mm × 5mm and feature analogue, digital and true RSSI outputs. Supply voltage can range from 2.7V to 10V.

Both the GT2HP-UHF and the GR2 have an operating temperature range of –10°C to +55°C and are EN 300-220-2 compliant.

For further information contact MK Consultants (UK) Ltd., 288a-290 Queens Road, Halifax, West Yorks HX1 4NS. Tel: +44 01422 329002. Fax: +44 01422 353153. Email: mo@mkconsultants.prestel.co.uk. Web: **www.mk consultants.eu**.

Studio 350 Pow Amplifier Modu

Want an audio power amplifier with some real grunt? Want an audio power amplifier which is really quiet and has very low distortion? Here is the one answer for both desires. The Studio 350 is a rugged power amplifier module capable of delivering 200 RMS watts into an 8-ohm load and 350 watts RMS into a 4-ohm load, at very low distortion.

Pt.1: By LEO SIMPSON & PETER SMITH

OUR first approach on designing this amp was to decide on the target power output, given a likely supply rail. We decided to aim for 200 watts into an 8-ohm load. A few back-of-an-envelope calculations showed that we would need supply rails of about ±70V or a total of 140V.

Naturally, we would also want to drive 4-ohms loads and with those same supply rails we would expect to obtain around 350 watts. But how many output transistors and what type would be required? As you can see from the photos and circuit, we have used eight 250V 200W plastic power transistors: four MJL21193/4 complementary pairs. These are teamed with the high-performance MJL15030/31 complementary driver transistors.

In addition, we have used some high-voltage low-noise transistors in the input stage and highly linear high-voltage video transistors in the voltage amplifier stage. The net result is a rugged power amplifier with very low residual noise and distortion.

Load lines and power ratings

So why did we end up using eight 200W transistors in order to get just 200W into 8Ω and 350W into 4Ω? It might seem like over-kill but it is not. To work out the dissipation in a transistor, you need to draw the load lines. These show power dissipation in the active device (in this case, one half of the output stage, consisting of four transistors). The vertical axis is in Amps while the horizontal axis is Volts. The various load lines for our amplifier are shown in Fig.1.

For a start, we plotted the lines for 8-ohm and 4-ohm resistive loads and these are straight lines, showing all possible conditions. The two resistive lines start at the 70V mark on the horizontal axis, corresponding to the supply voltage applied across one half of the output stage (either the NPN or the PNP transistors). For the 4Ω load, the load line runs up to 17·5A on the vertical axis, corresponding to the current delivered if the active device was fully turned on (ie. 70V/4Ω = 17·5A).

Similarly, for an 8Ω load, the load line runs up to 8·75A on the vertical axis (ie, 70V/8Ω = 8·75A). These load lines show the instantaneous power dissipation at any possible signal condition (including an output short circuit).

Also shown on the diagram are two hyperbolas. One represents the maximum safe power (for one second!) dissipation of four parallel-connected MJL21193/94 transistors. Depending on the instantaneous voltage across the transistors, this can be more than 900W for low voltages, reducing to 720W at 80V, and ultimately to just 400W at 250V (not shown on the curve). This hyperbola represents the maximum dissipation the four

transistors can withstand under a non-repetitive one-second pulse, the so-called Safe Operating Area (SOA).

Since the resistive load lines are well below the one-second SOA hyperbola, you may think that the transistors are operating far below their maximum ratings and so they would be, if all they had to drive was resistive loads. Sadly, loudspeakers are not resistive; they can be resistive, inductive or capacitive, depending on the signal frequency. Usually they are inductive which means the load current lags the load voltage.

This has two effects. First, the voltage across the output transistors can go much higher than the half-supply value of 70V. Conceivably, it can run to the full supply voltage of 140V (or beyond, if driven into clipping on an inductive load). Second, the instantaneous power dissipation across the power transistors can go far in excess of that shown for a resistive load line.

To show this effect, we have drawn 8Ω and 4Ω reactive load lines which represent speakers with complex impedances of 5·6Ω + j5·6Ω and 2·83Ω + j2·83Ω, respectively. In the 8Ω case, the 5·6Ω represents the voice coil resistance while the j5·6Ω is the coil inductance. The resulting curved load lines extend well beyond 70V (to almost 110V) and also show instantaneous dissipation figures far in excess of that for the resistive load lines. In fact, you can see that in the case of the 4Ω reactive case, there is far less power margin to spare.

We have also drawn the de-rated power hyperbola (50°C) for four transistors on Fig.1 and as you can see, it touches the 4Ω reactive curve. Does this mean there is a problem? Well no, because the load lines show instantaneous power dissipation, not average or total power dissipation. As long as the load lines are below the SOA curve, everything is OK.

All of the foregoing is a shortened explanation of the process whereby we decided to use eight transistors. It shows that eight is a good conservative figure whereas six of these transistors would not be enough.

Finally, before we leave the discussion on load lines, we need to mention short circuit and overload protection. Apart from fuses, this amplifier circuit has no protection. We could have chosen to run with six power transistors if we had incorporated "load line" protection into the circuit. This uses a pair of transistors to monitor the output transistor voltage and current conditions and then limit the base drive signal when the load line is exceeded.

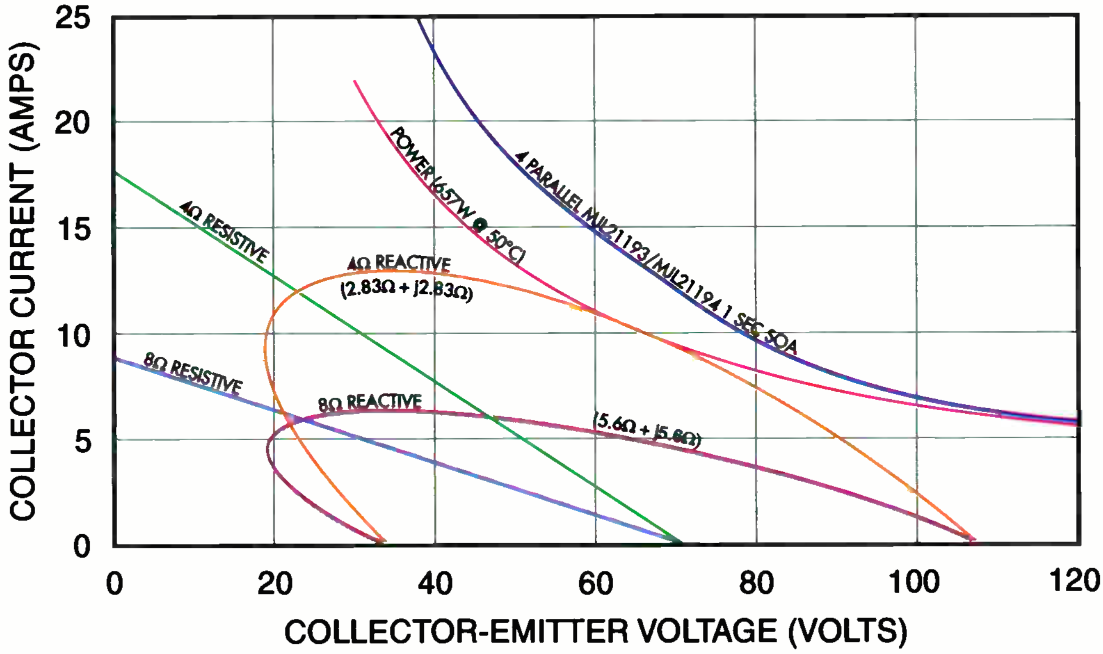

Fig.1: this diagram shows the resistive and reactive load lines for both 4Ω and 8Ω loads. Also shown are two hyperbolas. The blue curve shows the maximum safe operating area of four parallel-connected MJL21193/MJL21194 transistors, while the red curve shows the derated power curve for 50°C case temperature.

Such circuits can work quite well to protect the output stage but in practice their rapid switching action causes a burst of high frequency oscillation to be superimposed on the output signal. This means that not only do you get horrible distortion but the amplitude of the burst can be enough to overload and burn out tweeters if the overdrive situation persists.

Therefore, while we regard load line protection as important for PA amplifiers (which can easily have their output leads shorted), it is not desirable for a hifi amplifier. If you do short the outputs of this amplifier when it is under full drive, there will be a big spark and hopefully the only thing to be damaged will be the 5A fuses. If the fuses were increased in rating, the amplifier could ostensibly drive a 2Ω resistive load without damage, so we think the 5A fuses should provide adequate short circuit protection. Oh, but we don't recommend driving a 2Ω load!

Amplifier module

Two versions of this amplifier module are possible, both using the same PC board pattern. The one presented here employs a cast aluminium heatsink with an integral shelf which is convenient for mounting the power transistors. This heatsink is 300mm wide and the PC board itself is 240 × 136mm so the overall assembly is quite large.

The alternative approach is to mount the output transistors vertically on a single-sided or fan heatsink, in which case the PC board could be trimmed to 240mm wide by 100mm deep. This latter approach takes up less chassis space. Both approaches will be described in the constructional details to be presented next month.

Performance

As already noted, the Studio 350 delivers up to 200W RMS into an 8-ohm load and up to 350W into a 4-ohm load. Music power figures are substantially higher, around 240W into an 8-ohm load and 480W into a 4-ohm load. These figures apply only for the suggested power supply, which we will come to later.

Fig.2: total harmonic distortion versus power at 1kHz into an 8-ohm load (10Hz-22kHz measurement bandwidth).

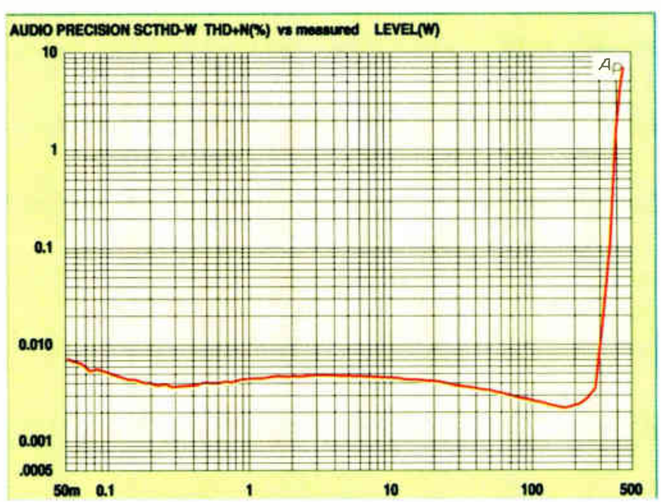

Fig.3: total harmonic distortion versus power at 1kHz into a 4-ohm load (10Hz-22kHz measurement bandwidth).

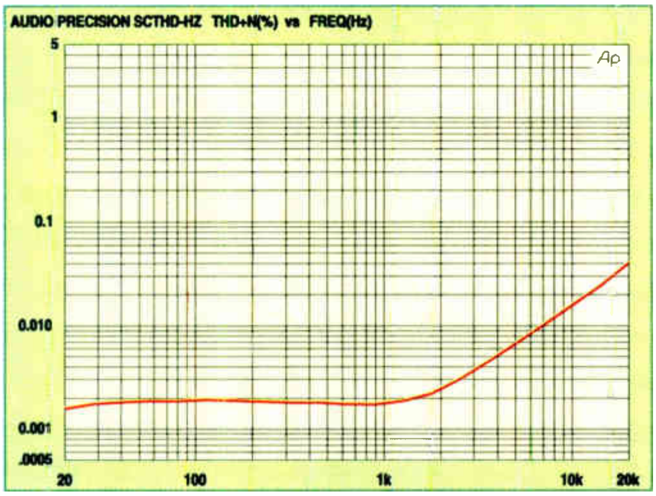

Fig.4: harmonic distortion versus frequency at 160W into an 8-ohm load (22Hz-80kHz measurement bandwidth).

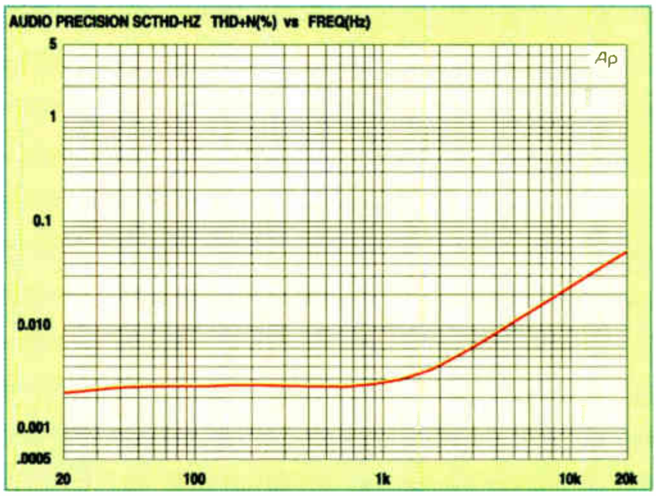

Fig.5: distortion versus frequency at 250W into a 4-ohm load (22Hz-80kHz measurement bandwidth).

Fig.2 shows the total harmonic distortion versus power at 1kHz into an 8-ohm load while Fig.3 shows distortion versus power at 1kHz into a 4-ohm load. As you can see, for an 8-ohm load, distortion is around 0·002% or less up to about 180W, rising to around 0·03% or thereabouts at 200W. At low powers, below 0·5W, the distortion figure rises but that is due to residual noise, not distortion. In reality, at low powers the distortion is well below 0·001%.

Similarly, for a 4-ohm load, distortion is around 0·0045% or less for powers up to around 280W, rising to 0·1% at around 350W. These figures were taken with a measurement bandwidth of 22Hz to 22kHz.

Fig.4 shows harmonic distortion versus frequency at 160W into an 8-ohm load while Fig.5 shows distortion versus frequency at 250W into a 4-ohm load. Both these curves were taken with a measurement bandwidth of 22Hz to 80kHz.

All of these distortion curves show a performance which is outstanding. This amplifier is also extremely quiet: −122dB unweighted (22Hz to 22kHz) or −125dB A-weighted. This is far quieter than any CD player!

Fig.6 shows the frequency response at 1W into 8Ω. It is 1dB down at 15Hz and 60kHz.

Circuit description

The full circuit is shown in Fig.7 and employs 17 transistors and five diodes.

The input signal is coupled via a 1μF bipolar capacitor and a 2·2kΩ resistor to the base of Q2. Q2 and Q3 are a differential pair using Hitachi 2SA1084 low-noise transistors which have a collector-emitter voltage rating of 90V, necessary because we are using 70V rails. Transistor Q1 and diodes D1 & D2 make up a constant current source running at about 1mA to set the current through the differential pair at 0·5mA each.

Trimpot VR1 in the emitter circuit to the differential pair is provided to adjust the offset voltage and thereby trim the output DC voltage very close to 0V (within a millivolt or so). This is largely academic if you are driving normal 4-ohm or 8-ohm loudspeakers but is particularly desirable if you intend driving electrostatic speakers which usually have a high voltage step-up transformer with very low primary resistance.

The same comment applies if the amplifier is used to drive 100V line transformers. Just to explain that, if you have a transformer primary resistance of 0·1Ω and a DC output offset from the amplifier of just 20mV, the resulting current through the transformer will be 200mA! Not only will this magnetise the core and degrade the transformer's performance, it will also result in additional power dissipation of 14W in one half of the amplifier's output stage. This is not good! Hence, trimpot VR1 has been included.

Signals from Q2 & Q3 drive another differential pair, Q4 & Q5, which have a "current mirror" as their collector loads. The current mirror comprises diode D3 and Q6, essentially a variation of a constant current load, which ensures high linearity in Q5. Q4, Q5 and Q6 are BF469 and BF470 types which are high-voltage (250V) video transistors, selected for their excellent linearity and wide bandwidth (F_t is 60MHz).

Q7 is a "V_{be}-multiplier", so-called because it multiplies the voltage

Fig.6: this graph shows the frequency response at 1W into 8Ω. It is just 1dB down at 15Hz and 60kHz and is virtually flat between those frequencies.

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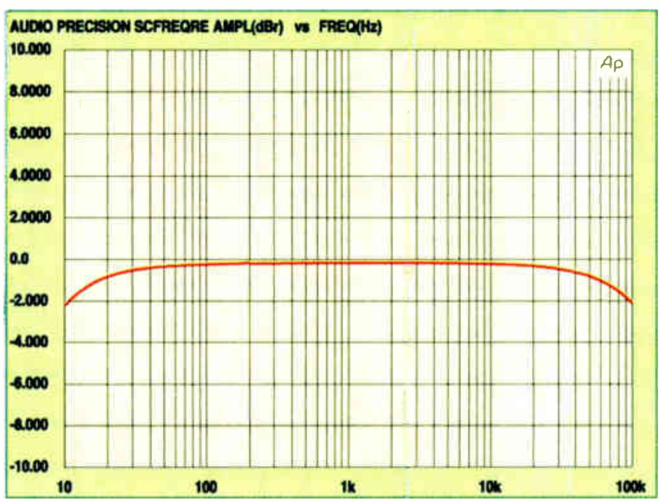
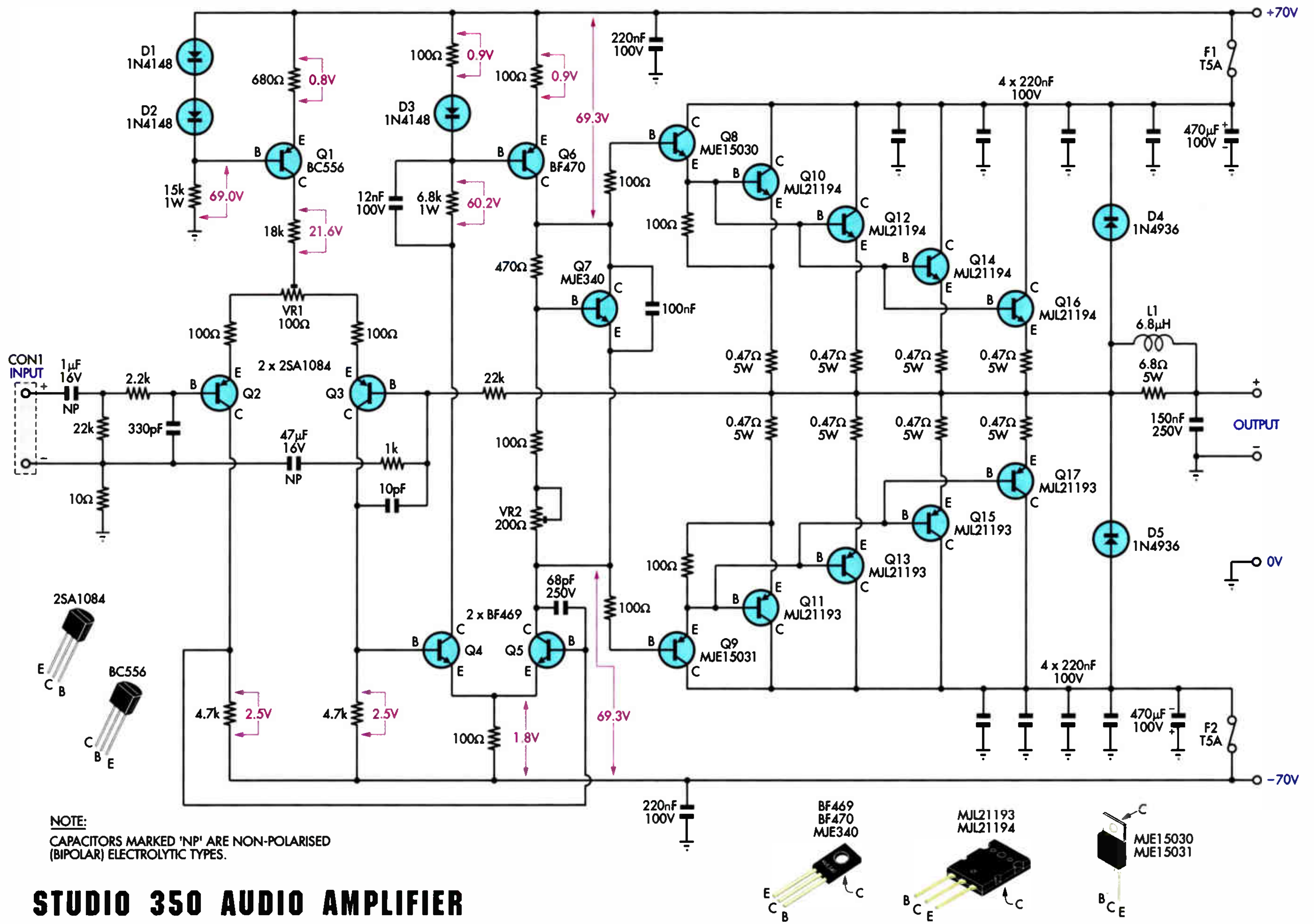




NOTE:
CAPACITORS MARKED 'NP' ARE NON-POLARISED (BIPOLAR) ELECTROLYTIC TYPES.

STUDIO 350 AUDIO AMPLIFIER

Fig.7: the circuit uses eight high-quality audio output transistors to give a rugged design with low distortion. The voltage readings on the circuit were taken with no input signal.

Performance	
Output Power	200W RMS into 8Ω; 350W RMS into 4Ω
Music Power	240W into 8Ω; 480W into 4Ω
Frequency Response	-1dB at 15Hz and 60kHz at 1W (see Fig.6)
Input Sensitivity	1·75V for 200W into 8Ω
Harmonic Distortion	Typically 0·002% at normal listening levels (see graphs)
Signal-to-Noise Ratio	-122dB unweighted (22Hz to 22kHz); -125dB A-weighted, both with respect to 200W into 8Ω
Damping Factor	75 at 10kHz, with respect to 8Ω
Protection	5A supply fuses (see text)
Stability	Unconditional

between its base/emitter to provide a floating voltage reference to bias the output stage and set the quiescent current. Quiescent current is needed in all class-B amplifiers, to minimise crossover distortion. In fact, this amplifier displays no trace of crossover distortion.

We use an MJE340 transistor for Q7 even though a small signal transistor could easily handle the task. The reason for using a power transistor is that its package and junction does a better job of tracking the temperature dependent changes in the junctions of the output power transistors and thereby gives better overall quiescent current control.

The driver transistors are the high performance MJE15030 and MJE15031 made by On Semiconductor (previously Motorola). These have a minimum current gain-bandwidth product (F_t) of 30MHz. These drive the paralleled output stage MJL21193/94 transistors which themselves have a typical F_t of around 6MHz.

Each of the power transistors in the output stage has a 5W wirewound emitter resistor of 0·47Ω. This relatively high value has the disadvantage that it causes a slight reduction in power output but this has been done to provide improved current sharing between the output transistors – an important factor in a high-power design.

Although not shown in the photographs, one of our prototypes used non-inductive wirewound emitter resistors. These have been recommended in some past designs in magazines, in order to minimise secondary crossover distortion effects. Our tests showed no benefit in this design (probably because of the PC board layout) and so they are not specified – ordinary wirewound emitter resistors are OK in this design.

Two 1N4936 fast recovery diodes are reverse-connected across the output stage transistors. Normally, these do nothing but if the amplifier is driven into clipping when driving highly inductive speakers or transformers, the diodes safely clamp the resulting back-EMF spikes to the supply rails.

Negative feedback

Overall negative feedback is applied from the output stage via the 22kΩ resistor to the base of Q3. The voltage gain is set by the ratio of the 22kΩ resistor to the 1kΩ resistor also connected to the base of Q3. This gives a voltage gain of 23 (+27dB). The 47µF bipolar capacitor in series with the 1kΩ resistor sets the −3dB point of the frequency response to about 3Hz. The other factor in the amplifier's low frequency response is the 1µF bipolar input capacitor.

We have used non-polarised (NP) capacitors for the input and feedback coupling instead of conventional electrolytic capacitors because the low voltages present in this part of the circuit are insufficient to polarise conventional electrolytics. Incidentally, some readers may disagree with our choice of electrolytics in the signal path but the alternative of plastic dielectric capacitors is not very attractive; they are large and expensive and unavailable, in the case of 47µF. Nor do we think that electrolytic capacitors, properly used, are the cause of high distortion

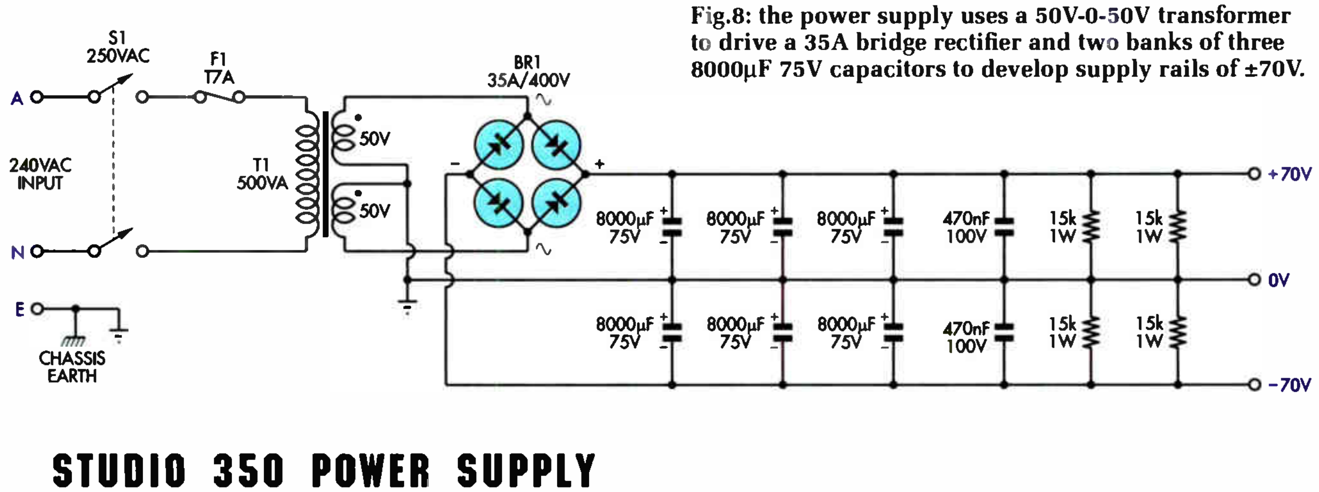
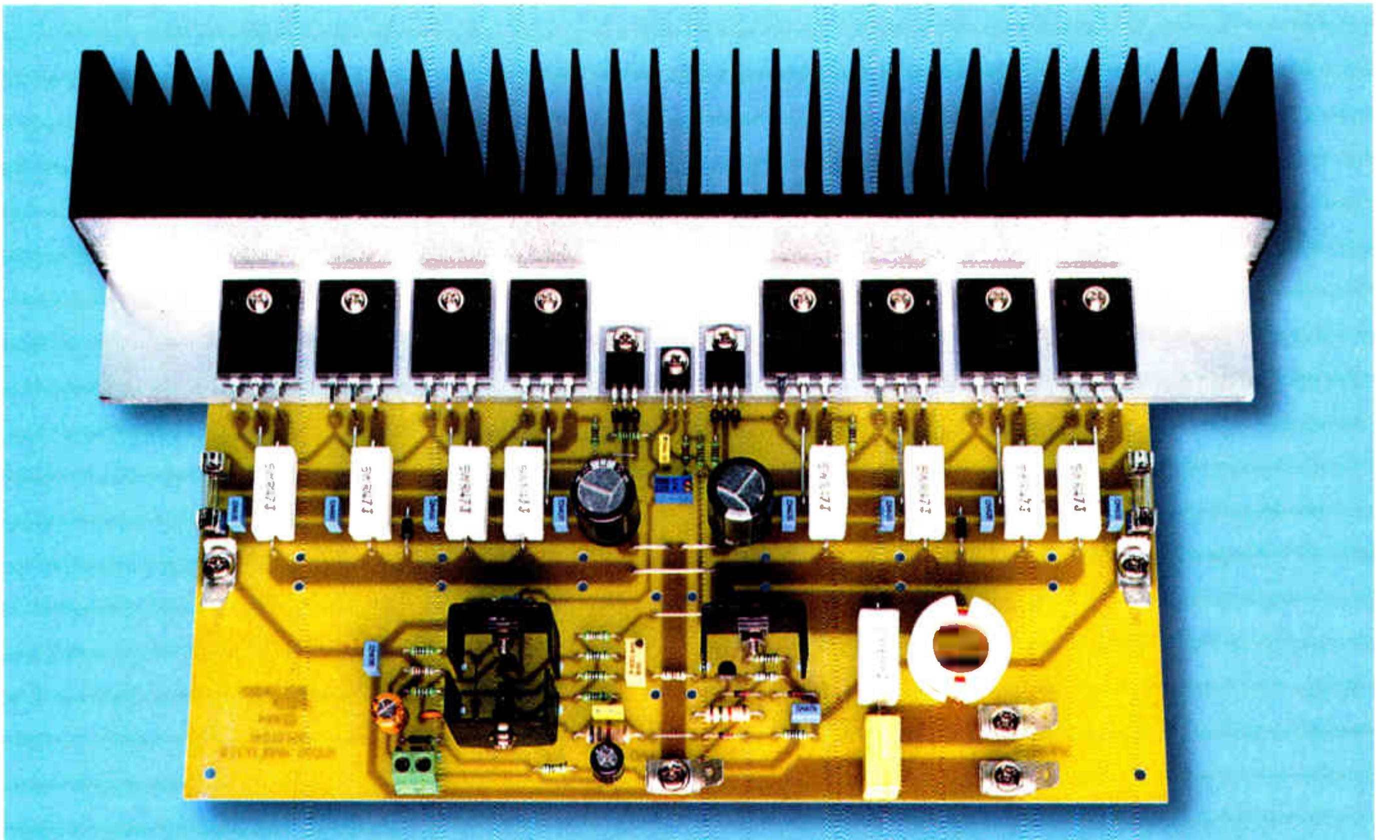


Fig.8: the power supply uses a 50V-0-50V transformer to drive a 35A bridge rectifier and two banks of three 8000µF 75V capacitors to develop supply rails of ±70V.



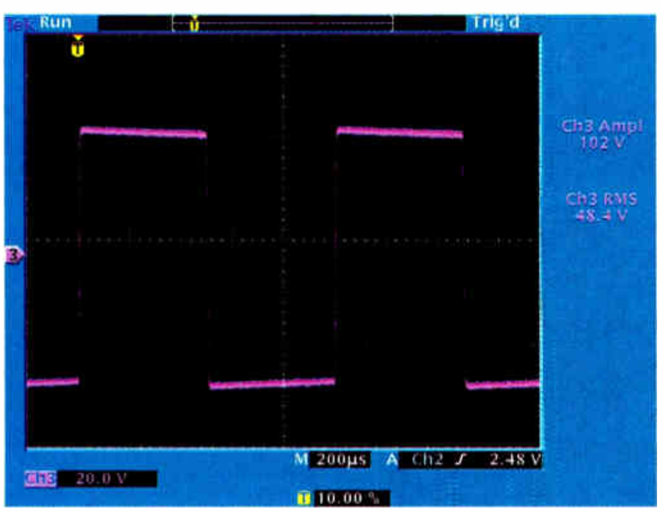
This view shows the fully completed audio amplifier module. The construction details are in next month's issue.

in audio circuits; there's no evidence of it in the case of this circuit.

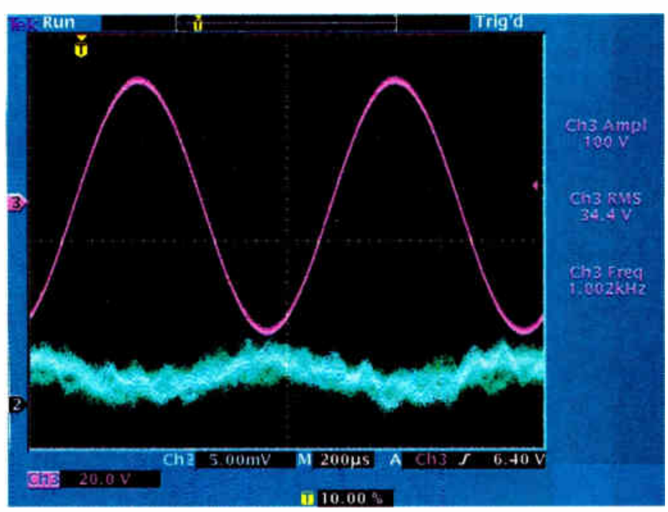
The 330pF shunt capacitor and 2·2kΩ resistor in series with the input signal constitute an RC low-pass filter, rolling off the high frequencies above 200kHz. The 68pF capacitor between Q5's base and collector rolls off the open loop gain to ensure stability with feedback applied.

Note that this capacitor can be ceramic or polystyrene but must have a rating of at least 250V. This is because the signal at this part of the circuit can be as high as 45V RMS (127V peak-to-peak). Other capacitor types (such as monolithics) are definitely not recommended.

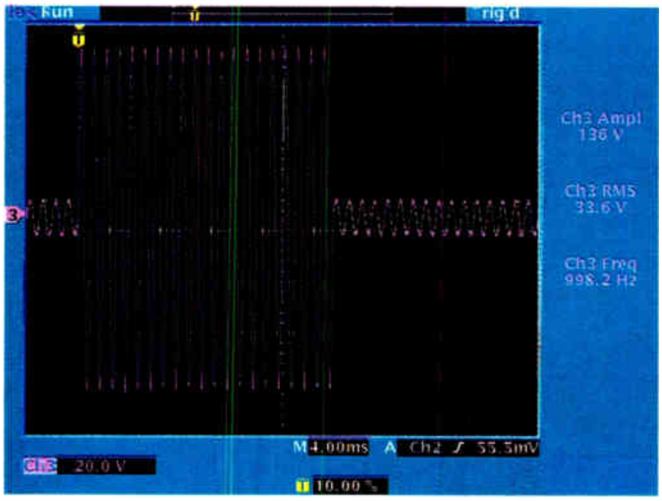
The output signal to the loudspeaker is fed via an RLC filter consisting of a 6·8µH choke, a 6·8Ω wirewound resistor and a 150nF 250V capacitor. This very well-proven filter network was originally developed by Neville Thiele and published in the September 1975 issue of the *Proceedings of the IREE*. The filter has two benefits: ensuring stability of the amplifier with reactive loads and as an attenuator of RF and mains-interference signals which are



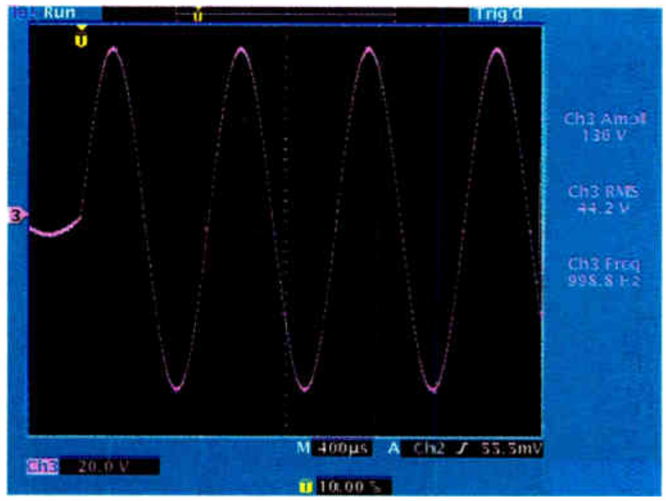
Scope1: this waveform shows the excellent square wave response of the amplifier, taken at 1kHz and 102V p-p into 8Ω. This equates to a power output of about 300W RMS.



Scope2: these waveforms show a 150W sinewave at 1kHz and the resulting total harmonic distortion waveform (ie, noise and distortion) which is at about 0·0015%.



Scope3: this is the pulse waveform used to measure music power. Note the excellent stability of the amplifier, particularly the recovery after the pulse.



Scope4: the same waveform as in Scope3, but with the scope switched to a faster timebase. In this case, the amplifier is delivering over 240W RMS into an 8-ohm load.

inevitably picked up by long loudspeaker leads.

Power supply

Fig.8 shows the power supply and as you can see, we've "gone for broke" on this one. It's a vital part of the performance package and unfortunately, with all those big electrolytic capacitors, is likely to be more expensive than the amp module itself. The consolation is that the same power supply could be used for a stereo version with two amplifier modules, provided the power transformer was uprated.

The 500VA transformer used has two 50V windings which are connected together to form a centre tap. This transformer drives a 35A bridge rectifier and two banks of three 8000µF 75V capacitors to develop ±70V supply rails. The 470nF capacitors are used to provide high frequency bypassing, while the 15kΩ 1W resistors are used as "bleeders" across the electrolytic capacitors.

PC board topology

Finally, the PC board has been laid out using distortion-cancelling topology. It also has "star" earthing whereby all earth currents come back to a single point on the board. This careful separation of output, supply and bypass currents avoids any interference with the signal currents and the distortion that this could cause.

As far as the "distortion cancelling" technique is concerned, this involves laying the copper tracks so that the magnetic fields produced by the asymmetric currents in the output stage are cancelled out, as far as possible. These asymmetric currents (think of them as half-wave rectified output signals) and their resultant magnetic fields induce unwanted distortion signals into the input stage transistors Q2 and Q3.

This approach is very worthwhile and constructors will not have to worry about whether the performance of their module is as good as the prototype featured here. As long as you follow closely the wiring layout in the construction article next month, you can expect the results to be very good indeed. *EPE*

TECHNO-TALK MARK NELSON

MUSHROOM MAGIC AND THE QUEST FOR GREEN VOLTS

Every potential source of cheap electricity ought to be investigated. Researchers are turning button mushrooms into button cells (in a manner of speaking). But going off-grid can generate problems of its own.

FIFTY years ago, on 17th October 1956, the Queen opened the world's first full-scale nuclear power station, at Calder Hall in Cumberland. With the opening ceremony attended by scientists and statesmen from almost 40 different countries, the eyes of the world were focused on this "epoch-making" event. The next day newspapers proudly stated that within ten years electricity would be so cheap to generate that it would not be worth metering.

This never happened of course, and when the station finally closed in 2003 the local MEP and Liberal Democrat party environment spokesman Chris Davies said, "When Calder Hall opened we were promised it would herald a new era of virtually free electricity. In practice it has been hugely expensive, surviving because of enormous subsidies from the taxpayer and extra charges on electricity bills."

Magic Mushrooms

Electricity was by no means dear in 1956, but with bills now set to rocket, the race is on to find affordable new means of generating power that do not harm the environment. One suggestion is mushroom power.

Scientists at Oxford University have managed to use fungal enzymes to create a hydrogen fuel cell that can run a digital watch, with the promise of more elaborate devices that could power mobile phones or digital cameras. *New Scientist* reports that the enzymes replace the expensive metal catalysts required to drive the cell's chemical reactions.

The report quotes the University's Kylie Vincent, who indicates these enzyme-powered fuel cells could be smaller, simpler and cheaper to make than conventional ones. Most fuel cells rely on electrodes incorporating expensive metal catalysts, such as platinum. Whereas the Oxford cell uses an enzyme harvested from fungus for this task. "This should cut the cost of making a fuel cell," she says, "and the enzymes are also completely biodegradable."

Paul Allen, Development Director at the Centre for Alternative Technology in mid-Wales, praises this achievement and told *New Scientist*, "The batteries used in watches and cameras are energy-intensive to produce and contain heavy metals, making them difficult to dispose of."

Cameron's Caper

Turning proven theory into practical reality can be hazardous, as Calder Hall demonstrated, and a non-toxic fuel cell still requires raw materials that may consume considerable energy to produce. Paul Allen brings us back to earth, reminding: "We must remember that fuel cells are energy stores, not energy generators. Unless we develop renewable energy-generating capacity in the first place, there will still be a nett energy shortfall in the future."

Someone who has tried conspicuously to generate autonomous electricity is Conservative leader David Cameron, who has equipped his Edwardian home in west London with a 1·1 metre diameter wind turbine and solar panels. Admirable as this is, the 'free' electricity does not come cheap. The turbine cost him around £700 excluding carriage and installation (which is by no means child's play) and you still need inverters, batteries and switchgear on top of this.

Multiple store Curry's hit the headlines in August by becoming the first mainstream electric retailer to sell solar panels, but at a price that was by no means as cheap as chips. Their solar system, stated to cut energy bills by half and reduce annual carbon dioxide emissions by two tonnes, would cost £9,000 for the average three-bedroom home, although in this case the price includes installation.

Unfortunately, photovoltaic (solar) systems tend not to add value to a home. There's also the negative visual impact to consider and the long payback period means that homeowners will probably not be beating a path to Curry's door. You shouldn't ignore the substantial energy input that goes into manufacturing them either, meaning the systems may never pay off their true cost.

Curry's have competition too, with the launch of the Bournemouth Energy Trust. Campaigner Brendan McNamara states that for £1,000 less than what the Curry's product costs, the trust will pay for two megawatt-hours per year per investor for 20 years at the lowest market price for grid electricity. "This will save the client from the bother of installing and maintaining a solar panel system for 20 years," he argues. Nett profits will be invested in sunny developing countries, he adds.

Off the Grid

Undeterred by all the disadvantages, there is a growing number of people (not all techies) who are determined to live "off the grid" by using locally generated power. One of them is Paul Allen, mentioned above. He is the designer of many non-mains power systems for the Centre for Alternative Technology (CAT) and its commercial subsidiary Dulas Ltd, and has himself lived for many years without mains electricity. *Off the Grid* is in fact the title of a textbook he has co-written with Bob Todd for CAT (**www.cat.org.uk**). It's available from their online bookshop (but not from other e-tailers such as Amazon; they sell another one with the same title!)

Allen's book is low-priced and covers topics such as designing, installing and monitoring a system, as well as dealing with basic questions about energy generation. Effectively it's an indispensable resource guide for anyone wishing to fulfil their own electricity needs in an efficient and ecologically sound manner.

The other *Off The Grid* book, by Lori Ryker, is a glitzier, more generalist book on how to live off the grid (geothermal energy use, wind turbines, photovoltaic arrays, micro hydropower, rainwater collection and reclamation). Naturally, there are numerous websites that *Google* will find for you if you put "off-grid" or "off the grid" into your search. Not all are exactly scintillating but the joy of discovery will doubtless outweigh any minor disappointment!

Feast or Famine

One of the fundamental problems of off-grid living is the "feast or famine" nature of homegrown energy. A letter to *The Guardian* earlier this year sums it up more eloquently than I can: "I've had solar panels for five years and except during conditions of very low cloud, they generated more than twice the electricity I need during the day. Also, there is no way to store the excess generation, which is fed back into the grid, and which I would prefer to have when the sun goes down."

Presumably the writer has not heard of storage batteries but the problems of photovoltaic systems goes deeper. A revealing article in the latest issue of *Clean Slate*, the CAT members' magazine, explains the dilemma.

The fundamental problem with photovoltaic power in the UK is the variation in sunlight. A solar panel array sized for midwinter, when the power demand is highest, will deliver 20 times the requirement in midsummer. As panel arrays do not come cheap users must settle for a compromise, such as an array that supplies sufficient power between March and September, augmented by a Whispergen generator in winter.

Whispergen is a novel and highly efficient replacement gas boiler that generates electricity to power lights and appliances, as well as supplying the home's central heating. I refer you to website: **www.greenconsumer guide.com/powergenminisite/index.htmr**

PIC N' MIX

MIKE HIBBETT

Our periodic column for your PIC programming enlightenment

Understanding PIC Datasheets

WHEN considering an IC for a new design, the first port of call should always be the datasheet. These documents can be a little intimidating at times, especially if they have been poorly translated from another language. Fortunately for us Microchip are very good at producing easy-to-read, well formatted specifications that follow a common format throughout their range of products. Datasheets still remain formidable though, especially for the hobbyist or occasional user. So this month we will attempt to unravel a typical datasheet.

Naturally, the Microchip website should be your main point of contact for datasheets and other material. The simple rule of thumb when using a part for the first time is to get all the information you possibly can, and read it. Some material will be irrelevant and quickly discarded but it can be surprising what gems of information can pop up – maybe a special initialisation routine required, advice on handling error conditions or just a different description of a topic that can help clarify the point. Application notes, also available from manufacturers' websites, give example circuits that can be used as the basis for your own – even for commercial use.

Beware Errors

The Internet is a good source of additional examples but, as with most things found on the internet, take them with a pinch of salt! Even Microchip have been known to have the odd hiccup with processor designs or documentation.

When Microchip do discover an error, either in the IC itself or in a datasheet, rather than republishing the document they produce an Errata sheet. Check to see if there are any for the processor you are interested in, and make sure you mark up your paper copy of the datasheet with the corrections.

While paper copies of specifications are always handy – especially for recording errata details – it is often useful to study the electronic format, when searching for keywords for example. If you find yourself dipping in and out of PDF files frequently and find the loading time of Adobe slow, try the "Foxit Pdf Viewer". It's tiny, loads quickly, and is free. A web link is provided at the end of the article.

Example Datasheet

Let's now take a look at a processor datasheet. We have chosen the PIC16F84A because it is a typical, fairly popular device. You can download this from the Microchip web site, see address list at the end of this article.

The document starts with an overview page, very handy for getting a quick grasp of the device; peripheral features, number of pins, voltage range etc. Nearby will be a table showing you the variants within the family which consist of different memory size and extra I/O pins.

The Pin Diagram pages are a very useful reference when wiring up a board; it is well worth making several paper copies of this page so that you can scribble on them. If you do use it as a wiring assistant, take the author's advice: cut off the diagrams relating to the packages you are not using. Many a project has been spoiled by accidentally looking at the wrong chip pinout! These pin diagrams are a high level, programmers view – the chip's dimensions are shown at the very end of the datasheet.

The device overview section will normally be several pages long and can often be the most intimidating aspect of a datasheet. References to 'alternate run modes' or 'on-the-fly switching' (found in the PIC18F family datasheets) can be very confusing, but as a general rule, remember that most features can be disabled. If the feature isn't of interest to you, ignore if for now. You will only need to make sure that the feature is disabled when configuring the chip in software.

A more detailed full page diagram called the Block Diagram normally follows. This is an excellent reference for programming and high level circuit design because it shows the features available and how they map to individual pins. In most cases pins will have dual functions, and this is the page where you normally discover that the feature you want to implement (perhaps 24 I/O pins) cannot be done on this part because the oscillator pins double as I/O lines. Now start the compromise tactics: can I use the internal RC oscillator to free up the pins, or do I need the stability of an external oscillator, and therefore a larger part?

The wiring on this diagram is largely superfluous; it shows that the device uses the Harvard architecture arrangement – separate data and instruction busses – but little else. More detailed and useful connection diagrams follow later on, in the datasheet.

Basic Descriptions

The Pinout I/O Descriptions normally follow, and these tables contain very important information. There is typically one per processor variant so find yours and take a good look at it. There is a list under each pin to describe the type of electronics driving the pin in different modes. Yes, that's correct – each pin may have different electrical characteristics depending on how it is configured, and this can have a major impact on your design.

The Pin Type parameter is quite straightforward; the pin may be input only (I), output only (O) or selected under software control (I/O). Not all I/O pins are actually I/O!

The Buffer Type describes the electrical implementation, typically summarised as Schmitt Trigger Input (ST), TTL compatible input (TTL), CMOS input (CMOS) or Analogue. Always read the description field in the table; some outputs, such as the RA4 pin on the many PIC16F devices, are open drain. This means that as outputs they can only pull down, and rely on an external pull-up to go high.

These various input types have subtle differences, the most important ones being the high/low voltage levels at which they switch at. These parameters are described right at the end of the datasheet under DC Electrical Characteristics which we will get to later.

The section on Memory Organisation provides a programmer's view of the processor; memory locations which are available to the user, and those which are reserved for special purposes. Being a Harvard architecture device, the PIC has separate code and data areas. So, for example, location 4 in the code space is allocated to the interrupt vector, whereas location 4 in data space is the FSR register. These diagrams are worth copying and keeping on display somewhere. You will be frequently referring to them. There is a third memory space, EEPROM data, which is essentially just another peripheral on the chip.

Data space memory is shared between general purpose variable locations (what we normally refer to as RAM – Random Access Memory) and special function registers, or SFRs. These registers are shown in a little more detail in the datasheet – just indicating the names of the bits within each byte. The registers are how you control all the features of the microcontroller, and again, this diagram is worth taking a copy of and keeping it within reach during programming. One or more SFRs are associated with a particular peripheral, such as an I/O port, timer, etc. Sometimes an SFR is used by more than one peripheral (INTCON, for example, is used by both timers and I/O ports) so take care when writing to an SFR to configure one peripheral that you do not accidently change another's setup.

Peripherals and Special Features

The datasheet now describes each peripheral unit in detail; EEPROM memory, I/O

Ports and Timer Module. These sections are to a large extent independent. They are self-contained, and if you do not intend to use them you can give those sections a quick read and then happily ignore.

In general, peripheral sections follow a standard format. A simple block diagram showing the functional components of the microcontroller that are associated with that feature; a list of the SFRs that are used to control that feature and a detailed description explaining how the peripheral can be controlled.

The block diagram often provides a very concise explanation and it is worth taking the time while reading the detailed description to cross refer to the block diagram. These diagrams are a common feature of all microcontroller datasheets and often provide a better explanation of how the peripheral will work than the actual text does.

Following the descriptions of peripheral features is a section called Special Features of the CPU, a mixed bag of features that are not specific to any one peripheral. Every PIC has one or more configuration registers, which are held in non-volatile memory outside of the data or code area and can only be changed by programming hardware. Setting these correctly is vital if your PIC is to operate. In the simpler parts like the PIC16F84, the Watchdog and Oscillator Settings are the most important to set correctly.

When you are first learning about a new processor it is always a good idea to keep the Watchdog feature disabled, especially if you do not know what it is used for. If you are using a 3·5MHz or higher frequency crystal or resonator to drive your PIC, then select the HS oscillator mode. This mode determines how hard the oscillator drives the crystal.

The section on Reset explains how it is possible to determine under which conditions the processor entered a device reset (i.e. power on, or as a result of the Watchdog timer) and importantly the state in which the SFRs are placed. It's obvious that some registers such as the Program Counter and the Status Register will have known values written, but several other do too. **Do not rely on this fact**.

The power supply rails are often quite noisy immediately following power-up, and registers may become corrupted. It is a good idea to pause for a few tens of milliseconds, then initialise all the SFRs to known values.

Instruction Set

The next section in the datasheet is the Instruction Set description. A handy one-page summary is provided; this is also worth taking a copy of and keeping to hand. You will refer to this one so much it is even worth laminating the copy in plastic. The 10F, 12F, 16F and 18F PIC families have subtly different instruction sets so it is worth double-checking when using a new processor that there are no unexpected additions or deletions.

The instruction set section marks the end of the programming information in the datasheet. You will notice though that you are only half way through it – the rest details electrical and mechanical characteristics of the parts. The mechanical section can normally be skipped through; you will only want to confirm that your chosen package is the same basic size as the footprint your CAD package or artwork expects. Dual-in-line and surface mount packages are standardised.

Electrical Characteristics

The electrical characteristics are split into three sections: absolute maximum ratings, DC parameters and AC parameters. Absolute maximum ratings define maximum voltages and currents the device can withstand – *Do not* design your circuit to operate up to these limits! The DC parameter section defines the more sensible working limits, such as power supply voltages, clock frequencies and the current drawn by the device under a variety of circuit conditions.

At the beginning of this article we mentioned how some pins may have different input types, namely Schmitt trigger, CMOS or TTL. This has an affect on the voltage levels at which an input will detect a low or a high. These levels, 'input high voltage' and 'input low voltage' are shown for each input type, and will help you work out whether an input will be compatible with other devices – especially important if you are interfacing a 5V PIC to a 3V device. If you look at the specification for Input High Voltage you will see that TTL inputs get a high at 2V, but Schmitt inputs get a high at $0{\cdot}8V_{dd}$. That's 4V, totally unsuitable for interfacing a 5V PIC to a 3V3 device. TTL inputs would be fine, however.

The final two parameters of interest are 'output high voltage' and 'output low voltage'. These define what actual voltage output level an output pin will drop (or rise) to when it is passing current. Remember, that an output pin is not a perfect switch; if, for example, you set it high and use it to power an LED, the current drawn will cause a small voltage drop across the 'on' FET transistor inside the PIC. The levels specified here are examples; you can draw more current (up to 25mA) but do not expect the pin to have an output of 5V – it will be lower!

The figures quoted are really a guideline for the maximum that you can draw from a pin if you intend to drive another device's input (especially if it has a Schmitt trigger input). You may notice that there is a lower voltage drop when the pin is sinking current (providing a path to ground) than acting as a source. This is quite common, and helps to explain why LEDs are normally connected from the I/O pin to the positive supply, rather than ground.

We have skipped very quickly through the example datasheet; if you have questions on an individual peripheral feature why not try out the *EPE Chat Zone* forum. You may also contact the author directly by email – see the references for web addresses and email contact information.

References

Microchip PIC datasheet download **http://www.microchip.com**, follow the links on-site

Foxit PDF viewer **http://www.foxitsoftware.com/**

EPE Chatzone forum **http://www.chatzones.co.uk/discus**

Mike Hibbett **mike.hibbett@gmail.com**

DON'T LOSE THAT CHILL!

Is your fridge or freezer door often left open for too long? Or does it sometimes not close properly? Ensure it's closed when it should be by building this nifty Fridge Alarm.

FRIDGE DOOR-OPEN ALARM

By JOHN CLARKE

A REFRIGERATOR OR freezer door that is left open or ajar may cause the food contents to spoil. In some cases, the internal temperature of the fridge or freezer will be maintained if the refrigeration system can cope with the open door.

But without the door sealing in the cold air, it may be a losing battle. Running costs will certainly rise.

Typically, refrigerators and freezers are in constant use in the summer months and so it is important to ensure that the door is not open for any longer than is necessary. Otherwise the fridge or freezer will not be able to keep the contents cool. And it will cost more money to needlessly run the fridge's compressor in a futile effort to keep the contents cool.

Even the most diligent fridge user may sometimes leave the door of the fridge or freezer open without realising it. And tilting the fridge or freezer slightly backward so that the door will fall shut is not completely foolproof as there may be an obstruction inside the door. The obstruction could be caused by an item inside the compartment which has moved or fallen over or because the compartment is too full.

This is where the Fridge Alarm is useful. It warns when the door of the refrigerator or freezer is left open for longer than a preset time period. It is great for indicating when someone is standing with the door open for too long and a real asset in warning when the door looks shut but is still partially ajar.

The fridge alarm operates by detecting when any light enters the compartment area. Therefore it is just as useful for freezers (which normally do not have a light) as it is for fridges (which normally do). As long as there is some ambient light which the alarm can react to, it will operate.

You don't *have* to house it in a transparent box, as we did . . . but if you don't, you'll need another hole in the appropriate place on the box wall so light can strike the LDR inside.

The alarm will sound if the light is present for longer than the preset period and will continue to sound until the door is closed. In practice, the preset period is adjusted so that in normal use the alarm will not sound. It will sound when the door is left wide open for too long or if left slightly ajar.

Commercial coolrooms and freezers

While the Fridge Alarm is primarily intended for domestic fridges, it has its applications for large (ie walk-in) commercial coolrooms and freezers. If you think that your fridge at home costs a lot of money to run, try paying the bill for one of those walk-in models that clubs and restaurants use. And in a busy club or restaurant, it is very common for staff to leave the door open. Because the door is so large, bulk cold escapes very quickly.

If the walk-in coolroom or freezer has a door-operated light, the Fridge Alarm will work in exactly the same way as in a domestic fridge. If the light switch is manual (as many are), it will warn that the light has been left on. And if it doesn't have a light inside, you could set it up near the doorway and have the alarm triggered by natural light from outside.

Note that the alarm cannot be used with display refrigerators or freezers that have a glass door.

Does the light really go off?

Do you or members of your family have doubts whether the fridge light really goes off when the door is closed? Does the little man in the fridge really do his job? Or is he sitting in there goofing off?

This Fridge Alarm will finally dispel any doubts on this score. If you open the door and can hear the alarm sounding immediately, it means that the light has remained on while the door was closed. Disbelievers will say it's a fault in the alarm unit itself rather than the light remaining on. Perhaps, we will never know.

The Fridge Alarm is battery operated and so does not need to be connected to any wiring inside the compartment. It comprises a small transparent box with the alarm circuit and battery housed inside. The box is placed within the freezer or refrigerator near to the door opening. In this way it can monitor both the light from the internal lamp and also light entering from the outside. Monitoring light from the outside is important since it allows detection of the door being left only slightly ajar. Monitoring the internal light only will not indicate when the door is left ajar since the internal light is switched off via the door switch before the door closes.

The circuit

Circuitry for the Fridge Alarm (Fig.1) comprises a single IC package, a Light Dependent Resistor (LDR), a siren plus a few resistors, diodes and capacitors. The low temperature operation has meant that all components need to be rated for sub-zero temperatures. The IC is rated to −40° C, while the piezo siren is rated to −20°C. Other components, such as the capacitors, diodes, LDR and resistors will operate to below −20°C.

The battery is specified as an alkaline type to provide the necessary current at lower temperatures. And current drain is not very high. When the circuit is in the dark, quiescent current is typically less than 6µA and this low current will prevent the battery discharging before the end of its shelf life. Current consumption when the alarm is sounding is a mere 2mA.

Operation of the alarm relies upon light detection using the LDR. This device has low resistance, below 10kΩ, when there is sufficient light on its surface and a high resistance of more than 1MΩ when in darkness.

We use this change in resistance in a voltage divider with a 1MΩ trimpot and a 150kΩ resistor across the 9V supply. Voltage across the LDR is monitored at the input of Schmitt trigger inverter IC1a (pin 1).

IC1a has two threshold voltages which are nominally 1/3rd the supply and 2/3rd the supply. These thresholds are 3V and 6V with a 9V supply. If the voltage at pin 1 is 6V or more then the output at pin 2 will be 0V. If the pin 1 voltage falls below 3V, then the output at pin 2 will be at 9V.

In the dark

When the fridge or freezer door is closed, the LDR is in complete darkness and so it has a high resistance. The total resistance of the 150kΩ resistor and VR1 is now smaller than the LDR resistance and this causes the voltage at pin 1 to rise above the upper threshold of the Schmitt trigger. As a result, the output at pin 2 will be at 0V.

Capacitor C1 is held at 0V via diode D1 and the series connected 2·2kΩ resistor. Schmitt trigger IC1b monitors

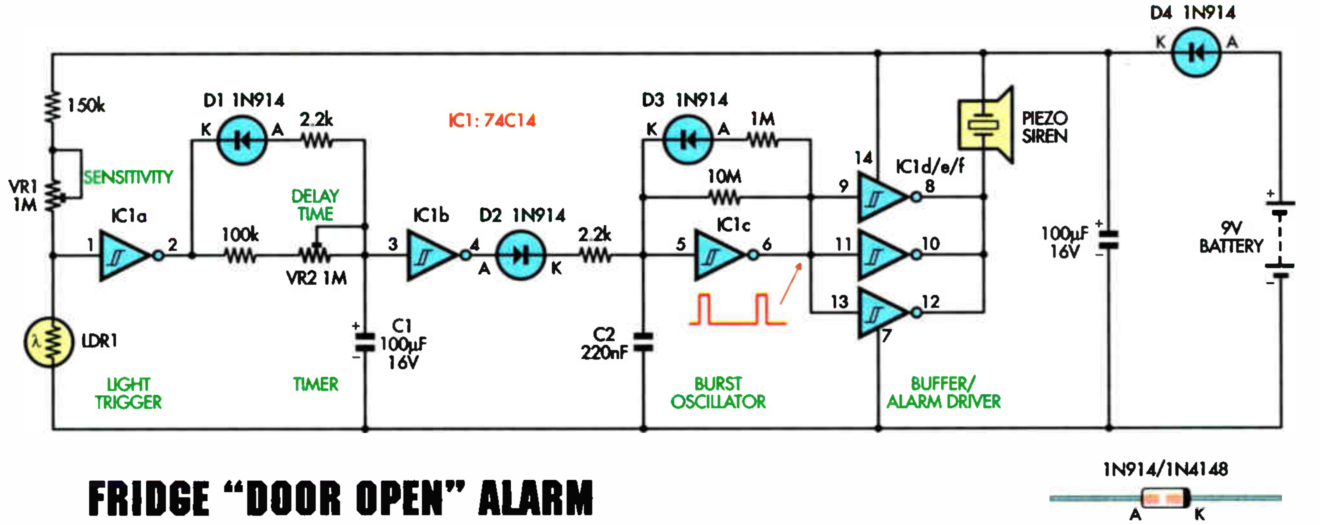


Fig.1: the circuit is basically a light trigger, timer, oscillator and piezo driver. It's all based on one low-cost IC.

the voltage across C1 at its pin 3 input. Since pin 3 is at 0V, pin 4 is at 9V.

Diode D2 and the series 2·2kΩ resistor pull the pin 5 input to IC1c close to 9V and so pin 6 is at 0V. The output of IC1c drives paralleled Schmitt triggers IC1d, IC1e and IC1f and since IC1c's output is at 0V, the paralleled Schmitt outputs are at 9V. Outputs of IC1d, IC1e and IC1f at pins 8, 10 and 12 respectively drive the (-) side of the piezo siren. At this stage the siren will not be driven since the (+) terminal of the piezo siren connects to the 9V supply and the (-) terminal is at 9V.

This is the Fridge Alarm's normal state when in darkness. Current drain from the battery is very low and is caused by several current paths.

The first is the current flow through the LDR, VR1 and the 150kΩ resistor. The LDR will be about 2MΩ or more in darkness and the current will be less than 4·5µA for this part of the circuit. Another current path is through diode D2, and the series connected 2·2kΩ resistor and the 10MΩ resistor connected between pins 5 and 6 of IC1c. Current flows because pin 4 of IC1b is at 9V and the pin 6 output of IC1c is at 0V. Current drain here is less than 1µA.

The final current drain is the supply to IC1 itself and the 100µF capacitor across the supply (after D4). For that reason we specify that both 100µF capacitors should be low-leakage types. IC1 is a CMOS device that has a very low supply current of typically below 0·05µA. The total current drain is therefore expected to be around 6 to 7µA.

Door open

When the fridge or freezer door is opened, the resistance of the LDR drops and this pulls pin 1 of IC1a below its lower threshold and pin 2 goes to 9V. Diode D1 becomes reverse biased and so capacitor C1 now begins to charge via the 9V at pin 2 and through the 100kΩ resistor and VR2 trimpot. Charging time for C1 can be adjusted using VR2, which allows timing values from around 10s to 100s.

When capacitor C1's voltage reaches about 6V, the voltage becomes more than the positive going threshold for IC1b, and its output goes to 0V.

Diode D2 is now reverse biased and the already charged capacitor C2 now discharges via the 10MΩ resistor between pin 5 and pin 6. When C2

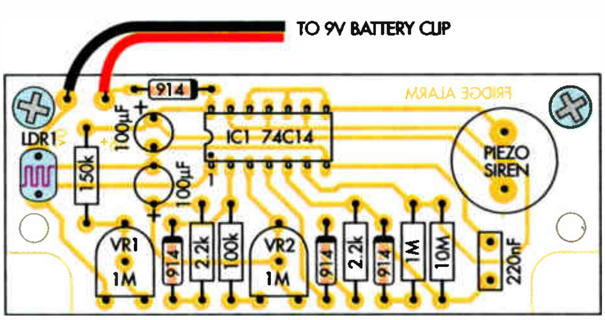
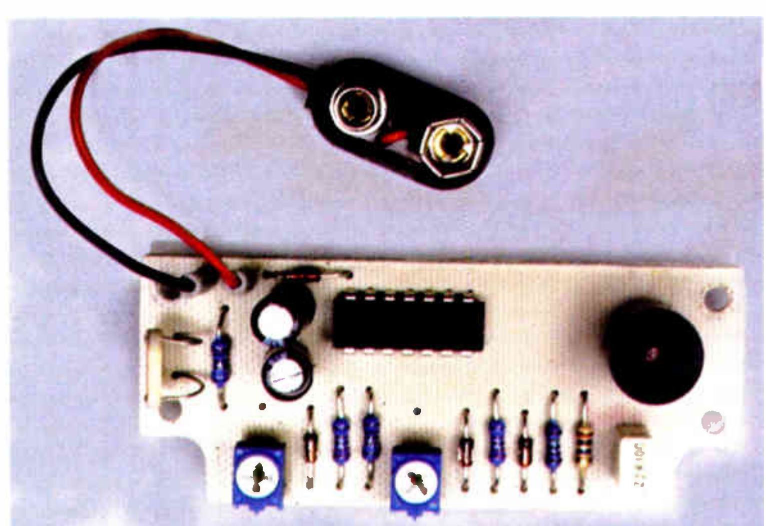
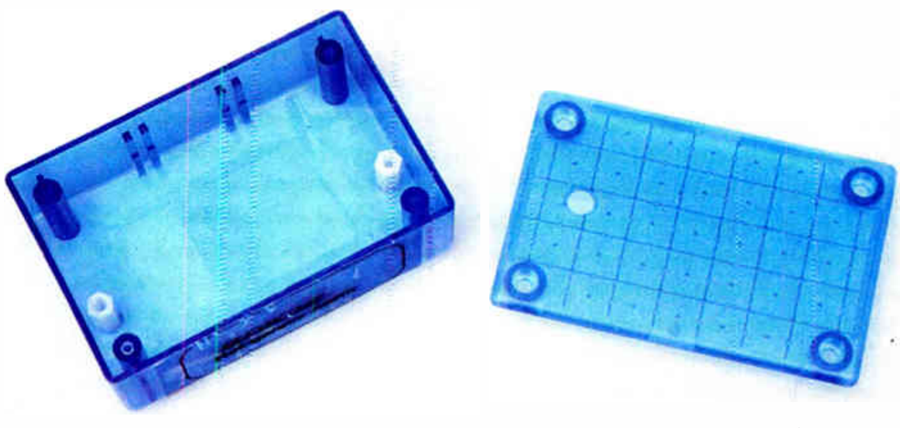
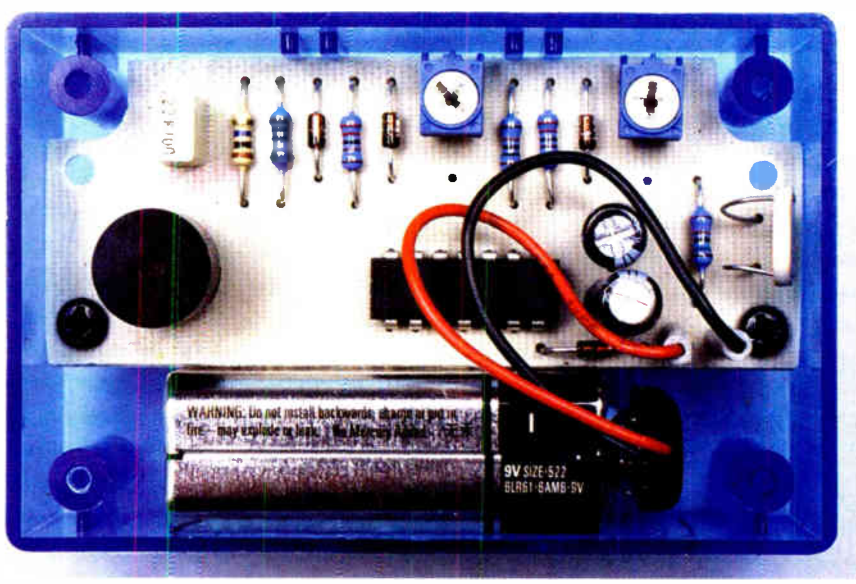


Fig.2: there's not much you can get back-to-front on the PC board – just the IC, diodes, electrolytic capacitors and the piezo siren (and of course the battery wires). The LDR is not polarised. Use this component layout along with the photo at right when putting it together.





The plastic box needs to have two holes drilled in the bottom (for the mounting pillars) and one in the top (to let the sound out).



Here's how it all goes together in the box. It's a nice snug fit with the battery held in place by the PC board.

discharges to about 3V, it reaches the lower threshold voltage for Schmitt trigger IC1c and its output at pin 6 goes to 9V. Capacitor C2 now charges up via the 1MΩ resistor and diode D3. This charge time is about 10 times faster than the discharge time and when the voltage reaches the upper threshold of IC1c's input the output at pin 6 goes to 0V.

IC1c thus forms a burst oscillator where the output is at 9V for only a short time compared to its low output period.

When IC1c's output is at 9V, the resulting 0V output of IC1d, IC1e and IC1f drive the piezo siren with a 9V supply and the siren sounds. When IC1c's output goes to 0V, the IC1d, IC1e and IC1f inverter outputs are at 9V and the siren is off. This sequence of signal drives the siren with bursts of sound.

When the refrigerator or freezer door closes again, the LDR goes to a high value of resistance. Thus pin 1 of IC1a rises toward the upper threshold of the Schmitt trigger. This may take several seconds because the dark resistance of the LDR slowly increases over time until it reaches its ultimate value.

It is a rather slow responding device to low ambient light levels. VR1 is included to adjust the sensitivity to darkness. It is adjusted so that the alarm will still operate even with very low light levels, which are typical when the door of the fridge or freezer is left ajar.

Ultimately, when in complete darkness, pin 1 of IC1a will reach 6V and the IC1a output will go low to discharge C1. The resulting 9V at pin 4 of IC1b charges capacitor C2 via D2 and the 2·2kΩ resistor. This holds the burst oscillator off with the pin 6 output at 0V.

Power for the circuit is obtained from a 9V battery. Diode D4 provides reverse polarity protection if the battery is connected in reverse. A 100µF capacitor decouples the supply and provides energy for the piezo siren when it draws bursts of current.

Construction

Parts for the Fridge Door-Open Alarm are assembled on a PC board coded 587 and measures 78 x 32mm. The PC component layout and full-size underside copper foil master are shown in Figs 2 and 3 respectively. The PC board is mounted inside a translucent box measuring 83 x 54 x 31mm. The box can either be uncoloured or tinted.

Begin construction by checking the PC board for any shorts between tracks or breaks in the copper. Check hole sizes and file out the corner section of the PC board on two corners if not already removed. These cutouts are required to allow access for the internal pillars in the box. The mounting holes need to be 3mm in diameter.

Now install the resistors, diodes and IC1. This IC and the diodes must be oriented as shown in Fig.2.

Resistors are marked with a colour code and these are shown in the accompanying resistor code table. You can use this table as a guide to selecting each value. Also it is a good idea to check the value with a digital multimeter. Install the two trim pots VR1 and VR2. These have a 1MΩ resistance and may have a 105 marking on the side.

The two 100µF electrolytic capacitors should be *low leakage* types, as previously mentioned, and must be oriented with the polarity shown in the overlay diagram.

Place the PC stakes at the 9V battery lead connection points and in the holes allocated for the piezo siren. The siren is mounted by soldering its leads to the PC stakes. Note that the PC stakes and siren leads will need to be shortened so that when installed the top of the siren is 14mm above the top of the PC board.

The LDR is mounted by inserting its leads into the PC board leaving a 10mm length between the LDR and

Parts List
Fridge Door-Open Alarm

- 1 PC board, code 587, available from the *EPE PCB Service*, 78 x 32mm
- 1 UB5 translucent box, 83 x 54 x 31mm
- 1 panel label
- 1 piezo siren, 12mm diameter, 7.6mm pin spacing (–20°C operation)
- 1 9V alkaline battery
- 1 9V battery clip lead
- 1 LDR with greater than 1MΩ dark resistance
- 2 10mm M3 tapped spacers
- 2 M3 x 6mm countersunk screws
- 2 M3 x 6mm pan head screws
- 4 PC stakes

Semiconductors
- 1 MM74C14, CD40106BC (–40°C to 85°C) hex Schmitt trigger (IC1)
- 4 1N914 or 1N4148 diodes (D1-D4)

Capacitors
- 2 100µF 16V low leakage electrolytics
- 1 220nF MKT polyester (code 224 or 220n or 0·22µF)

Resistors (0·25W, 1%)
- 1 10MΩ (10%) 1 1MΩ
- 1 150kΩ 1 100kΩ 2 2·2kΩ
- 2 1MΩ horizontal trimpots (VR1, VR2)

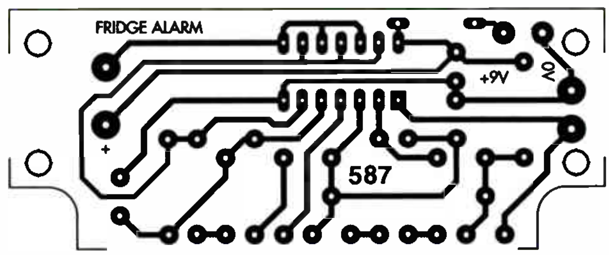


Fig.3. Full-size etching pattern for the Fridge Door-Open Alarm PC board.

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PC board. After soldering, the LDR is carefully bent over at right angles to face the edge of the board.

The PC board is mounted within the case using two 10mm long spacers to support the outside edge of the PC board while the edge that has the pillar cutouts is held within the integral side supports on the case. Place the board in the case with its edge pressed into the side supports and mark out the hole positions for the outer edge mounting holes. Drill out these holes in the base of the case and countersink them from the underside of the box suitable for countersunk screws.

The side supports on the other side of the case need to be removed to provide space for the battery to mount between the box side and PC board – see photo. These are removed with a pair of pliers twisting them sideways until they break out. Alternatively side cutters could be used or a chisel. Use safety goggles when doing this as pieces can fly out as they break.

Secure the 10mm tapped spacers to the base of the case with the countersunk screws. The PC board is secured to the top of the spacers using M3 pan head screws. Solder the battery leads to the supply PC stakes as shown on the overlay diagram (Fig.2).

Place the lid onto the case and mark out the centre position of the piezo siren. The hole in the lid needs to be about 6mm in diameter to ensure the full sound intensity can be emitted from the siren.

The alarm is now ready to be tested. Adjust VR1 to centre position and VR2 fully anticlockwise. Connect up the battery. The alarm should sound after about ten seconds, giving short bursts of sound. If this does not happen, make sure you are not working in the dark. Also check that the parts have been correctly placed on the PC board. Also measure the voltage at pin 2 of IC1. This should be close to 9V. Pin 4 of IC1b should be at 0V. The voltage between pin 7 and pin 14 of IC1 should be about 9V.

Adjust VR2 for the desired timeout before the alarm sounds. Fully clockwise will provide a nominal 100 seconds before the alarm will sound.

The alarm needs to be placed in complete darkness before the siren can be silenced. Simply placing a finger over the LDR is not sufficient. Note also that the alarm may take some 10 to 20 seconds to switch off in darkness as the LDR slowly increases its dark resistance. In a freezer, this time might increase to several minutes!

You can test the alarm by placing it inside a drawer instead of the refrigerator. Adjust VR1 so that the alarm sounds if the drawer is opened slightly. Now place the alarm unit inside the fridge or freezer and check that it operates correctly after its temperature has stabilised.

You will need to readjust VR1 if the alarm is placed inside the freezer. This is because the threshold voltages for IC1a change with temperature. Also the dark resistance of the LDR does not rise to the same value found at room temperatures.

Variations

If you want a longer delay time, increase the value of capacitor C1. A 220µF capacitor will double the delay time. If you want to increase the alarm burst rate, decrease C2 in value.

The Fridge Door-Open Alarm could also be used as a locker or drawer alarm. In this case, a shorter delay time may be better. Reducing C1 will reduce the time. Also an on and off switch could be placed in the supply to the battery to disable the alarm. ***EPE***

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	10MΩ (10%)	brown black blue silver	brown black black green silver
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	1	150kΩ	brown green yellow brown	brown green black orange brown
❑	1	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	2·2kΩ	red red red brown	red red black brown brown

INTERFACE

Robert Penfold

MORE ON A VISUAL APPROACH TO PRODUCING VIRTUAL CONTROLS

IN the previous *Interface* article we made a start on the subject of using Visual BASIC 6 (VB6) to produce programs for use with your own add-on PC projects. Visual BASIC is well suited to producing virtual controls, meters, lights, and so on, and this subject will be explored further in the present article.

Free Lunch

However, before continuing with VB6 programming, some clarification is required regarding Visual BASIC Express. One or two readers have queried the lack of Shape and Line components in Visual BASIC Express. These components make it easy to produce things like virtual control knobs and meters.

This shortcoming was pointed out in the article on Visual BASIC Express, and since this version is free, you have to accept that it will have some features omitted. However, it is possible to draw on-screen objects using Visual BASIC Express, but via conventional programming rather than using the visual approach. I will try to cover this subject in a future *Interface* article.

There is supposedly 'no such thing as a free lunch', but those who have yet to download Visual BASIC Express Edition might be interested to known that there has been a change in Microsoft's pricing policy on all the Visual Studio Express software. Visual BASIC Express Edition is, of course, one of these programs. Instead of being free for one year after release, these programs are now permanently free. Although the Express versions have some limitations, they do seem to disprove the free lunch theory!

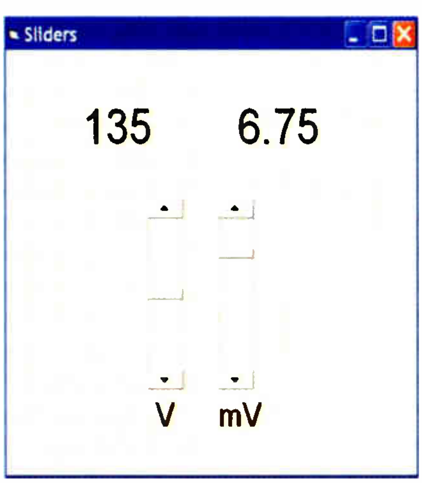

Fig.1. Using two slider controls rather than one makes it easier to set the required output level. Line and Label components can be used to add scales to the controls

On the Slide

Several circuits featured in previous *Interface* articles have used a simple program to set the value sent to an 8-bit port. Typically, this value is fed to a digital-to-analogue converter where it becomes an output voltage. For example, in a computer controlled power supply the value could be used to provide an output voltage from 0 to 12.75 volts with a resolution of 50 millivolts (0.05 volts). The example programs have relied on a slider control and a digital readout to control the output level.

The simple slider method works, but it can be tricky to set precisely the required output level. A simple solution to this type of thing is to have the output level set via two controls. In this example, there could be one control to set the number of whole volts and another to set the millivolts. Fig.1 shows a simple demonstration program of this type.

There are two digital readouts, with the one on the left showing the raw 8-bit value and the one on the right providing the voltage display. Of course, in a real control program the raw value would be output to the appropriate port instead of being displayed.

Listing 1

```
Private Sub Form_Load()
VScroll1.Value = 12
VScroll2.Value = 19
End Sub

Private Sub VScroll1_Change()
Volts = 12 - VScroll1.Value
Volts = Volts * 20
Output = Volts + (19 - VScroll2.Value)
If Output > 255 Then Output = 255
Label1.Caption = Output
Label2.Caption = Output / 20
End Sub
```

This program requires a form that has two label components to provide the displays, two vertical scrollbars, and a further two label components to provide the legends for the two controls. The maximum values for the two scrollbars are 12 (volts) and 19 (millivolts). A maximum of 19 rather than 999 is used for the millivolt control because it provides increments of 50 millivolts and not one millivolt.

Listing 1 shows the routines for the form and VScroll1. The routine for VScroll2 is essentially the same as the one for VScroll1, and has therefore been omitted to save space.

One slight problem with vertical scrollbars is that they provide the minimum value at the top and the maximum value at the bottom. This is presumably done to match the Visual BASIC co-ordinate system, but probably most people would find it more intuitive to have zero at the bottom. Some simple software tricks have therefore been used to make the controls operate in this fashion.

By default the scrollbars start at zero, which is with the slider knobs at the top. The two lines of code in the routine for the form set the knobs at the bottom. When one of the scrollbars is adjusted, the values from both scrollbars are read and mathematically manipulated to produce the appropriate port value and voltage readout. The value from VScroll1 is deducted from 12 to effectively invert the control and set zero at the bottom. Similarly, the value from VScroll2 is deducted from 19.

The value for the output port, which is actually used as the caption for Label1 here, is obtained by multiplying the value from VScroll1 by 20 and then adding it to the value from VScroll2. This value is divided by 20 to give the output voltage, which is then used as the caption for Label2.

Error Handling

One advantage of using a single scrollbar is that it is impossible for the user to generate out-of-range values. The maximum and minimum values for the control are set at the appropriate figures by the programmer, and the control is then foolproof.

The same is not true for all methods of control though, and it is often necessary to include some simple error trapping. Otherwise an erroneous value will be written to a port and the program will come to a halt with the appropriate error message being displayed.

In this case it is possible for an excessive value to be generated. The two controls can set output potentials of up to 12.95 volts, but the maximum valid value is 12.75 volts. Anything higher than 12.75 volts outputs a value of more than 255 to the port and generates an error message.

The simple solution is to have a program line that checks to see if the value for the port, which is held in the variable called Output, is greater than 255. If it is, the value stored in Output is made 255, and an error is avoided.

Keypad Entry

Back in the days of GW BASIC it was normal to enter numeric data via the keyboard. It is still possible to do things this way, but the more modern alternative is to have an on-screen keypad that is used to enter the data. Things like virtual keypads are very easy to implement using Visual BASIC.

The demonstration program of Fig.2 has a keypad that is formed by a block of 12 command buttons plus a larger Cancel button. These have been given suitable captions, including a full stop to act as the decimal point, 'ENT' for the one that will be used as the Enter button, and Cancel for the large button.

There are two label components, and the upper one shows the output voltage that is keyed-in by the user. The lower one displays the value that would be written to the output port if the program was the genuine article.

Part of the program is shown in Listing 2. The first line declares 'output' as a Public variable, which means that it can be accessed by any subroutine. It is made a Variant, which basically means that Visual BASIC will set its type to suit whatever operation is being performed.

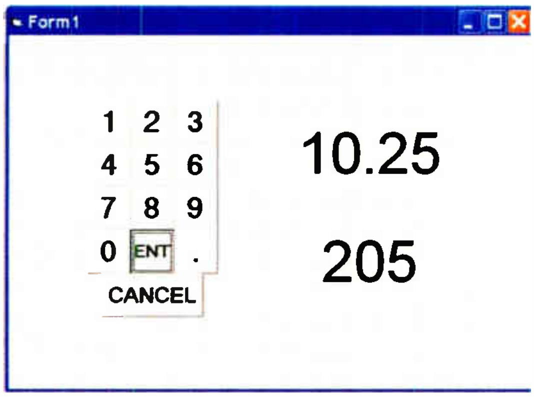

Fig.2. Since Visual BASIC6 has a button component, making a keypad is very straightforward. The Cancel button can be replaced with a Backspace type, or the keypad could incorporate both types of button

This is very convenient in the current application where it will initially hold a string of characters that provide the voltage display. The same variable then has to be treated as a numeric variable that is mathematically manipulated to produce the value for the second label. A Variant enables this to be achieved without the need for the program to provide any conversions.

The first subroutine is for the '1' key, but essentially the same routine is used for the others apart from the Enter and Cancel keys. Pressing this key adds the '1' character to the existing string of characters stored in 'output'. Of course, the appropriate character rather than '1' is used for each of the other keys.

Initially there will be no characters in the string, so the character for whatever key is pressed becomes the contents of 'output'. Pressing further keys results in the relevant characters being added to the string, as the requited output voltage is entered. The contents of 'output' are written to the caption of Label1 each time a key is pressed, so that the user can check that they have entered the correct data.

In Error

The next routine is for the Cancel button. This is used if an error is made when entering data. It simply clears the contents of 'output' by making it equal to an empty string, and then writes 'output' to the caption of Label1 so that the display is cleared. The user can then start again from scratch.

Visual BASIC has excellent string handling functions, and producing a Backspace key instead is very easy. A suitable subroutine is provided in Listing 3. This just detects the length of the string and replaces it with a substring that is one character shorter, deleting the most recently entered character.

The final routine is the one for the Enter key. First, this multiplies by 20 the voltage entered by the user, which gives the correct value for the output port. Some error checking is needed here, because it is possible to enter voltages in 10 millivolt steps, but the resolution of the system is actually 50 millivolts. Entering a value of (say) 12.14 volts would not produce an integer, and would produce an error message when it was written to the output port.

It is also possible to enter potentials greater than the maximum of 12.75 volts that the system can handle. Entering an excessive voltage would produce a value of more than 255, which would again produce an error message when it was written to the output port. Dividing 'output' by one using the \ symbol instead of the more usual / symbol results in any decimals being stripped off.

The next two lines detect values of more than 255 and respectively write 'Error' to the caption of Label1 and set 'output' at zero. The value of 'output' is then written to the caption of Label2, but in a real control program it would be sent to the appropriate port instead. Assuming no errors have been detected, this sets the hardware to produce the correct output voltage. Finally, the contents of 'output' are cleared so that the program is ready for a new voltage to be entered.

Listing 2

```
Public output As Variant

Private Sub Command1_Click()
output = output & "1"
Label1.Caption = output
End Sub

Private Sub Command13_Click()
output = ""
Label1.Caption = output
End Sub

Private Sub Command11_Click()
output = output * 20
output = output \ 1
If output > 255 Then Label1.
  Caption = "Error"
If output > 255 Then output = 0
Label2.Caption = output
output = ""
End Sub
```

Listing 3

```
Private Sub Command13_Click()
Length = Len(output)
If Length = 0 Then Exit Sub
Length = Length - 1
output = Left(output, Length)
Label1.Caption = output
End Sub
```

Listing 4

```
Private Sub HScroll1_Change()
Reading = HScroll1.Value
Reading = Reading * 30
Reading = Reading + 840
Line66.X2 = Reading
End Sub
```

Panel Meter

A panel meter, such as the example in Fig.3, is easily produced using Visual BASIC. This reads from zero to 12.75 volts. The whole thing can be drawn using the Line, Shape, and Label components, and it is then just a matter of controlling the X2 co-ordinate of the line that acts as the pointer. This requires some simple mathematical manipulation in order to get the scaling right. In this program the meter is controlled by a horizontal scrollbar that mimics an 8-bit input port by providing values from 0 to 255. Listing 4 shows the routine for the scrollbar.

The voltage divisions of the meter's scale are spaced by 600 in the Visual BASIC co-ordinate system, and zero line is at an X value of 840. The resolution of the system is 50 millivolts (0.05 volts), which means that there are 20 increments per volt. Multiplication by 30 is therefore needed in order to match the output of the scrollbar to the Visual BASIC co-ordinate system (30 × 20 = 600).

Likewise, 840 must be added in order to compensate for the fact that zero on the meter is at 840 in the co-ordinate system. The modified value is in the variable called Reading, and this is used as the X2 co-ordinate of the line used as the pointer (Line66). As is often the case with Visual BASIC, very little conventional program code is needed in order to make it work properly.

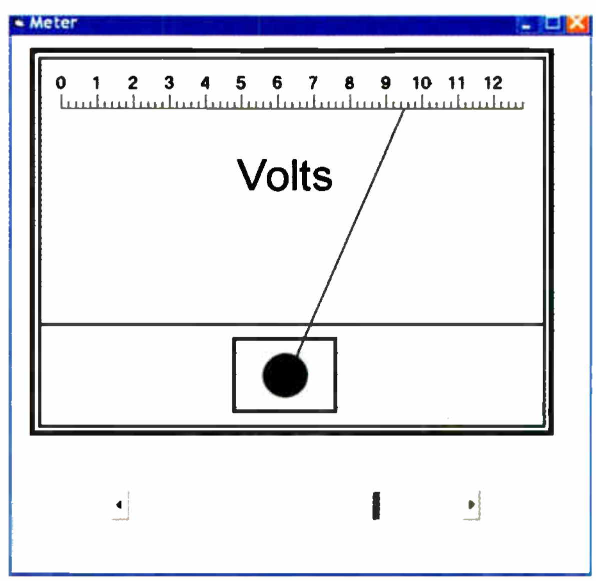

Fig.3. Provided the scale is straight rather than an arc, a virtual panel meter is easily drawn using the Line, Shape and Label components. Some simnple mathematics is needed in order to get the scaling right, but little conventional programming is needed in order to make the meter work properly

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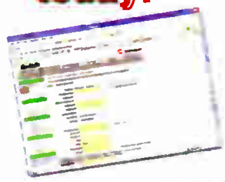

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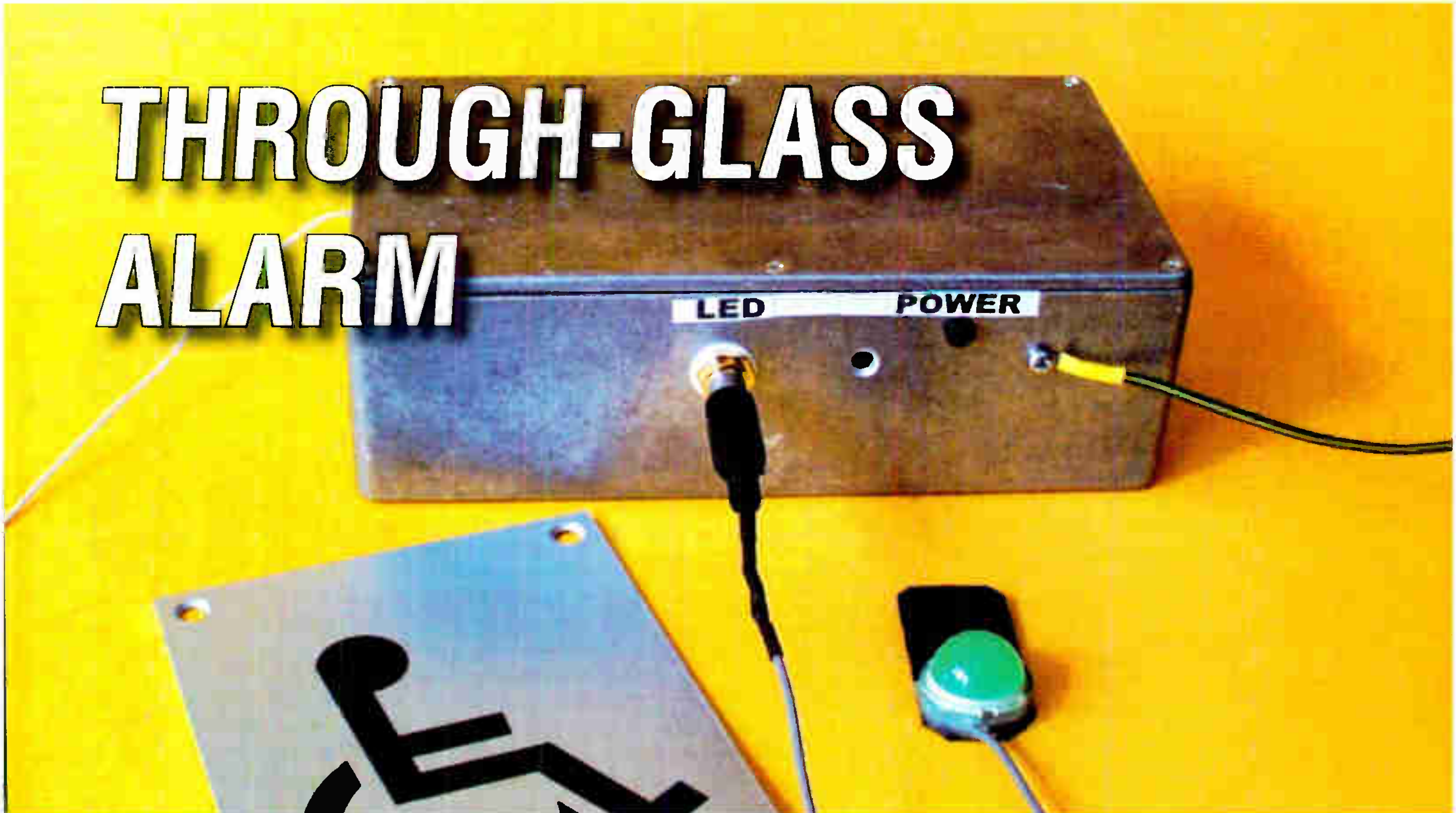


THROUGH-GLASS ALARM

Permits a disabled person to attract attention through a glass window

By Godfrey Manning BSc, MB BS, G4GLM

MODERN engineering can be sub-divided into the disciplines of mechanical, electrical/electronic, software and socially-beneficial. This project is in the latter category.

When Chris, the author's girlfriend, opened a retail art gallery, compliance with the Disability Discrimination Act (1995) was a problem. Mobility-impaired people would have trouble with the steps and right-angle turn into the shop and, being a Grade Two listed building, structural alteration was not possible.

To save even drilling a hole for a door-bell wire, the author devised the circuit now described. Inside the window, which must be a single-glazed simple sheet of glass, is a metal plate with a notice inviting the disabled person to place their hand, or the cheek of their face, over it (from the outside). When sufficient cover is achieved, an alarm sounds inside and a light, also visible in the window, comes on to show the caller that attention is being drawn to them.

The sensor plate is one side of a capacitor, the window makes a dielectric and the hand is part of the other, earthy (indifferent) side. Refer to Fig.1. By changing the capacitance, the balance of a radio-frequency bridge is altered. The bridge output is diode-detected and the resulting voltage compared to a fixed reference. When the changing bridge output voltage becomes sufficiently different to the reference, a monostable timer is triggered that activates the alarm.

Regard this design as an intermediate level project. The assembly is straight-forward and the parts easy to find, but to make it reliable you need an oscilloscope, a high-impedance (digital) voltmeter, a source of mild heat (hairdryer or adjustable heatgun) and patience!

Circuit operation

The complete circuit diagram for the Through-Glass Alarm is shown in Fig.2.

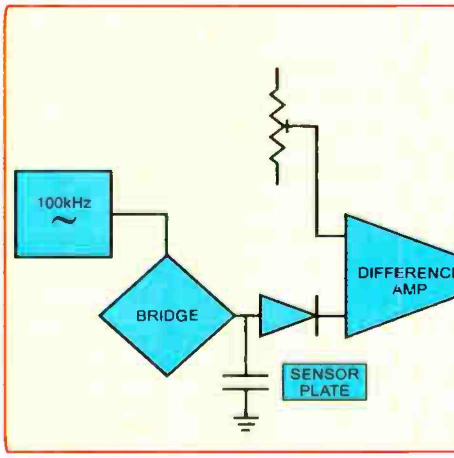
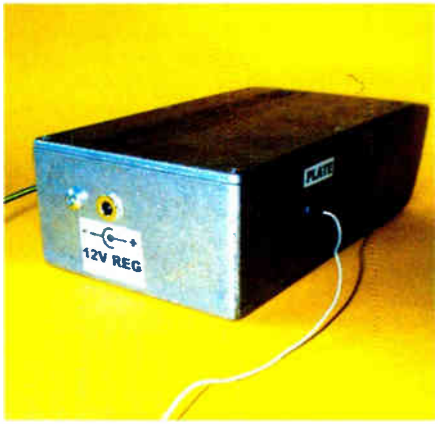


Fig.1. Basic block diagram for the Through-Glass Alarm



The unit is powered via socket SK1 with a regulated 12V DC supply, and decoupled by capacitors C1 and C2. Light emitting diode (LED) D2, current-limited by resistor R1, gives continuous reassurance that 12V is present.

If the worst comes to the worst (power supplies can fail with unregulated volts passed straight through), Zener diode D1 will conduct and blow fuse FS1, preventing damaging voltages reaching the rest of the circuit. Full crowbar protection of the circuit was not justified as the chips are cheap.

Being a radio amateur, the author knows not to cause electromagnetic compatibility interference and inductor L1 in the positive power supply lead keeps internal radio frequencies (RF) from appearing on the supply cable (which could act as an aerial).

Wien Bridge

The RF signal that powers the circuit's measuring bridge is generated by IC1a. (Don't get confused, this part of the circuit is also called a bridge but is a totally different type: a Wien bridge.) This is directly derived from the *Low-Frequency Wien Oscillator* circuit by Edwin Chicken (May '04).

The original circuit is modified to have a fixed frequency around 100kHz, determined by R4, C4 and R5, C5. A mid-rail voltage is produced by R2 and R3 with C3 providing decoupling. The other components, R6 to R8, arrange the right amount of feedback for reliable but undistorted oscillation.

Note back-to-back diodes D3 and D4 in the feedback path. These achieve rapid changes in feedback according to the generated voltage. Other types of component that can do this include filament bulbs (not very professional-looking to have a delicate lamp bulb in the middle of the circuit board) or expensive, delicate glass-encapsulated thermistors.

Parts List – Through-Glass Alarm

1 PC board, code 589, available from the *EPE PCB Service*, size 152mm × 89mm
1 diecast box, size 190mm × 110mm × 60mm
1 isolated phono socket, panel mounting (SK2)
1 phono plug (PL1)
1 2·1mm power socket, panel mounting (SK1), with matching plug
1 2·2mH 0·9A choke (L1)
1 4·7mH 500mA choke (L2)
1 20mm fuseholder, chassis mounting
1 20mm 500mA glass fuse
1 12V self-oscillating piezo sounder (WD1)
1 8-pin DIL socket
2 14-pin DIL sockets
1 12V DC 1A regulated, plug-in, mains adaptor
1 3-pin mains plug, see text
1 2-way fused mains multiplug
5 PCB supports, see text

Semiconductors
1 1N5350B 13V 5W Zener diode
1 red LED, 5mm
1 green LED, 20mm high-brightness, high current
3 1N4148 signal diodes
2 BAT85 Schottky diodes
1 ZTX605 *npn* Darlington transistor
2 TL074 quad op amp ICs
1 555 timer IC

Capacitors
2 100p ceramic disc, 2·5mm pitch
1 1n ceramic disc, 3mm pitch
6 100n ceramic disc, 5mm pitch
1 470n polyester, 15mm pitch
1 10µ radial elect. 25V
2 47µ radial elect. 25V
1 100µ radial elect. 16V
1 220µ radial elect. 16V

Resistors (0·25W 5% carbon film, except R25 & R26)

1 110Ω	1 510Ω	2 4k7
1 5k1	1 6k8	3 10k
1 12k	3 15k	1 27k
2 47k	3 100k	1 200k
1 680k	2 1M	

1 10k n.t.c. thermistor (R25)
1 100k n.t.c. thermistor (R26)

Potentiometers (All top adjust)
1 10k 25-turn cermet preset
3 20k 25-turn cermet preset
1 100k 25-turn cermet preset
2 500k 25-turn cermet preset

Multistrand connecting wire
1mm terminal pins; nuts, bolts, washers; 20mm closed grommet; aluminium sensor plate, size to choice (or metal disabled toilet door sign); 1A mains plug fuse; solder, etc.

Temperature compensation

For all their rugged simplicity, though, the diodes introduce a problem of their own. They are temperature-sensitive. Don't think you can leave this circuit in a shop window in full sunlight as it will heat up and false trigger.

However, the temperature compensation is adequate if the circuit is placed out of the window in a reasonably stable room-temperature environment. This is achieved by n.t.c. (negative-temperature coefficient) thermistor R25, a cheap and rugged type, whose influence on the feedback (and hence gain) of buffer amplifier IC1b is adjusted by presets VR1 and VR2.

The other gain-determining component is resistor R9. So, from IC1b pin 7, via C6, comes a stable, amplitude RF signal that is coupled to the (Charles) Wheatstone (inventor of the concertina!) measuring bridge.

Bridge over the waves

Two arms of the bridge are formed by the two parts of the track of preset VR3, as defined by the wiper position. The other two arms are resistors R10 and R11, but the 'human capacitor' appears in parallel with R11 and reduces the AC voltage seen at the bridge output at capacitor C7. Again, a half-rail reference is provided (R12, R13, C9) as the PCB layout was easier this way than picking off from R2, R3.

A standard RF detector circuit then uses Schottky diodes D5 and D6 to derive a DC voltage across capacitor C8. This large(ish) capacitor offers a compromise time constant; the caller will be rewarded by a rapid response and yet transient noise will not cause a false alarm.

From here onwards, no more RF, everything's DC and easy! (sounds like an electronic version of the *Lambeth Walk*!).

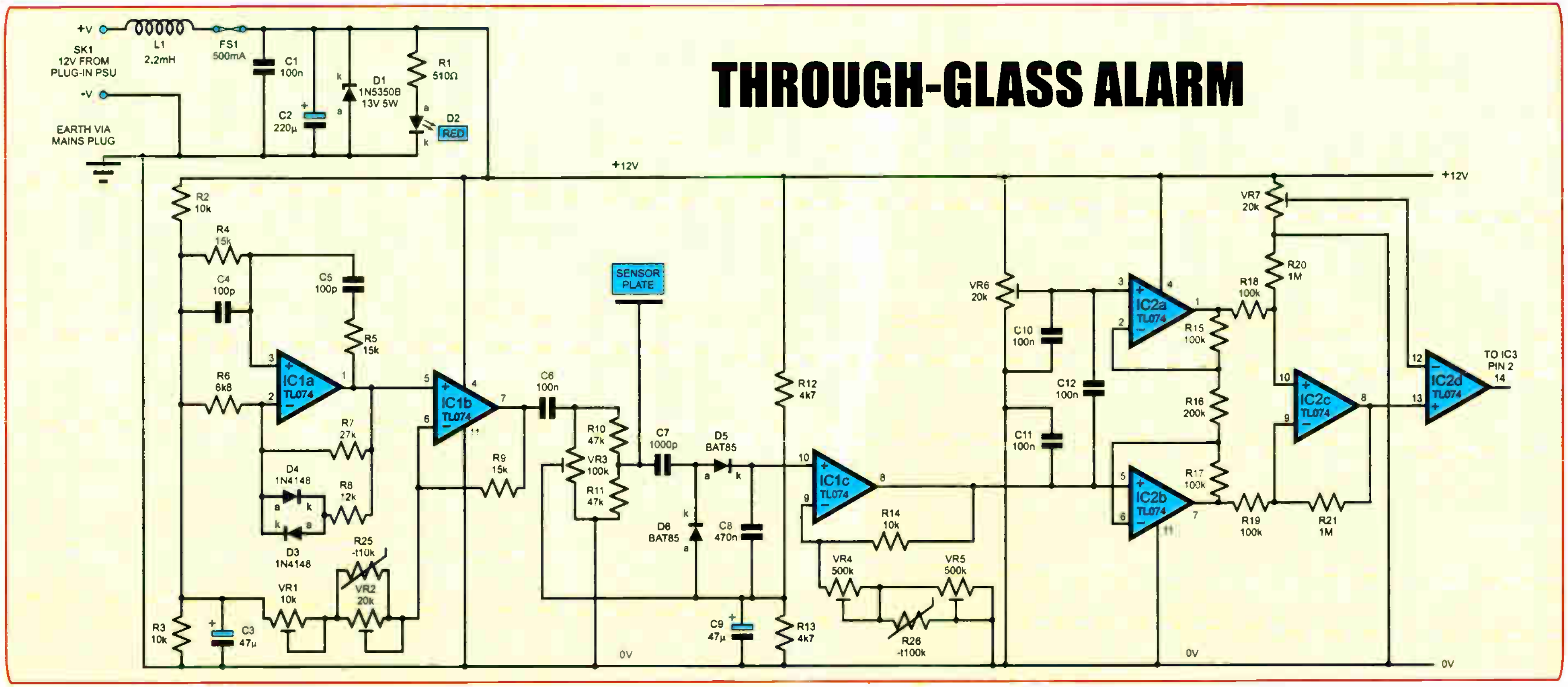
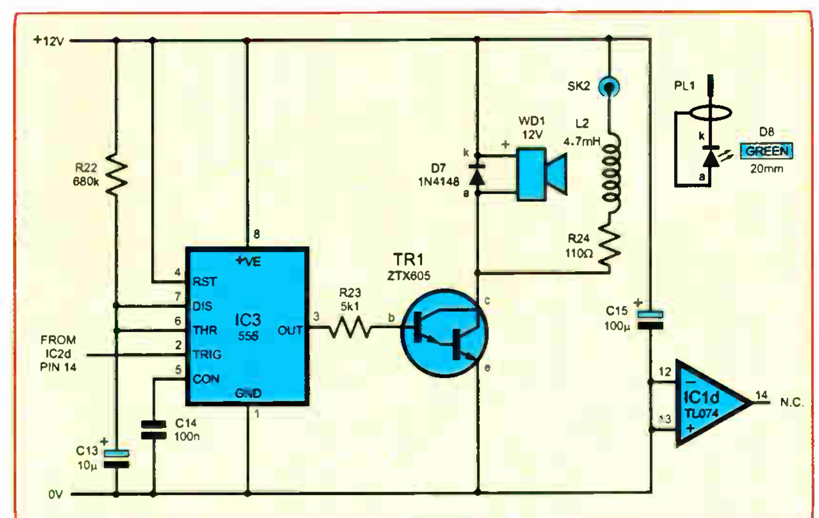


Fig.2. Joining these two circuits together completes the full circuit diagram for the Through-Glass Alarm project



Feeble problem

Of course, you say, that DC voltage is feeble, and that's why it is buffered by a high input impedance amplifier, IC1c. Here comes the next problem. First there was the crystal set, then point-contact germanium diodes which were more reliable and only wasted a tiny voltage drop (about 300mV). Even better, along came silicon but, unfortunately, 600mV is wasted so these aren't suitable for efficient detection of tiny signals. Luckily, the modern 'cat's whisker' is actually a sophisticated Schottky semiconductor that gives rise to alliterations, 300mV drop and temperature instability. Not so easy after all.

Diode characteristics change slightly with temperature, enough to matter here. This effect can even be used to measure temperature. Hence another thermistor, R26, its influence adjusted by presets VR4 and VR5, is needed along with R14 in the IC1c buffer's feedback loop. Schottky is the new germanium, if not cat's whisker! (It's not known if Wheatstone had a cat. No animals were harmed in the making of this project!)

Instrument amplifier

Another instrument – not a musical one this time! Op amps IC2a, IC2b and IC2c form an instrumentation amplifier (the workings of which were 'amplified' in *Teach In 2002* March '02). The advantage of this type of amplifier, when the input changes by only a small amount, is that its output correctly follows the differential inputs while common-mode errors are minimised.

The buffered DC from the detector depends on the bridge balance. This voltage is applied to pin 5 of IC2b and compared to the reference from preset VR6 on IC2a pin 3. Input noise is eliminated by capacitors C10 to C12. Differential gain is determined by resistors R15 to R17.

The differential output swing is now large enough to reliably feed an open-loop 'bang-bang' comparator at IC2d pin 13. When the voltage exceeds that set by preset VR7 on IC2d pin 12, output pin 14 swings well below the trigger threshold of timer IC3 pin 2. This standard retriggerable monostable turns on Darlington transistor TR1 via output pin 3 and current limiter R23. The on-time (about nine seconds) being determined by components R22 and C13 (which can be varied for different timings).

The standard 555 timer used for IC3 is a chip that is known to place a pulsatile load on the supply when it triggers, so locally-mounted capacitor C15 meets the demand and decouples the transient from the +12V rail.

Transistor TR1 should be capable of powering more than just the self-oscillating buzzer/bleeper, WD1, and LED D8 that tells the caller that they have successfully activated the alarm.

Because D8 is on the end of a long lead (plugged in via SK2) it is fed through RF choke L2 to reduce unwanted emissions. The internal resistance of the choke plus that of resistor R24 limits the current to the maximum 25mA allowed for the specified LED.

Diode D7 across the entire collector load of TR1 eliminates the back-EMF hazard of certain types of electromechanical buzzer or, if desired, a relay that could optionally be added. There's room at one end of the box for a relay, the coil of which would be wired to the same terminal pins as WD1.

Total TR1 load shouldn't take the overall circuit consumption too close to the 500mA rating of fuse FS1 and the interconnecting wire. If uprating these for a bigger load, remember that L1 is limited to 900mA and the voltage drop across it might become important.

IC1 and IC2, TL074 quad op amps, were chosen so as to minimise the package count. In fact, op amp IC1d is redundant and its inputs are tied safely to ground. The other feature of the TL074 is that it offers low noise, helpful in an environment where small signals are being measured. It is also cheap!

If the circuit is less sensitive than expected, the earth coupling (indifferent side of the 'human capacitor') can be increased by simply connecting the 0V rail to mains earth as the only connection to a standard mains plug.

Power supply

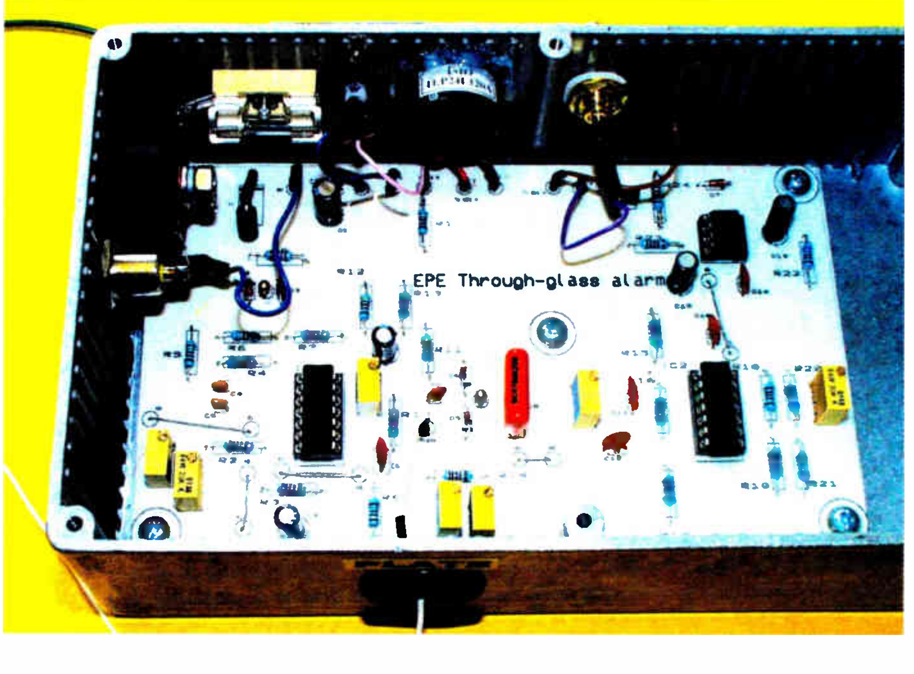
The power supply is ready-made and self-contained in what looks like an overgrown mains plug. The logic is unclear, but such devices have no fuse and so defeat the protection required of equipment plugged into a ring-main. The worst case would be to blow the 30A fuse (or 32A circuit breaker) back at the consumer unit; a frightening bang could occur!

Unfortunately, with imports of these power supplies in profusion, it seems to be 'commerce before safety'. So, the author recommends the addition of a fuse to restore safe conditions – simply place a 1A fuse in a fused two-way multiplug, then plug the power supply into the multiplug. This inserts a fuse into the circuit and also offers a second outlet for the earth connection referred to earlier.

Construction

Printed circuit board component and track layout details are shown in Fig.3. This board is available from the *EPE PCB Service*, code 589.

Solder the five wire links first and then add the resistors. Build up with the larger components, the IC sockets, terminal pins, preset potentiometers and the capacitors. Finally, add the thermistors, diodes and transistor. You can mount Zener diode D1 flat to the board, not end-on as shown in the photograph. Observe the correct orientation of the electrolytic capacitors and the semiconductors.



Do not insert the ICs in their sockets until the complete assembly has been checked for accuracy. Check that the soldering is free from bridges across tracks, all joints nice and shiny and none missed. An ohmmeter correctly polarised across the supply input pins should read around 3kΩ (not a short!), mainly due to the resistor networks that are across the supply.

Turn each 25-turn preset's adjuster (with a suitable trim tool) to the end of its range (feels stiffer and clicks) then back 12.5 turns to the half-way position.

You know the drill

Drill the box and fit the parts that it carries. The five stand-offs needed are each held in the base of the box simply by M3 × 6mm countersunk screws. The wire to the sensor plate passes through a 20mm blanking grommet, the standard size for electrical box knock-outs.

The box is continuous with earth because socket SK1 is not insulated. Throw away the socket's washer and install with just the nut.

Attach inductor L1 with an M5 × 25mm panel-head bolt, introduced from the outside. Slide L1 over the bolt from the inside, followed by a fibre washer, a plain washer, a spring washer and a nut (all M5) and secure (not too tightly, don't crush the ferrite) with the connecting wires in a horizontal position. The wires are thus placed to solder easily to the centre terminal of SK1 and to the fuseholder.

Attach the fuseholder for fuse FS1 by M3 hardware, first slipping a shakeproof 'star' washer then a solder tag over an M3 × 12mm panel-head bolt, introducing this stack through the box from the outside. Inside the box, slide the fuseholder over the bolt followed by a plain washer, a spring washer and a nut. Again, protect the plastic by not overtightening. Access is fiddly, locking forceps help with placement. The fuseholder sits horizontally. Correct tightness means that a spring washer is just compressed flat, but the underlying part is not deformed nor the bolt stretched.

LED D2 is self-contained and mounts in its hole in the conventional manner. Buzzer/sounder WD1 is held by a fillet of glue such as hot-melt. Socket SK2 *must be isolated* from the box, note that one of its plastic washers has a narrow shoulder. Slip this washer onto the socket with the shoulder pointing away from the mating end. Introduce into the hole and make sure that the shoulder seats within the hole. Slip the other plastic washer and then the solder tag onto the threaded body from within the box, follow up with the nut and do not overtighten. Use an ohmmeter to prove that the body of the socket is *not* electrically connected to the box.

Wiring up

Do NOT fit fuse FS1 in its holder, or any chip into its socket yet. Don't connect WD1 as the sound will get on your nerves during setting-up. Likewise, do not wire the solder tag side of SK2 yet as the current to D8 needs to be verified.

Otherwise, place the PC board into the box and attach loosely to one spacer, by an M3 × 6mm panel head bolt over which has been slipped a plain then a nylon M3 washer. This is the attaching regime for all five points when complete, but if anything does not seem right, you might need to uproot the board again at this stage.

When wiring, use sleeving (preferably heatshrink) wherever possible and adopt a sensible colour-code; 10 × 0.1mm wire is ideal. Avoid excessive lead lengths. The centre terminal of SK1 should be in easy reach for soldering a wire from choke L1 to it. SK1's solder tag is wired to the 0V terminal pin. The other side of L1 is soldered to the fuseholder and the other side of the fuseholder goes to the 'From FS1' terminal pin.

LED D2 wires go straight to the appropriate PCB terminal pins but verify it first with an ohmmeter to get the polarity correct. L2 is soldered hard up to the centre terminal of SK2, its other end is now wired to the allocated board terminal pin.

Sensor plate

The sensor plate wire ought to have sleeving where it passes through the grommet. A tie-wrap around the wire, close to the inside wall of the box, can prevent it from being pulled out. The other end attaches to the sensor plate by a solder tag. An M5 × 6mm countersunk bolt is introduced through a corner hole of the plate from the front side, on the other side is slipped a solder tag and shakeproof 'star' washer and then a nut.

The bolt head might still stand proud and tend to lift the plate off the window, so slightly bend that corner of the plate backwards until the plate itself is a perfect flush fit against the glass. For convenience with the prototype, the author broke the connection with a 1mm plug/socket.

LED D8 is wired by a convenient length of lap-screened audio cable, soldered directly to it, screen to anode (a). The other end of the cable solders to a phono plug, PL1, screen to body and inner to tip. Hot-melt glue the LED to a small piece of plastic sheet, which then acts as a means of mounting.

Lastly, sensitivity might be improved if the 0V rail (the box itself) is a true earth, for which purpose a wire from the external solder tag (adjacent to fuse FS1) is taken to the Earth pin of a mains plug (leave out the plug's fuse, loose live terminal and the neutral screw).

Ready, go!

Insert fuse FS1 and check again for about 3kΩ resistance with an ohmmeter at socket SK1. Power up and, with reference to the box which is at 0V, check for +12V at the IC sockets, at IC1 pin 4, IC2 pin 4 and IC3 pins 4 and 8. Then, with reference to +12V at the output side of fuse FS1, check for 0V on IC1 pins 11, 12 and 13, IC2 pin 11 and IC3 pin 1. LED D2 should glow. Switch off.

Remove fuse FS1 and, with antistatic precautions, insert the three ICs. Bridge the fuseholder with a current meter and power up – around 40mA is normal. Switch off and replace the meter by the fuse. Switch on but leave the earthing mains plug disconnected, so as not to form a hum loop with the oscilloscope, which is now needed.

The scope should show a reasonable sine wave, around 100kHz and 2.5V peak-to-peak at IC1 pin 1 (all measurements referenced to the box). Switch off.

Temporarily link terminal pin for SK2 to the solder tag of SK2 via a current meter and plug in PL1, to which LED D8 was previously wired. Power up briefly and confirm that D8 lights, noting the current. This should be just below the maximum rating of 25mA and depends on the internal resistance of inductor L2 in series with resistor R24. Any great deviation from this current requires replacement of R24 with a value that correctly achieves the right current.

Complete the wiring of SK2's solder tag. You might now like to temporarily shunt resistor R22 with a 10kΩ resistor so that the alarm-sounding period becomes very short while testing. Ignore LED D8 for now as it might stay on continuously until further adjustments are made.

Patience is appreciated

In cool ambient conditions, look at IC1 pin 7 output with the scope while adjusting presets VR1 and VR2. Turn VR2 clockwise (CW) to its end-stop, then adjust VR1 CW until the waveform shrinks and is no longer clipped (or anti-clockwise, (ACW), to expand the wave just prior to the point of clipping).

THROUGH-GLASS ALARM CIRCUIT BOARD CONSTRUCTION

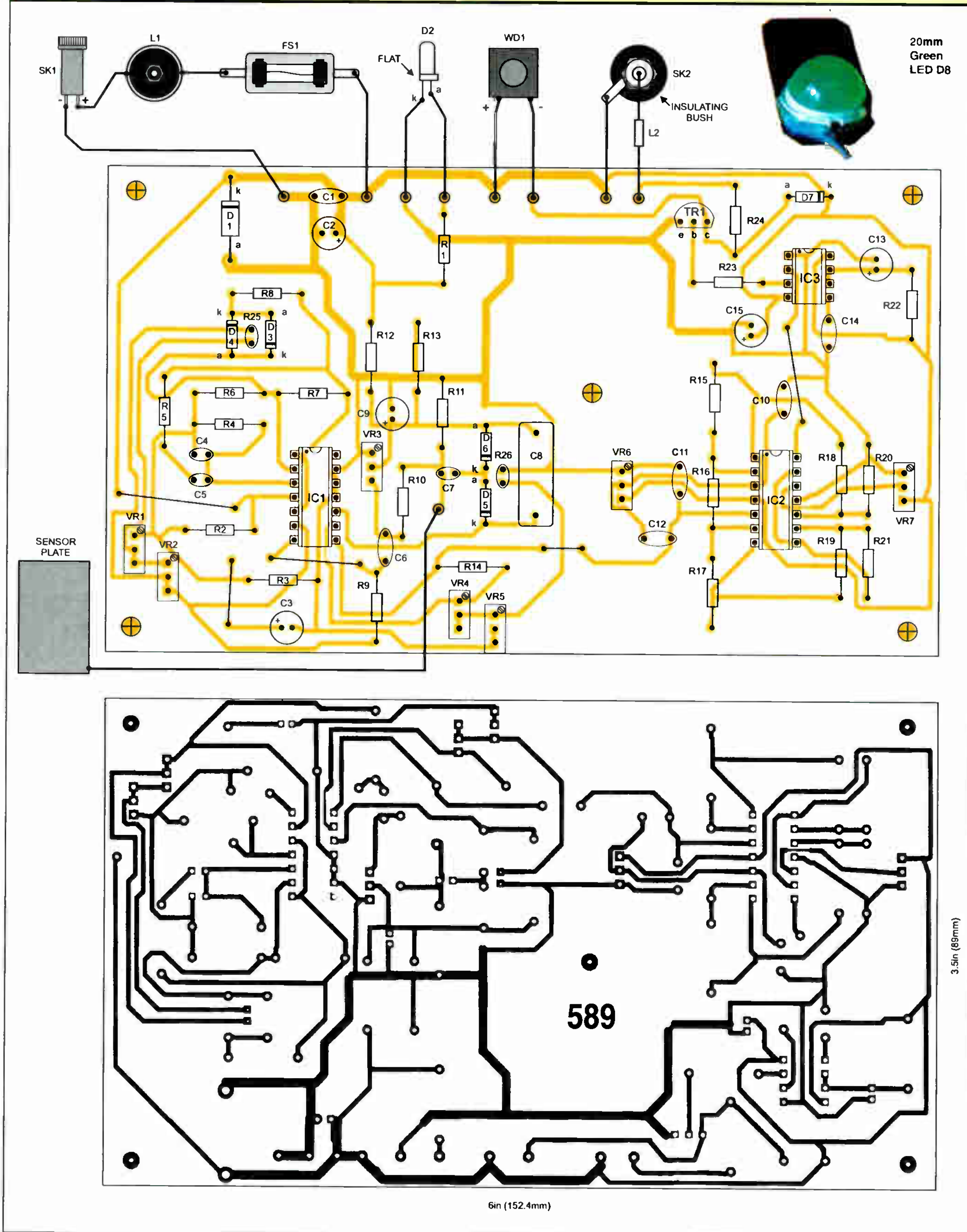


Fig.3. Through-Glass Alarm printed circuit board component layout, full-size underside copper foil master and interwiring details to off-board components. Note the 20mm Green LED is attached to phono plug PL1

Now to compensate for temperature changes. You will need to apply quick blasts of hot air, observe the result, allow to cool (an air-duster aerosol helps), adjust a little, then repeat. Patience with this interactive process pays dividends.

It's like getting the right temperature in your bath. The two mixer taps can provide the same temperature but at different flow rates. If one tap is moved, the other can be altered to restore the temperature – but the total flow will be different. Eventually, one tap reaches the end of its range and further adjustment of the other will alter the temperature. So with VR1 and VR2.

A quick blast of hot air (from hair-dryer/heatgun/Parliamentary committee!) in the direction of diodes D3/D4 might make the waveform grow (causing insensitivity) so reduce the influence of thermistor R25 by turning VR2 ACW, initially by two turns, less when nearly right, and compensate by VR1 CW to prevent distortion. Eventually, there will be little change, but err on the side of growth-with-heat.

Insufficient influence from thermistor R25 causes reduced amplitude with heat and false triggering. With the prototype there was less than 100mV change.

Sensitive touch

Dress the wire to the sensor plate along the bench, lay the plate out such that it and the wire are not near anything else. Put a small sheet of glass flush over the plate. Transfer the scope to the junction of resistors R10 and R11, and turn preset VR3 CW until the sinewave just vanishes.

Now turn slowly ACW until the trace reappears, keep going for maximum amplitude and two more turns beyond that. You will see about 2V peak-to-peak and this will reduce by perhaps 400mV when a hand is placed over the plate in contact with the outside of the glass.

Remove the scope, plug in the earth connection and take readings with a high-impedance voltmeter, starting at IC1 pin 8. Hopefully, the voltage here will drop by about 300mV when the hand covers the plate. Now, with preset VR5 fully CW and VR4 fully ACW, thermistor R26 has greatest influence.

If a blast of hot air over diodes D5 and D6 makes the voltage rise, VR5 needs to go one turn ACW and VR4 one turn CW. Conversely, for voltage fall with hot air. Eventually, it gets critical with just tiny adjustments. Remember the bath taps. Aim to minimise the temperature variation, better than 100mV either way.

That should set up the temperature compensation. Hopefully, none of the foregoing will need further adjustment even if the unit is moved to a different location. Allow the unit's temperature to equilibrate to ambient and place the box in its final position. Make sure that it is away from direct heat and sunlight (not actually in view in the window!) and secure, so it will not get moved around any further.

Attach the sensor plate flush with the inside of the glass with ultraviolet-proof 'all-weather' tape; likewise LED D8. Remember that wheelchair-bound people see the world from a sitting height, allow for this when deciding the position of the plate.

Final adjustment

Right, we've worked hard for this, here comes the reward of seeing it work. Initially, the alarm can be triggered from inside by putting a hand over the plate. Final adjustment requires an assistant stationed where intended, outside the window.

With the prototype it was noted that at IC1 pin 8 the voltage was about 9.7V quiescent, 9.3V with the hand. You are allowed to differ! Adjust preset VR6 while monitoring IC2 pin 3, to get about half-way between these voltages, CW to increase. Now the voltage at IC2 pin 8 becomes the amplified difference between the reference at preset VR6's wiper and whatever is coming from the bridge. On the prototype, there was something like 1.3V quiescent (probably the minimum output possible from this type of op amp) going over 5V with the hand across the sensor plate.

Adjusting VR6 in 50mV steps can make a difference to the sensitivity. But the main chance to set a sensitivity threshold comes next, where IC2d makes a simple comparison between the reference at IC2d pin 12 from VR7, and the amplified difference signal on IC2d pin 13. The idea is that VR7 is set so that a concerted effort is needed to cross the threshold, avoiding false triggering, but that once the hand is placed over the plate, the threshold will be crossed with certainty and enable the caller to trigger the alarm with ease.

Start with VR7's wiper holding IC2d pin 12 at a voltage midway within the swing seen at IC2d pin 13. Make repeated triggerings and adjustments of VR7 until sensitivity seems acceptable.

That's it! If all's well, attach the PCB definitively, solder the wires to sounder WD1 and remove the shunt from across resistor R22. You now might like to wear ear defenders if you've chosen a loud sounder for WD1!

Test out the circuit a few more times (sounds for about nine seconds each time), drawing around 75mA from the supply (25mA of which is lighting LED D8) and then you can screw down the lid.

Epilogue

As a radio amateur, the author is hardly likely to go causing interference if he can help it (would that commercial designers were this aware!). A wire antenna from his sensitive communications receiver, draped over the PCB, barely picked up the internal RF It was just heard heterodyning in the background and almost swamped by the other noises arriving at the receiver.

The completed diecast box makes a good RF seal, unlike less-secure folded sheet aluminium enclosures.

Temperature compensation is possible over a sensible room-air range. The author got to the stage where he could heat the box such that it was too hot to touch, especially underneath where the PCB is mounted. It did not false trigger, but became slightly less sensitive to the hand. You would not plan to allow such equipment to get this hot in practice.

There is no reason to deny a wide range of experiences, including the world of fine art, to the less physically fortunate in our society. This project assists, but above all, what really matters is to converse with people as individuals and not consider them as unapproachable just on the grounds of a disability. Most medical conditions are a matter of chance; you might be one of the lucky ones, but never forget that it could happen to any of us and there's no way of predicting the future. ***EPE***

Acknowledgements

The author wishes to thank Christine Mlynek who let him use her shop as a test-bed (an example of what she's had to put up with over the 20 years that they've been together!). Also his cousin Norman who, much longer than 20 years ago, unwittingly helped him realise how significant hand-capacitance effects are at these frequencies.

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- Requires 9V battery

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KC-5209 £7.50 + post, packing & VAT

This kit will let you control a DVD or Hi-Fi system using a remote control from another room. It picks up the signal from the remote control and sends it via 2 - wire cable to an infrared LED located close to the DVD or IR receiving equipment. The kit is a breeze to construct and will work with virtually any remote control system. The Jaycar kit comes complete with case with silk screened front panel, PCB, hardware and all electronic components with clear English instructions.

- 2 wire cable required

Requires 9VDC wall adaptor (Maplin #G574R £9.99)

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KC-5425 £7.25 + post, packing & VAT

This kit converts coaxial digital audio signals into optical or vice-versa. Use this bit stream converter in situations where one piece of equipment has an optical audio input and the other a coaxial digital output. Kit includes Toslink optical modules, PCB with overlay, case with screen printed lid, all electronic components and clear English instructions.

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Requires 9-12VDC wall adaptor (Maplin #JC91Y £14.99)

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KC-5427 £29.00 + post, packing & VAT

This kit attacks a common cause of failure in wet lead acid cell batteries: sulphation. The circuit produces short bursts of high level energy to reverse the damaging sulphation effect. This new Improved unit features a battery health checker with LED indicator, new circuit protection against badly sulphated batteries, test points for a DMM and connection for a battery charger. Kit includes case with screen printed lid, PCB with overlay, all electronic components and clear English instructions.

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EPE had been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are brilliantly designed, '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.

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- As published in Everyday Practical Electronics September 2006

Requires 9VDC wall adaptor (Maplin #GS74R £9.99).

Studio 350 High Power Amplifier Kit

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

As published in this month's Everyday Practical Electronics Magazine

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This unit will test for continuity from 1-100ohms, making it ideal for measuring low resistance devices. It is accurate, reliable, and works extremely well. Kit supplied with PCB, case with silkscreened panel and all electronic components.

- As published in Everyday Practical Electronics April 2006

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KC-5361 £15.95 + post, packing & VAT

Program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. Card used need to conform to ISO-7816 standards, which includes ones sold by Jaycar. Powered by 9-12 VDC wall adaptor or a 9V battery. Instructions outline software requirements that are freely available on the internet. Kit supplied with PCB, wafer card socket and all electronic components. PCB measures: 141 x 101mm.

- As published in Everyday Practical Electronics May 2006

Requires 9-12VDC wall adaptor (Maplin #JC91Y £14.99)

Jaycar cannot accept responsibility for the operation of this device, its related software, or its potential to be used in relation to illegal copying of smart cards in cable TV set top boxes.

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This kit will step-up 12V to between 13.8 and 24VDC. Use it to charge 12V sealed lead acid batteries (6.5Ah or larger), run your laptop and many other devices from a 12V supply. It uses an efficient switchmode design, features fuse and reverse polarity protection, and an LED power indicator. Kit includes PCB, all electronic components, and silkscreened front panel.

- As published in Everyday Practical Electronics August 2006

Tiptronic Style Gear Indicator Kit

KC-5344 £20.30 + post, packing & VAT

This display indicates up to 9 gears, neutral and reverse. The unit is calibrated in setup, so it will work with almost any vehicle. Using a PIC microcontroller, it calculates the gear via the engine RPM and road speed. Gear indication is displayed on a 7 segment LED display, and features an automatic dimmer for night driving. Supplied with case, pre-punched silkscreened front panel, PCB and all electronic components. Hall effect sensor included!

- As published in Everyday Practical Electronics January 2006

AC/DC Current Clamp Meter Kit for DMM's

KC-5368 £8.75 + post, packing & VAT

A great low cost alternative. It uses a simple hall effect sensor, an iron ring core and connects to your digital multimeter. It will measure AC and DC current and has a calibration dial to allow for any magnetising of the core. Kit supplied with PCB, clamp, case with silkscreened front panel and all electronic components.

- As published in Everyday Practical Electronics January 2006

Audio Video Booster Kit

KC-5350 £31.95 + post, packing & VAT

This kit will boost your video and audio signals preserving them for the highest quality transmission to your projector or large screen TV. It boosts composite, S-Video and stereo audio signals. Kit includes case with silkscreened and punched panels, PCB and all electronic components.

- As published in Everyday Practical Electronics March 2006

Requires 9VAC wall adaptor (Maplin #GU09K £9.99).

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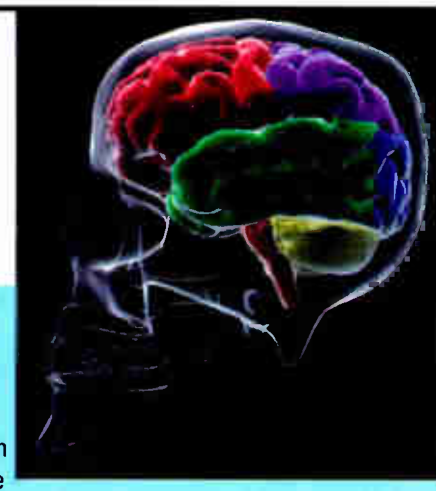

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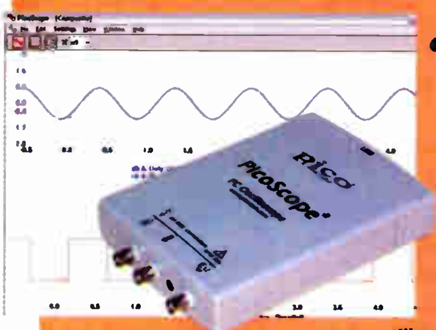

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC-based oscilloscope could be yours. Every 12 months, Pico Technology will be awarding a PicoScope 3205 digital storage oscilloscope for the best IU submission. In addition a DrDAQ Data Logger/Scope worth £59 will be presented to the runner up.

Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been published or submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: *Ingenuity Unlimited,* Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. (We do **not** accept submissions for IU via email.) Your ideas could earn you some cash and a **prize!**

Random Colour Generator – *Rearranged Rainbows?*

THE circuit diagram shown in Fig.1 was originally designed to illuminate a small translucent Santa Claus Christmas decoration, but could also be used in any number of applications, from a warning indication to a child's nightlight.

It controls one of the new RGB LEDs which contain separate red, green and blue LEDs all housed in a single 5mm package, each having its own anode and common cathode connections, enabling you to theoretically produce any colour of the spectrum. To keep things simple, this circuit only uses seven different colours, made by having various combinations of the three LEDs illuminated at any one time at their maximum intensity (red, green, yellow, blue, purple, cyan, white or off).

The circuit uses a 556 dual timer (although you could just as easily use two 555 timers) in astable mode. One output is at a high frequency, set by the combination of R3, R4 and C2, and is fed into the input of IC2, which is a 4040 12-stage binary count-

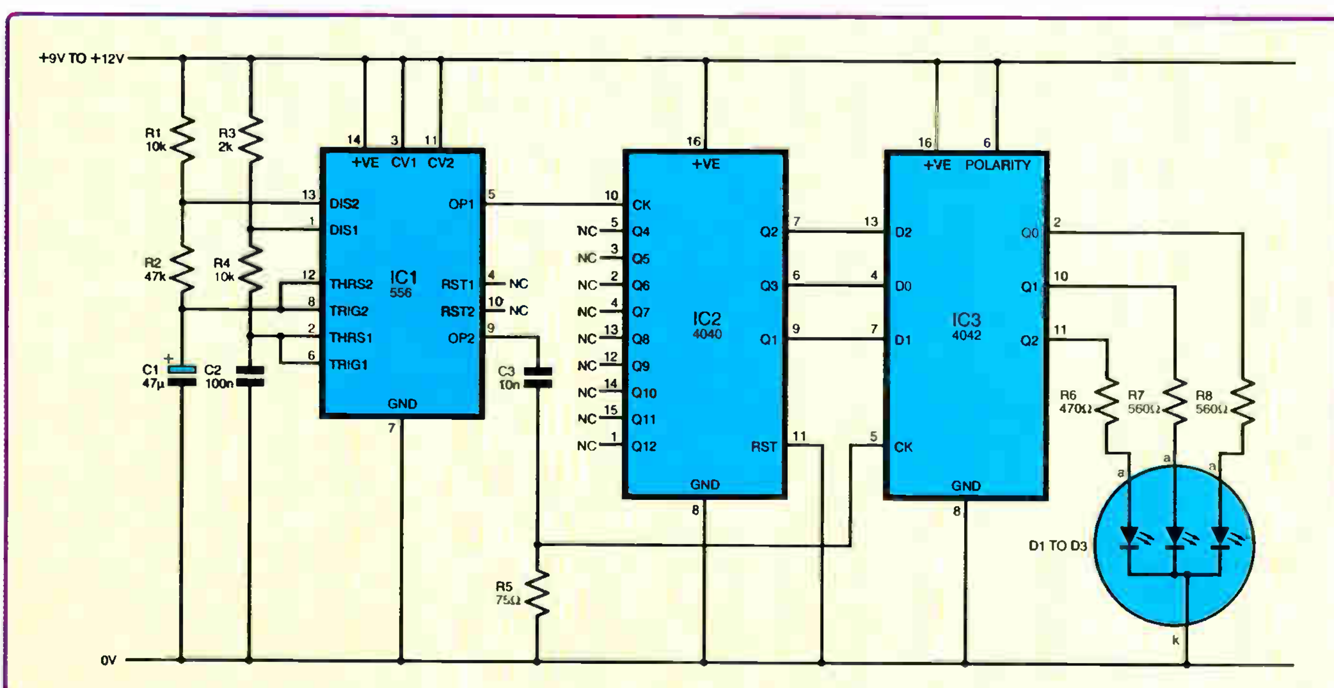

Fig.1. Complete circuit diagram for a Random Colour Generator using a tri-colour LED

er, although only the first three stages are used. These three outputs are fed into IC3, a 4042 quad latch which is clocked by the second clock output from IC1 via C3 and R5.

The frequency of this clock signal is approximately one pulse every three seconds and is set by the values of R1, R2 and C1. The outputs of IC3 are free to change according to the corresponding inputs as long as the clock signal is high. Therefore, it is important for the high period of the clock signal to be shorter than the frequency of the binary counter, otherwise there would be a brief burst of white light every time a clock pulse was received. This is achieved by the effective filtering effect of C3 and R5.

The three outputs from IC3 are each fed to the LEDs (D1 to D3) via current limiting resistors, R6 to R8. The outputs of IC2 are constantly changing at a very high rate and each time IC3 receives a clock pulse the present values of IC2's outputs are stored in the latch of IC3. As the two outputs from IC1 are out of phase with each other, the combination of LEDs illuminated changes in a seemingly random way.

The circuit shown here controls a single RGB LED, but as IC2 has a total of 12 outputs, it would be possible to control up to four such LEDs with only the addition of two more quad latches, and with each LED producing colours in a random sequence independently of each other. The frequency at which the LEDs change could also be controlled by replacing R2 with a variable resistor (potentiometer).

Ian Hill,
Plymouth, Devon

Switch Mode LED Unit – *Better Brightness*

THIS Switch Mode LED circuit was built for use in the author's garage, running off a 12V car battery. The light gives a constant output brightness from less than 8V to over 12V. The basic operation is shown in Fig.2.

At switch-on, the current through the LEDs gradually increases until a predetermined level is reached, as set by the latch. At this point a switch is opened, the supply to the LEDs is disconnected and their current is supplied by the energy stored in the magnetic field of inductor L1, via diode D1. This continues until the energy falls to a lower predetermined level, at which point the supply is reconnected. The process continues indefinitely.

The complete circuit diagram is shown in Fig.3. At switch-on, transistor TR2 is switched off, so TR3 conducts due to the base bias provided via resistors R2 and R3. This causes transistor TR1 to switch on via resistor R5, thus providing power to the LEDs, and also latching TR3 on via diode D2, thus providing hysterisis. The current flowing through the LEDs gradually increases via L1 until the voltage developed across R1 is sufficient to turn on transistor TR2.

When TR2 turns on, it removes the base bias for TR3, thereby unlatching the TR1/TR3 latch. The LED supply current suddenly stops flowing through TR1, but the back-EMF energy developed across L1 continues to supply current to the LEDs via D1 and R1. Eventually the current through R1 becomes insufficient to hold TR2 on, so it switches off and TR1 and TR3 latch back on again, reconnecting the supply to the LEDs and refreshing the magnetic field in inductor L1.

This cycle continues indefinitly, so providing a reasonably constant current of about 22mA to the LEDs. The operating frequency is about 20kHz, though the mark-space ratio and switching frequency vary with the supply voltage.

The circuit takes about 16mA at a supply of 12V, so its efficiency is less than 100%, but better than that provided by using a normal ballast resistor. The LEDs used in the prototype were red hyperbright ones, with about 1.7V dropped across them. Any type of LED could be used as long as any different working voltage is taken into consideration. Inductor L1 is a standard PCB-mounting choke, As it runs cold, a hefty coil is not needed.

P.A. Tomlinson, Hull, W. Yorks.

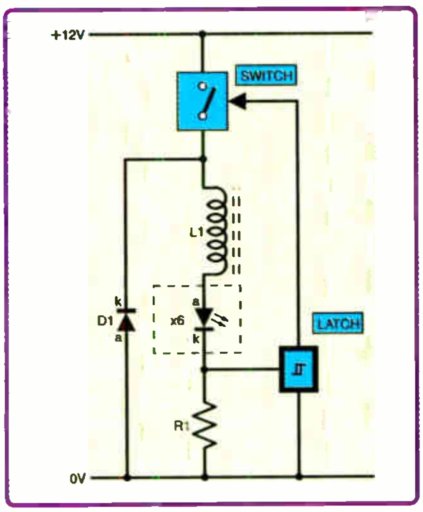

Fig.2. Basic circuit operation

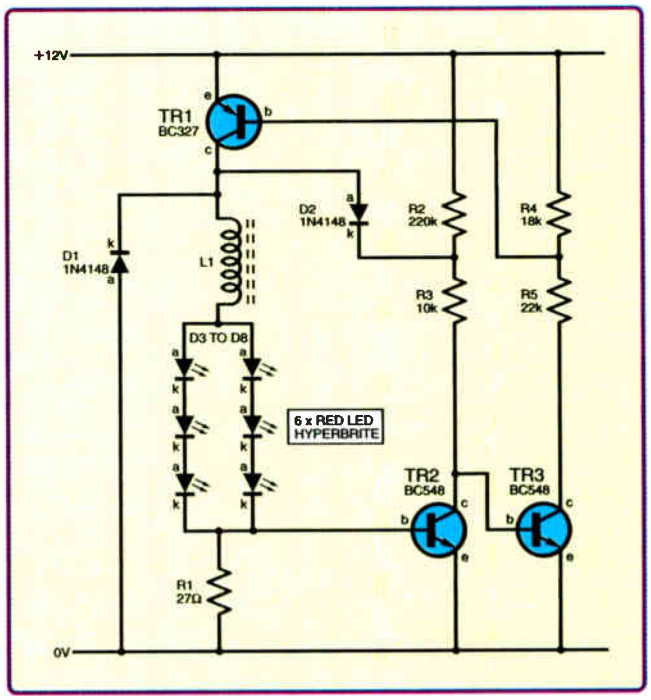

Fig.3. Final citcuit diagram for the Switch Mode LED Unit

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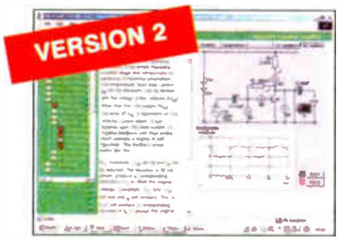
ELECTRONICS PROJECTS

Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

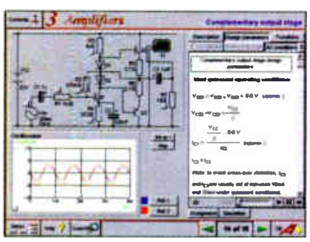
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

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

ANALOGUE ELECTRONICS



Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

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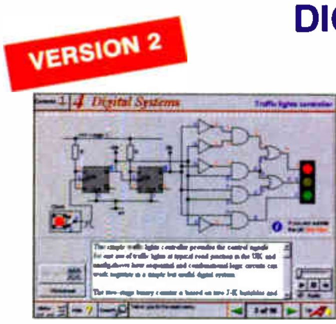
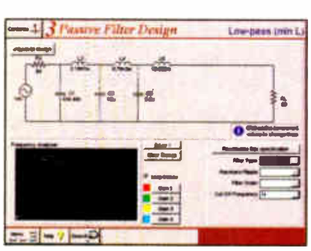


Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

ANALOGUE FILTERS



Filter synthesis

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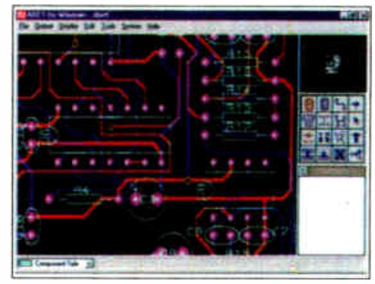
ELECTRONICS CAD PACK



PCB Layout

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

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

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(Formerly PICtutor)

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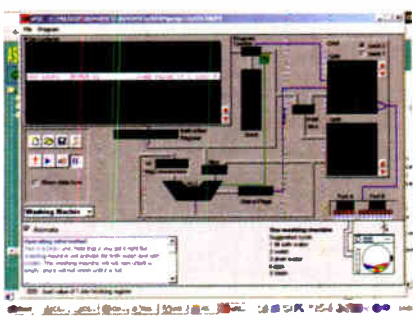

'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

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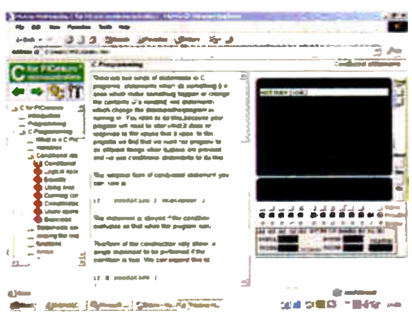

Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

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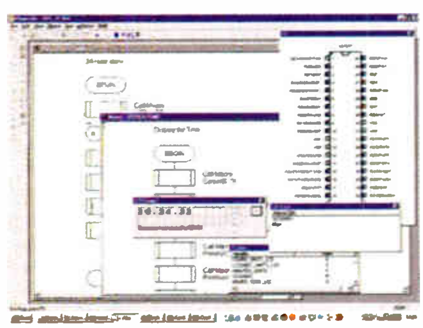

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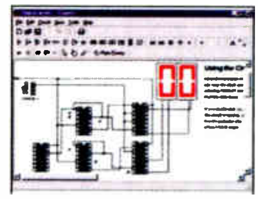

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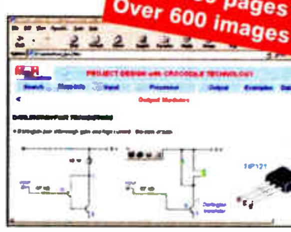

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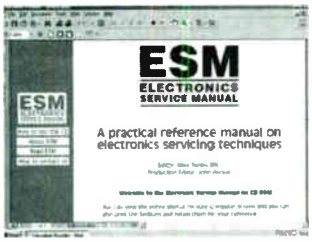

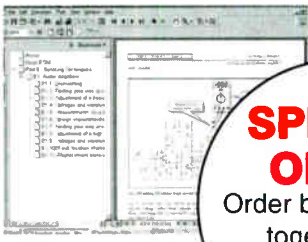

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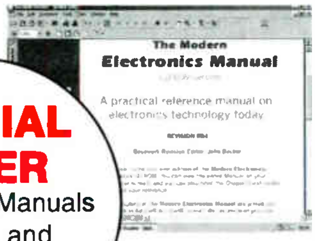

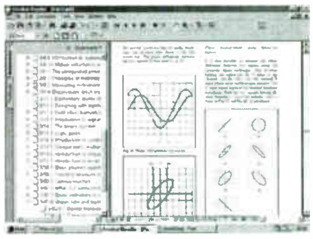

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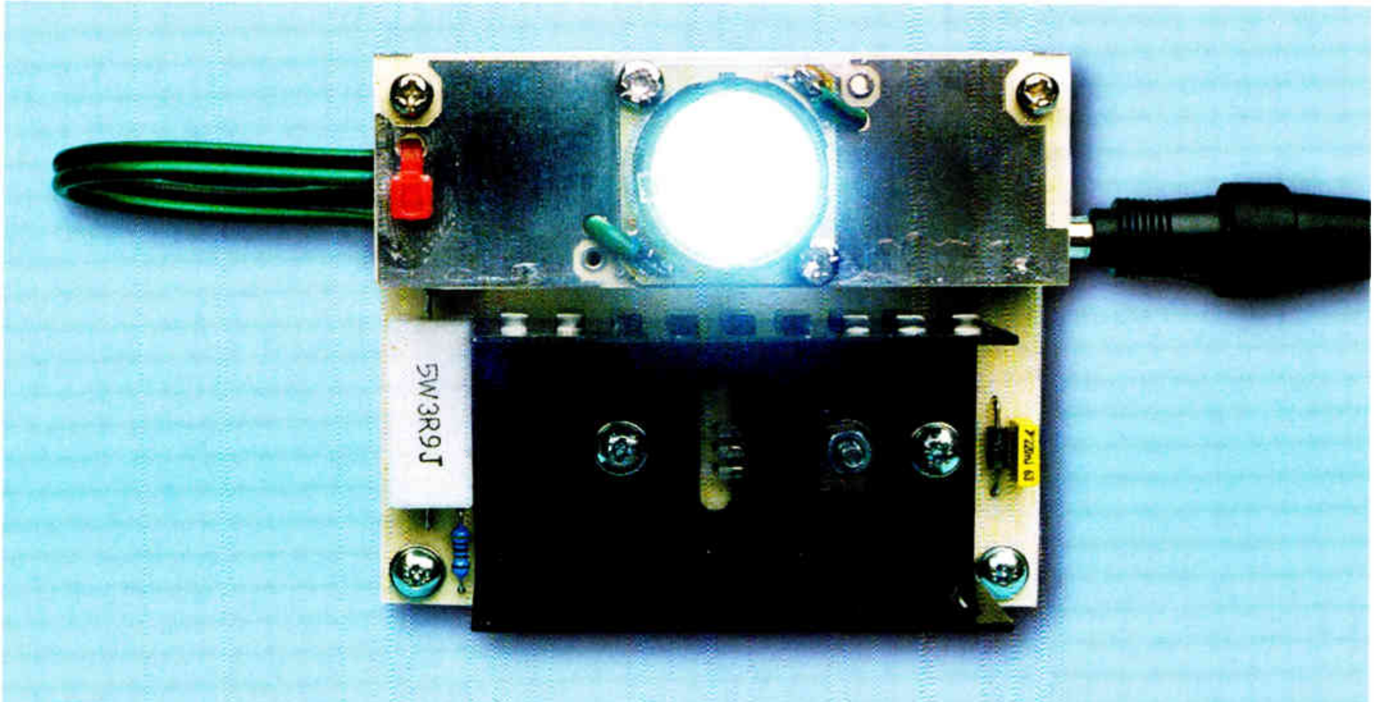


Power the brightest LEDs with this simple linear supply!

Want to run one or more Luxeon 1W Star/0 white LEDs from a 12V battery or a DC plugpack? This circuit allows you to do it and allows for dimming as well. It uses bog-standard parts, including a 555 timer and two three-terminal regulators.

By PETER SMITH

OUR sophisticated *High Intensity Torch* project (published in our August 2006 issue) employed a PIC microcontroller to drive a Luxeon Star LED but the circuit was limited to a 3V to 6V supply. The simple design presented here uses conventional components, thus avoiding any programming, and can be supplied with 7·5V to 24V DC; it will also drive up to four 1W Stars in series.

Unlike the (much) smaller 3mm and 5mm LEDs that we're all familiar with, driving these Luxeon Star devices with just a series current-limiting resistor can be a bit risky. A better way is to power them from a constant current source, to achieve full brightness without exceeding maximum ratings.

This simple circuit will allow you to drive the 1W version (any colour) with the maximum rated current and keep it cool as well. It also gives you control over LED brightness, which can be varied from about 10% to 100% with an on-board potentiometer.

How it works

The circuit diagram for the power supply appears in Fig.1. It consists of two main elements – a current source and a variable duty cycle oscillator. Let's examine the current source first – it uses a LM317 3-terminal regulator (REG1). Commonly, these regulators are programmed with two resistors to provide a particular output voltage, as shown in Fig.2. To maintain the programmed output voltage, the regulator keeps the difference between

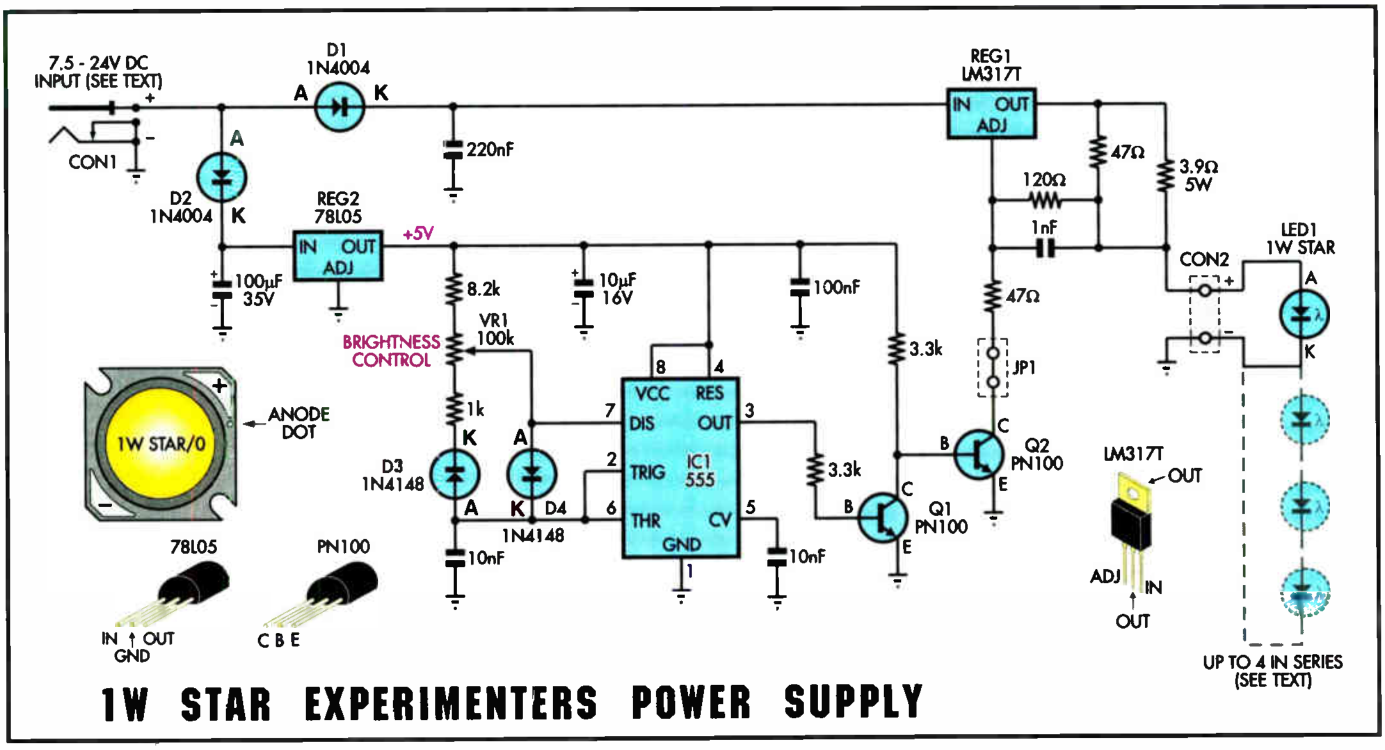


Fig.1: the "Star" power supply circuit is based on an LM317 regulator and a 555 timer IC. The regulator is connected as a 350mA constant current source, with its "on" time varied by the 555 to control LED brightness.

Main Features

- Simple construction
- Variable LED brightness
- Plugpack or battery powered
- Drives 1 to 4 x 1W Luxeon Stars

its 'ADJ' and 'OUT' terminals equal to an internal 1·25V reference.

Fig.3 shows that without the resistor to ground (R2), the regulator still maintains 1·25V across R1. But rather than a regulated voltage, we now have a constant current source proportional to 1·25V/R1.

Calculating R1 for our 350mA Star is easy:

R1 = 1·25V/350mA = 3·57Ω

Referring again to the main circuit (Fig.1), you can see that "R1" consists of 3·9Ω and 47Ω resistors in parallel, for a total resistance of 3·6Ω. Unlike the simple schematic in Fig.3, the output is connected back to the 'ADJ' pin via a 120Ω resistor. This additional resistor has virtually no effect on the programmed current and its purpose will become clear in a moment.

For our description thus far, we've assumed that jumper link JP1 is open circuit. But what happens when it's shorted? Well, when transistor Q2 switches on, the LM317 begins to regulate the output voltage (instead of current), with the 120Ω and 47Ω resistors forming "R1" & "R2" as depicted in Fig.2. The output voltage will be:

$V_{OUT} = 1{\cdot}25V(1 + 47\Omega/120\Omega) = 1{\cdot}7V$

Taking into account Q2's collector to emitter saturation voltage, the output voltage is slightly higher than our calculated value. However, it's still less than the minimum forward voltage of the red/amber and white/blue Stars (about 2·3V and 2·8V respectively), so the LED will be switched off.

Pulse-width modulation

Rather than reducing drive current, Luxeon recommends using pulse width modulation (PWM) switching to reduce the brightness of the Star. This results in a much more colour-uniform light output, right down to minimum brightness. If you just vary the drive voltage in a linear fashion, the Star's light output tends to become yellowish as the drive voltage is reduced.

PWM switching is just a matter of switching the LED on and off at a fixed frequency and varying the duty cycle (on/off time) to vary brightness. With a high enough frequency, the switching effects are invisible. This is due to the long persistence of the phosphors (in white LEDs) and the natural light integration of the human eye.

As you've probably guessed, transistor Q2 in our circuit is responsible for switching the current source (REG1) to give PWM control. Transistor Q2 is driven by Q1, which is simply a buffer and inverter stage. The real work is performed by IC1, an old 555 workhorse.

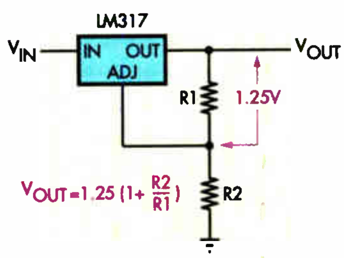


Fig.2: the LM317's output voltage is set with two resistors.

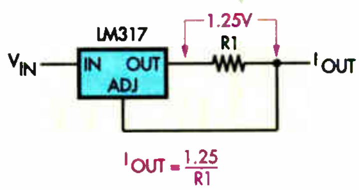


Fig.3: with a single resistor between its 'OUT' and 'ADJ' terminals, the LM317 acts as a constant current source.

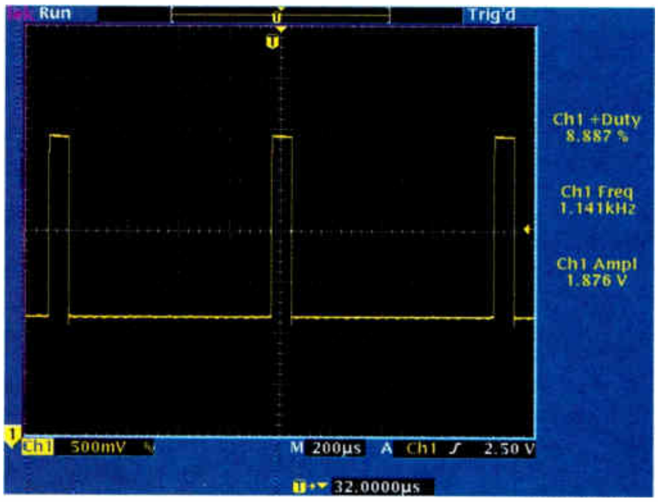


Fig.4: these two waveforms were captured at the output of the supply. With the brightness pot (VR1) set to minimum resistance, only 9% of the power is delivered to the LED.

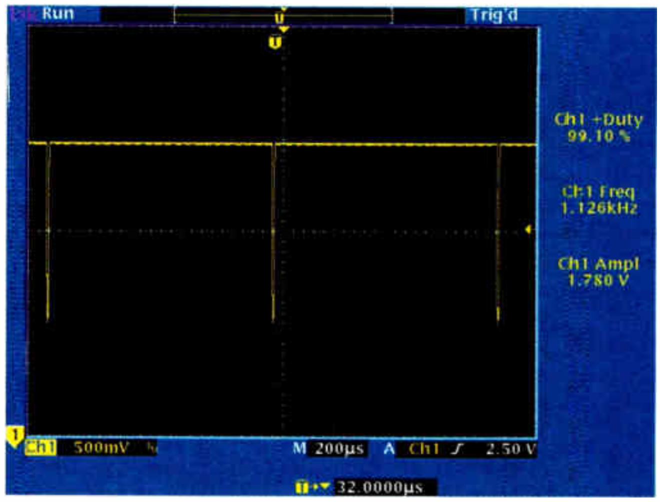


Fig.5: when trimpot VR1 is at the maximum setting, a duty cycle of 99% drives the LED at virtually full brilliance.

IC1 is configured as a free-running oscillator (or "astable multivibrator") with a nominal frequency of about 1·1kHz. Diodes D3 & D4 provide independent charge and discharge paths for the 10nF capacitor, allowing the duty cycle to be controlled without much variation in the frequency of oscillation.

As a result, trimpot VR1 can vary the duty cycle from 9% to 99% (see Figs.4 & 5), resulting in an average current of between about 30mA and 346mA. Even at minimum brightness, you can still read a book by one of these little marvels!

When driving three or four LEDs in series, the circuit input voltage can exceed 18V (the 555's max. supply voltage), so we've provided a separate +5V supply for IC1 and associated circuitry. This is generated by REG2, a 78L05 +5V low-power regulator.

Supply input to REG1 and REG2 is via series diodes D1 and D2, ensuring nothing bad happens if the supply is accidentally reversed.

Input power (single LED)

For a single Star, the input voltage should be between 7·5V and 12·5V. This means that you can drive it from a 7·5V or 9V plugpack (min. 500mA rating), or a 12V SLA battery. 12V plugpacks are generally not suitable, because they put out excessively high voltages when lightly loaded.

The maximum input voltage that can be applied is limited by available power dissipation. When properly mounted on the specified heatsink, the temperature rise of regulator REG1 is about 25°C above ambient with a 12·5V input. This is well within the regulator's rating and the heatsink won't burn your fingers or start a fire!

The minimum input voltage is governed by circuit overhead (about 3·9V) and the LED's forward voltage (about 3·4V for white or blue Stars). So for a single white or blue Star, about 7·3V minimum is required to obtain full brilliance.

Driving multiple Stars

Up to four stars (any colour) can be driven in series. The recommended voltage ranges are shown in Table 3. This should be considered as a *rough* guide only, as the total voltage across any LED string will vary considerably, according to LED colour and individual device characteristics.

The optimum input voltage can be established using a variable power supply. When the LEDs just reach maximum brilliance, the minimum input voltage has been established. Alternatively, monitor the voltage drop across the 3·9Ω resistor while slowly increasing the input voltage. When it reaches 1·25V, the LM317 is in regulation and therefore sourcing the full 350mA.

Using a lower voltage than recommended will result in less than maximum brightness, whereas higher voltages may (eventually) overheat the assembly.

The LM317 regulator has in-built over-temperature protection and can survive short-term abuse. However, extended high temperatures will eventually destroy it and burn (or delaminate) the PC board.

Table 2: Capacitor Codes

Value	µF Code	EIA Code	IEC Code
220nF	0·22µF	224	220n
100nF	0·1µF	104	100n
10nF	0·01µF	103	10n
1nF	0·001µF	102	1n

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	3·3kΩ	orange orange red brown	orange orange black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	1	120Ω	brown red brown brown	brown red black black brown
❑	2	47Ω	yellow violet black brown	yellow violet black gold brown

If the heatsink is too hot to touch, then the input voltage is too high!

Note: do not attempt to drive these LEDs in parallel. Although possible, parallel configurations require voltage-matched devices.

Power supply board assembly

All parts (except for the LED) mount on a single PC board, code 588A/B. Using the overlay diagram in Fig.6 as a guide, begin by installing the two wire links, followed by the 0·25W resistors.

Diodes D1 to D4 can go in next, making sure that you have the cathode (banded) ends oriented as shown. Follow up with the two transistors (Q1 & Q2), 78L05 regulator (REG2) and trimpot (VR1).

All remaining components, apart from the LM317 (REG1) and its heatsink, can now be installed. Note that the 555 timer (IC1) and electrolytic capacitors (100µF & 10µF) must go in the right way around.

The final step involves mounting the heatsink and installing regulator REG1. To do this, first secure the heatsink firmly to the PC board with two M3 × 6mm screws, nuts and flat washers. Next, bend the regulator's leads at 90° about 3mm from the body and temporarily slip it into position, correctly orientated..

Verify that the hole in the regulator's tab lines up with the hole in the heatsink, which should in turn match the hole in the PC board underneath. If all is well, you can now remove the regulator and apply a thin smear of heatsink compound to both the rear of the metal tab and the mating area on the heatsink surface.

Finally, slip the regulator back into position and fasten it securely to the heatsink & PC board with an M3 × 10mm screw, nut and washer. Solder and trim the regulator leads to complete the job.

Note: the metal tab of the regulator is internally connected to the "OUT" terminal, so the heatsink will be *live*. The LED (and any other uninsulated wiring) must not be allowed to make contact with the heatsink! If you don't like this idea, then you can mount the regulator on the heatsink using an insulating pad and washer. The down-side to this arrangement is higher regulator temperature.

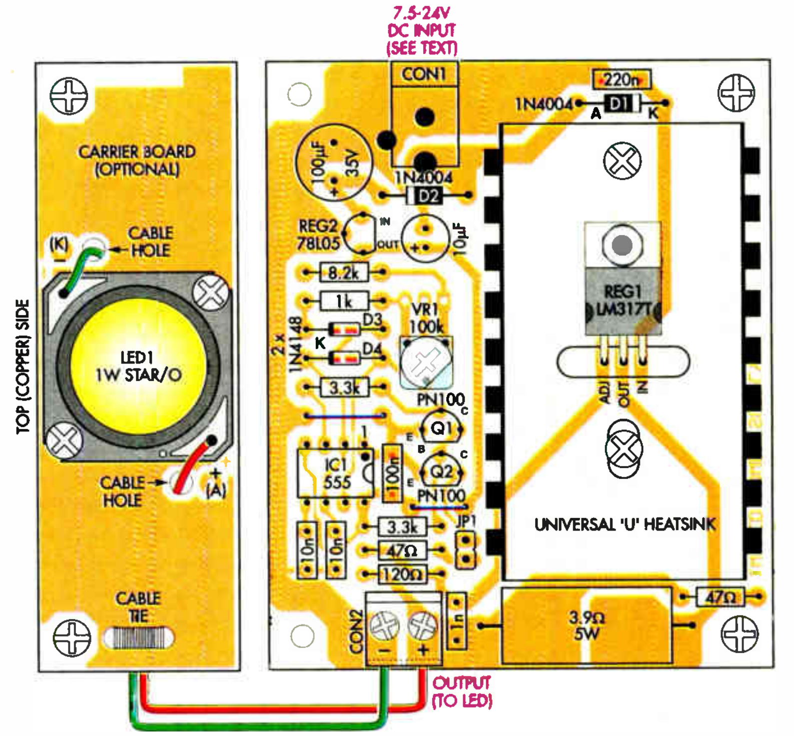
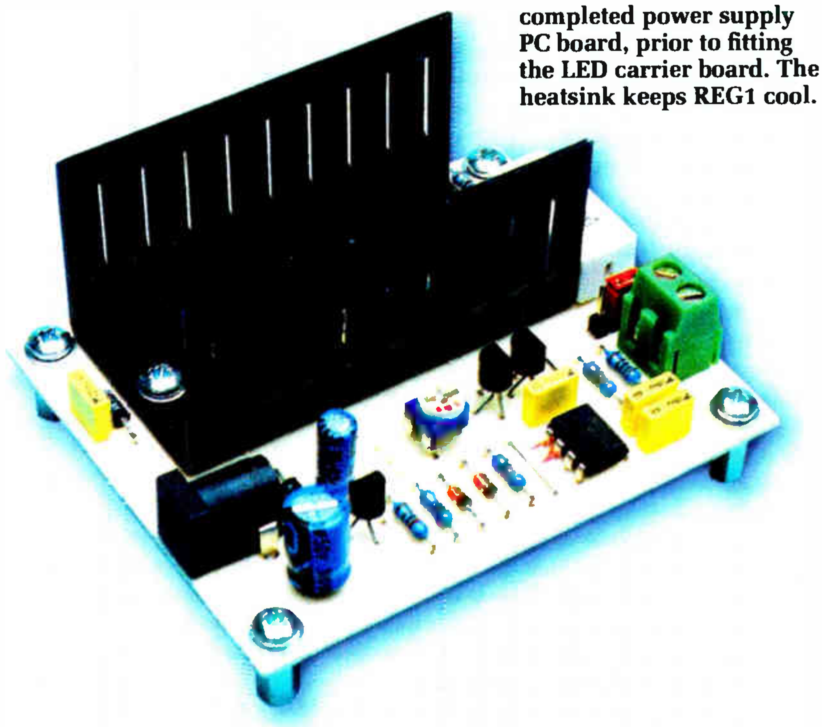


Fig.6: follow this diagram closely when assembling your boards. To make the job easier, leave the heatsink and regulator (REG1) until last.



This view shows the completed power supply PC board, prior to fitting the LED carrier board. The heatsink keeps REG1 cool.

LED mounting

The Star's emitter and collimating optics are mounted directly onto an aluminium-cored PC board. In most cases, no additional heatsinking is required. However, a small heatsink reduces junction temperature significantly and ensures maximum LED life.

Just about any small aluminium heatsink with a flat area large enough

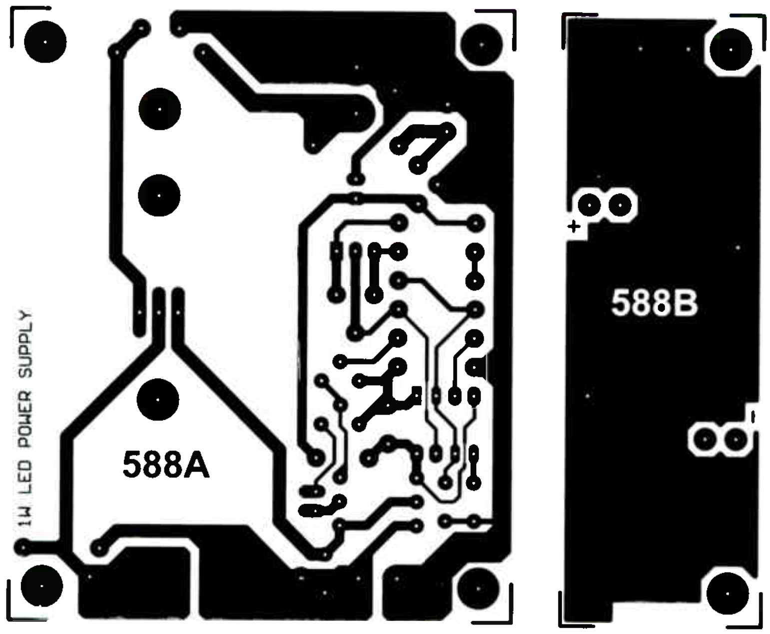
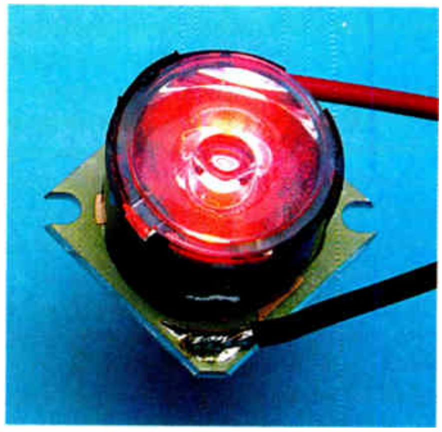


Fig.7: here are the full-size etching patterns for the two PC boards. Check your etched boards carefully before installing the parts.



The 1W Star/0 LED module is available in seven colours: white, green, cyan, blue, royal blue, red and amber. They can all be driven by this constant current power supply.

to accommodate the Star's 25mm footprint can be pressed into service. For example, an old 486 PC processor heatsink would probably be ideal!

For experimentation purposes, an area of PC board copper also does the job nicely. This is the purpose of our simple "carrier" board, which also provides a convenient mounting and terminating method for the LED module.

LED carrier board assembly

Before mounting the LED module, make sure that the mating surface is completely smooth. If there are any "lumps" of solder, then they must be removed using desoldering braid.

Apply a thin smear of heatsink compound to the rear of the LED module as well as to the mating surface (copper side) of the PC board. The module can then be attached to the PC board using two M3 × 6mm screws, nuts & washers.

With opposing corner holes (see photo), the module can be mounted one of two ways. To determine the correct orientation, look for a tiny copper "dot" next to one of the corner solder pads. This indicates the anode (A) or positive (+) connection and should be aligned as shown on the overlay diagram (Fig.6).

Once mounted, all that remains is to wire up the LED anode (A) and cathode (K) terminals, provided in the form of two solder pads on opposite corners of the module's PC board.

Solder a short length (about 15cm) of wire to one of the pads and pass it through the neighbouring hole in the carrier board. Repeat for the opposite pad and then twist the two wires together under the board. Secure at the end of the carrier board with a small cable tie to ensure that no tension can be applied to the solder joints.

Before connecting your LED to the power supply output terminals, it's important to verify that the supply is working properly. A faulty supply could destroy your investment in a blinding flash!

Testing

Connect a 10Ω 5W resistor directly across the power supply output terminals. Position the body of the resistor so that it is clear of your workbench (and your pinkies!), as it could get extremely hot. If you fitted a jumper shunt on JP1 earlier, remove it for now.

Plug in your chosen DC power source and hit the "go" switch. Assuming there are no ominous bangs or puffs of smoke, use your multimeter to measure the voltage drop across the 10Ω resistor. If the supply is sourcing the expected 350mA (nominal) of current, your measurement should fall within the 3·2V to 3·8V range.

Power off, disconnect the test resistor and then re-apply power. Measure the voltage between pins 1 & 8 of the 555 (IC1). These are the power supply pins, so your meter should read 5V or thereabouts.

All done! Assuming your board passed the tests, hook up the LED leads to the output terminals. Be particularly careful that the anode (A) terminal of the LED connects to the positive (+) output, as the LED module will be destroyed if reverse voltage is applied.

Hold your breath and power up. **DO NOT** stare directly into the LED's beam at close range, as it is (according to Luxeon) bright enough to damage your eyesight!

Brightness control

To enable brightness control, install a jumper shunt on JP1. Now by rotating trimpot VR1, you should be able to vary LED intensity from dim to almost full brightness.

LED carrier board mounting

To make a neat "one-piece" module, the LED carrier board can be mounted

Table 3: A Rough Guide To Input Voltage Ranges

No. of Stars	Min. Voltage	Max. Voltage
1	7·3V	12·5V
2	10·7V	15·9V
3	14·1V	19·3V
4	17·5V	22·7V

Parts List – 1W Star/0 PSU

1 PC board, code 588A/B available from the *EPE PCB Service*, 80mm x 66mm
1 2·5mm PC-mount DC socket
1 2-way 2·54mm terminal block
1 2-way 2·54mm SIL header
1 jumper shunt
1 Universal 'U' heatsink
4 M3 x 10mm tapped spacers
1 M3 x 10mm pan-head screw
6 M3 x 6mm pan-head screws
6 M3 flat washers
3 M3 nuts
Red & black light-duty hook-up wire
Heatsink compound
1 9V DC 500mA (min.) plugpack (see text)
1 100kΩ miniature horizontal trimpot

Semiconductors
1 LM317T adjustable voltage regulator (REG1)
1 78L05 +5V regulator (REG2)
1 555 timer IC (IC1)
2 PN100 NPN transistors (Q1, Q2)
2 1N4004 rect. diodes (D1, D2)
2 1N4148 signal diodes (D3, D4)
1 1W Luxeon Star/0 LED w/optics (see text)

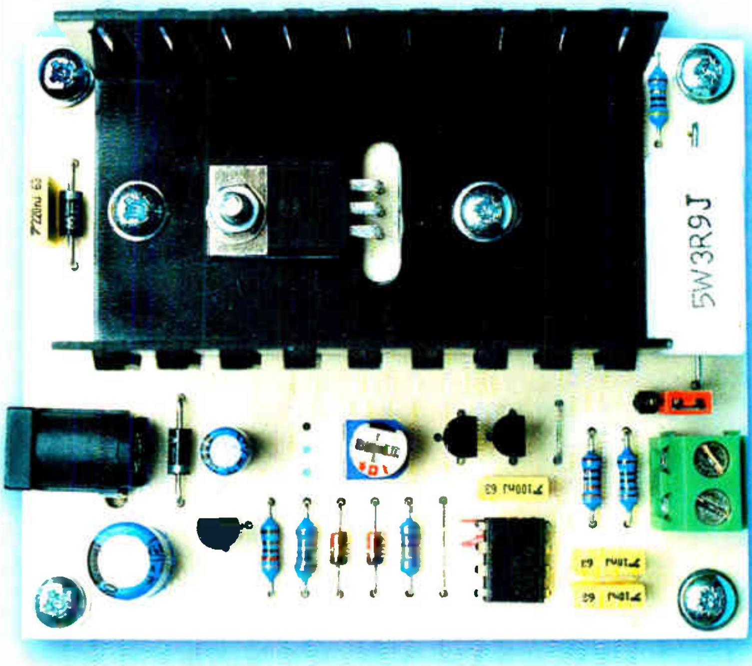
Capacitors
1 100µF 35V PC electrolytic
1 10µF 16V PC electrolytic
1 220nF 63V MKT polyester
1 100nF 63V MKT polyester
2 10nF 63V MKT polyester
1 1nF 63V MKT polyester

Resistors (0·25W, 1%)

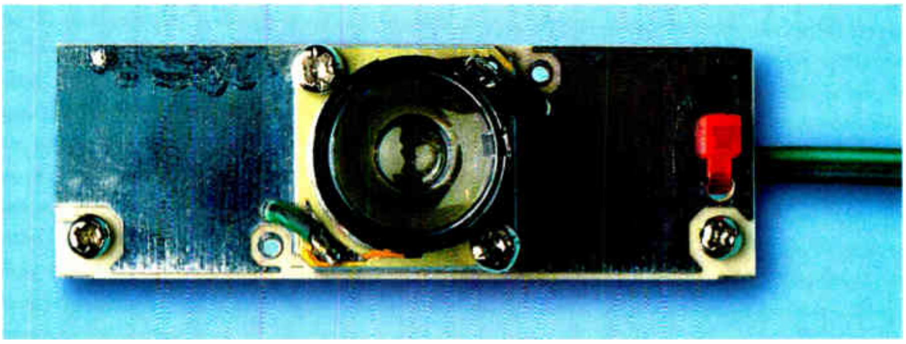
2 3·3kΩ	1 120Ω
1 8·2k	2 47Ω
1 1kΩ	1 3·9Ω 5W 5%

1 10Ω 5W 5% (for testing)

Parts for optional LED carrier
2 M3 x 15mm untapped brass or nylon spacers
2 M3 x 25mm pan-head screws
4 M3 x 6mm pan-head screws
6 M3 nuts
4 M3 flat washers
1 small cable tie



Take care to ensure that all polarised parts are correctly oriented when building the power supply PC board. Note that this prototype PC board differs slightly from the final version shown in Fig.6.



The completed LED carrier board provides a convenient method for mounting the 1W Star LED module and also provides heatsinking.

piggyback style on the power supply board. (See heading photograph.)

To do this, insert an M3 × 25mm screw in one corner hole and slide on a 15mm spacer from the bottom. Wind up an M3 nut to hold the spacer in place, then repeat for the other corner. The completed assembly can now be slipped into place in the two corner holes of the power supply board, replacing the existing M3 × 6mm screws (see photos).

With the carrier board installed, you'll note that the brightness trimpot (VR1) is no longer easily accessible. If you need to continually vary the brightness with the board in-situ, then you can either reposition the trimpot to the opposite (copper) side of the board or install an external potentiometer.

When installing an external pot, keep the wire lengths as short as possible (say, no more than about 50mm) and twist the three connecting wires tightly together.

Lumileds also manufacture higher output Stars. Naturally, these devices are more expensive that the 1W versions and require more elaborate heatsinking. Their higher current requirements (up to 700mA) make them unsuitable for use with this supply.

Detailed technical information on Luxeon Star LEDs can be obtained from the Lumileds web site at **www.lumileds.com**. ***EPE***

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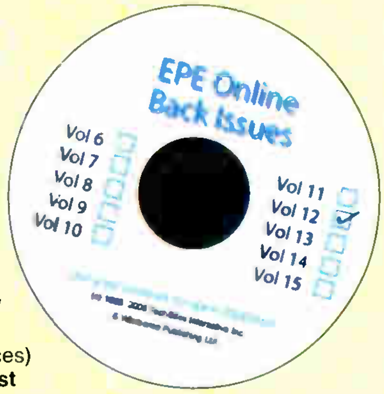

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Circuit Surgery

Ian Bell

Timing formulae for 555 timers

THERE has been a bit of discussion of RC timing circuits on the *EPE Chatzone* (via **www.epemag.co.uk**) recently, in particular user **CherryTree** posted a question about timing formulae for 555 timers.

"I've got this diagram in a book (30 Simple Terminal Block Projects) *and it gives equations on how the 555 timer sets its frequency: t1 = (R1 + R2) × C1, t2 = R2 × C1, and T = t1 + t2. The t1 + t2 in relation to the timer calculations is confusing me. Say that I wanted a 555 running at 900Hz, what would be R1 and R2 values, and also C1's value? How did they arrive at that equation?"*

The RC circuit shown in Fig.1 is deceptively simple; a full mathematical analysis of its behaviour requires calculus, a maths topic which people will typically only have looked at in detail if they studied mathematics, science or engineering at an advanced level.

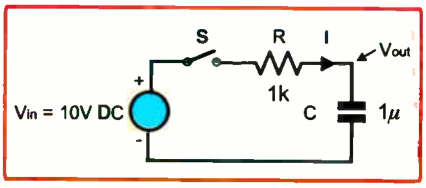


Fig.1. RC circuit. Capacitor C charges through R when S is closed. V_{out} is the voltage across the capacitor

In this month's *Circuit Surgery* we will attempt to give some insight into the behaviour and maths of the RC (resistor-capacitor) circuit and next month we will progress onto its use in timers such as the famous 555 chip and its derivatives. We will work step by step towards the basic structure and operation of the 555 circuit, which should make the formulae in books and data sheets a little more meaningful. Hopefully our look at the maths will not be too hard, we will really only be using basic algebra and arithmetic in this article – you do not have to know any calculus, so read on without fear!

Circuit Basics

Comparing the RC circuit in Fig.1 with the potential divider in shown in Fig.2 might lead us to think that the RC circuit could be similarly simple. It is quite well

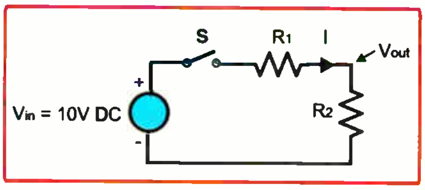


Fig.2. Potential divider – the circuit topology is very similar to that in Fig.1, but the maths is much simpler!

known that V_{out} for the potential divider is given by the formula:

$$V_{out} = \frac{R2\ V_{in}}{R1 + R2}$$

When we close switch S in Fig.2, V_{out} goes to this voltage instantaneously and stays there. We are, of course, ignoring things like the speed at which the electric current travels through the wires and any imperfections in the components and wiring. That's OK, we will do the same thing for the RC circuit; it is not what we are concerned with here.

Speed of Change

When we close S in Fig.1 the situation is very different from that in Fig.2: V_{out} does not go to a fixed voltage – in fact it never stops changing and the rate of change also varies continuously.

This varying rate of change is important here; it is the key reason why we have to resort to calculus to fully describe the RC circuit mathematically.

The real life situation in which we are probably most familiar with rate of change, is driving a car (or other vehicle). We know that acceleration is rate of change of speed. Car acceleration is often specified in terms of the time it takes to go from 0 to (say) 60mph. Here we assume that the driver 'floors' the accelerator (gas pedal) and that the car accelerates at its maximum rate (which we assume is constant) until the desired speed is reached.

Now, instead, imagine the driver initially applies maximum acceleration, but straight away starts to ease off. Imagine the driver decreases the acceleration more and more the nearer the car gets to the target speed. The acceleration is at all times decreased exactly proportionately with the difference between the current speed and the target speed. The car never reaches the target speed because as the speed gets closer, the rate of increase gets less and less, and hence the time required to make up the difference increases more and more.

If we plot a graph of speed against time for this thought experiment it would have the same shape as a graph of V_{out} against time after S is closed in Fig.1. This graph

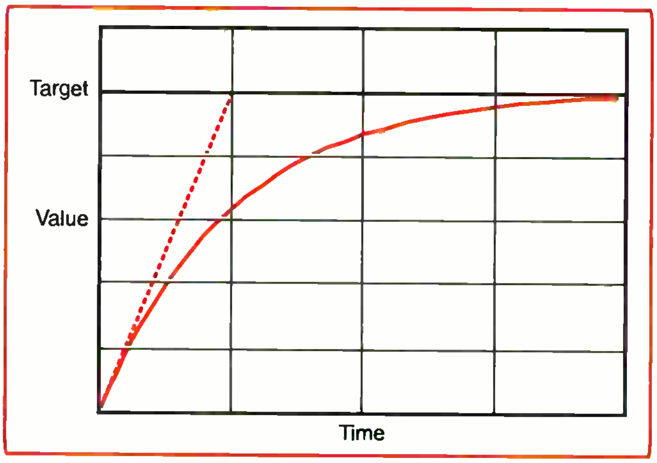


Fig.3. The solid line is the shape of the RC charging curve and also represents the speed of our thought experiment car with constantly decrerasing acceleration (see text). The dashed line represents a constant rate of charging (or acceleration).

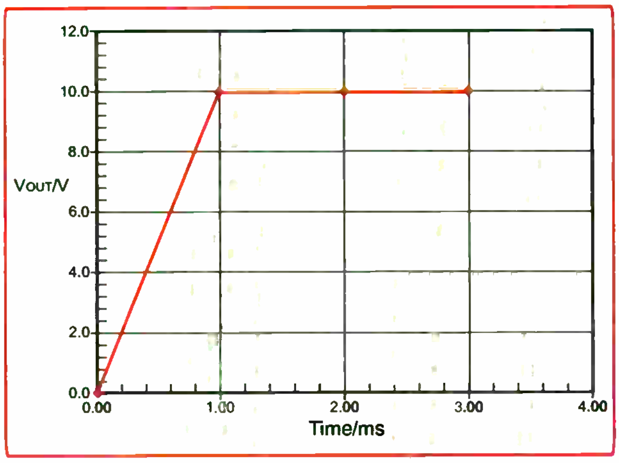


Fig.4. Approximate graph of V_{out} in Fig.1 using one voltage step of 10V

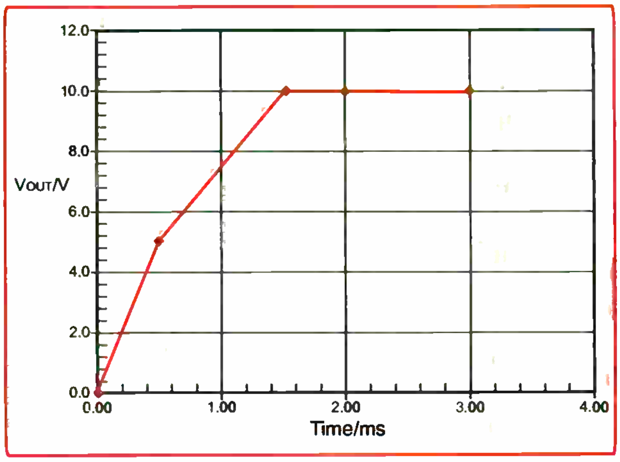


Fig.5. Approximate graph of V_{out} in Fig.1 using two voltage steps of 5V each.

is shown in Fig.3 (solid curve) together with the constant maximum acceleration curve (dotted line).

The difference between our thought experiment and Fig.1 is that the former requires the skill and intelligence of our imaginary driver, whereas the behaviour of the RC circuit is simply dependent on the physics of the situation. The rate at which a capacitor charges (and hence the rate of change of the voltage across it) is directly proportional to the current flowing into it. In the RC circuit (Fig.1), as the capacitor charges the voltage V_{out} rises.

However, the current depends on the voltage drop across the resistor (R). V_{in} is fixed, so as V_{out} increases, the current decreases in proportion to the change in V_{out}. The larger V_{out} gets, the smaller the current and the slower the capacitor charges. Alo, V_{out} never reaches V_{in} because the closer it gets the slower the change becomes. In practice, of course, V_{out} will reach a point where noise and instrument accuracy mean we cannot tell the difference between V_{out} and V_{in}.

Fundamental Definitions

Now we know what to expect, let's see where we get when we try to apply some simple circuit theory to the RC circuit. We have to start with fundamental definitions of capacitance and current in terms of electrical charge. A capacitor of value C (in Farads) with a charge of Q (Coulombs) held on its plates has a voltage V (Volts) across it, given by:

$$V = \frac{Q}{C}$$

Electric current is defined as the rate of flow of charge. A current of I (Amps) occurs when an amount of charge ΔQ (Coulombs) flows in time Δt. Note that we use the symbol Δ (delta) because we are dealing with changes of values. So Δt represents a time interval – a change in time – rather than a specific instance in time, or the time elapsed since some starting point. We have:

$$I = \frac{\Delta Q}{\Delta t}$$

Although electronics is all about the movement of charge, we do not often deal with it directly, and the same is true here. We combine the two equations using $\Delta Q = C\Delta V$ from the first equation – relating a change of charge to a change in voltage (the capacitance is fixed) – and substituting $C\Delta V$ for ΔQ in the second equation. This gives:

$$I = C\frac{\Delta V_{out}}{\Delta t}$$

in which we have written V_{out} for V to more explicitly relate to Fig.1.

We can find the current in Fig.1 by using Ohms law. The voltage drop across the resistor is $V_{in} - V_{out}$, so the current is :

$$I = \frac{V_{in} - V_{out}}{R}$$

The current in the resistor must be equal to the current flowing into the capacitor so we have:

$$\frac{V_{in} - V_{out}}{R} = C\frac{\Delta V_{out}}{\Delta t}$$

We will use this formula to try and predict the voltage on the capacitor. One way of doing this is to start with a known initial voltage on the capacitor (V_{out}), and choose an amount of change that we want to consider (the value of ΔV_{out}) and work out how long this will take (the value of Δt). We note that the values of R, C and V_{in} are fixed, it is only time and V_{out} that are changing. To do this we rearrange the equation above to get the value of Δt. We get:

$$\Delta t = RC\frac{\Delta V_{out}}{(V_{in} - V_{out})}$$

This equation contains the term RC, which should not be surprising if you have dealt with resistor-capacitor timing circuits, as this term always appears in the formulae. Using the values from Fig.1:

$RC = 1{\cdot}0 \times 10^3 \times 1{\cdot}0 \times 10^{-6}$
$= 1{\cdot}0 \times 10^{-3} = 1ms$

Note that when we multiply resistance and capacitance together we get a value with units of time.

First Example

We assume that V_{out} starts at 0V (when S is closed), but what value should we take for ΔV_{out}? Let's start with 10V, which is the maximum change we could have, as the capacitor will not charge beyond the value of V_{in}. With this value we get:

$$\Delta t = 1ms \times 10 / (10 - 0) = 1ms$$

V_{out} goes from 0V to 10V in 1ms.

We have plotted this in Fig.4. We see immediately that the graph does not match the required RC charging curve, but note that we have produced the *constant acceleration* line from Fig.3. We also note that the target voltage is reached at the time given by the product RC, which is known as the *time constant* of the circuit. If V_{out} in the RC circuit *continued to rise at its initial rate* it would reach V_{in} when t = RC.

Why has the formula given us the wrong curve? The answer is that we chose too large a value for ΔV_{out}. Let's halve the value of ΔV_{out} and see what happens. We do the calculation as follows.

We start with same initial condition, that is V_{out} = 0V, but choose ΔV_{out} = 5V. The formula gives Δt = 1ms × 5 / (10 – 0) = 0·5ms, so we get to 5V in 0·5ms. We then

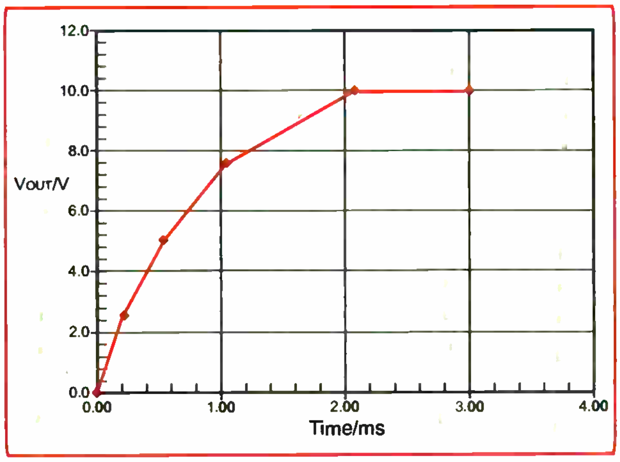
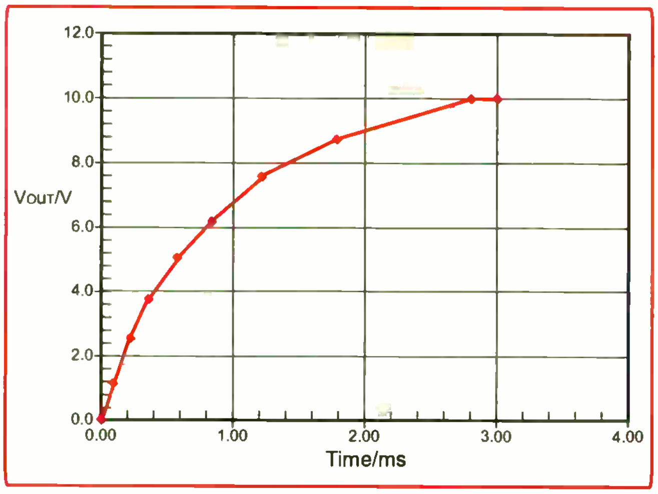


Fig.6. Approximate graph of V_{out} in Fig.1 using four voltage steps of 2.5V each.



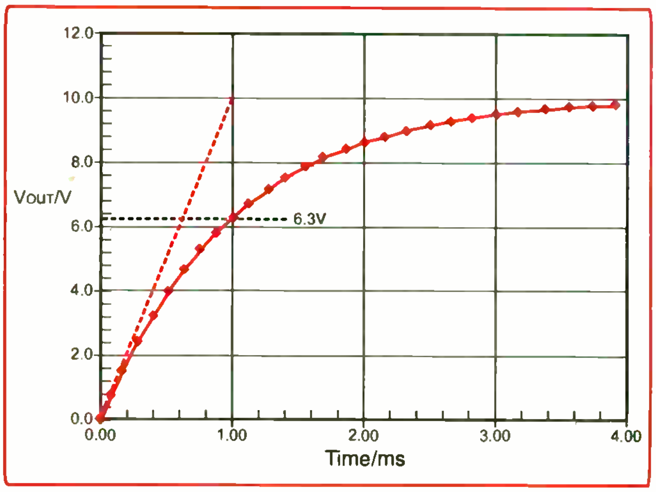


Fig.7. Approximate graph of V_{out} in Fig.1 using eight voltage steps of 1.25V each.

Fig.8. RC curve plotted using exponential equation. The initial rate of change line is also shown. This figure is similar to Fig.3 but has the actual times and voltages for Fig.1

need to apply the formula again. This time we start from 5V so V_{out} = 5V and again ΔV_{out} = 5V. We get Δt = 1ms × 5 / (10 − 5) = 1ms, so we go from 5V to 10V in 1ms. The resulting graph is plotted in Fig.5.

More Steps

The curve in Fig.5 looks slightly more like the RC charging curve, but it is still a long way off. Let's try halving the value of ΔV_{out} again (to 2·5V) to see if there is any improvement. We now have four steps in our calculation.

0V to 2·5V	Δt = 1ms × 2·5 / (10 − 0) = 0·25ms total time = 0·25ms
2·5V to 5V	Δt = 1ms × 2·5 / (10 − 2·5) = 0·33ms total time = 0·58ms
5V to 7·5V	Δt = 1ms × 2·5 / (10 − 5) = 0·5ms total time = 1·08ms
7·5V to 10V	Δt = 1ms × 2·5 / (10 − 7·5) = 1·0ms total time = 2·08ms

So we get to 2·5V at 0·25ms, 5V at 0·58ms, 7·5V at 1·08ms and 10V at 2·08ms. This is plotted in Fig.6, which clearly shows a better approximation to the curve in Fig.3 than that in Fig.5.

We can continue to reduce ΔV_{out} and get ever better approximations. For example, Fig.7 shows the curve with eight steps of 0·125V. This was produced in the same way as that in Fig.6. The time values are 0·125ms, 0·268ms, 0·435ms, 0·635ms, 0·885ms, 1·218ms, 1·718ms and 2·718ms.

As we make ΔV_{out} smaller and smaller, and hence perform more and more calculation steps, the curve we obtain gets closer and closer to what we observe in a real circuit. This approach to solving an equation is called a *numerical method* by mathematicians. There are many situations where this is the only possible approach for equations (or sets of equations) that cannot be solved by direct mathematical methods.

These numerical calculations are, of course, tedious to do by hand, but we can program computers to do the work very efficiently. It would take a modern PC virtually no time at all to use the above method to calculate a 10,000 step version of the RC curve which would be a very close approximation to the real thing. However, in this case there is a full mathematical solution.

If we go back to the equation we had before:

$$\frac{V_{in} - V_{out}}{R} = C\frac{\Delta V_{out}}{\Delta t}$$

and rearrange it to get:

$$V_{in} = RC\frac{\Delta V_{out}}{\Delta t} + V_{out}$$

We have already seen that to get an accurate result ΔV_{out}, and hence Δt must be as small as possible. So we can make them infinitely small. When we do this we rewrite them as dV_{out} and dt and the equation becomes:

$$V_{in} = RC\frac{dV_{out}}{dt} + V_{out}$$

which is a differential equation. We need calculus to solve this, which is beyond the scope of this article. In effect the calculus works out a series of steps on the curve algebraically (rather than numerically as we have done) and also algebraically reduces the step size towards zero to provide an accurate solution. The result of solving the equation is :

$$V_{out} = V_{in}\left[1 - \exp\left(\frac{-t}{RC}\right)\right]$$

in which *exp* is the exponential function. You will find it on scientific calculators written either as *exp* or e^x. Fig.8 shows this function plotted for the circuit in Fig.1, that is: 10 × (1 − exp(− t)) with t in milliseconds (V_{in} = 10V and RC = 1ms in this example). Note that when t = RC the voltage is 6·3V, which is 63% of the final value. In the formula we get V_{in} × (1 − exp(− 1)) = V_{in} × 0·63 when t = RC (the RC and t cancel to give 1). This 63% rule applies whatever the value of RC and V_{in} because when t = RC we always get the exponential function of − 1.

Next Month

Next month we will take a short look at the *exp* function and then move on to more practical aspects of RC timing circuits.

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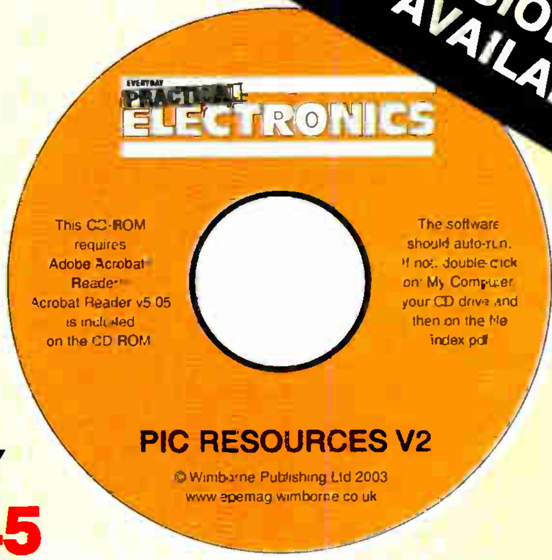

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Net Work

Alan Winstanley

A Slipped Disk

A RECENT documentary broadcast on BBC TV (*Real World* – see the BBC web site at **http://tinyurl.com/rsjpw**) highlighted some shocking examples of how personal computer data can find its way onto the open market without the owner's consent or knowledge. British consumers were naively dumping old unwanted PCs at their local authority landfill site, with the expectation that their machines would be scrapped in a proper manner.

Imagine their surprise when a BBC TV presenter knocked on their door several months later, armed with their complete personal profile – dates of birth, family names, addresses, passport details, bank account numbers, pets, school student records and much more besides. The source of all this information was, of course, the discarded hard disk. What was far more shocking was the fact that the entire computer system had mysteriously found its way to Nigeria, where PC components were on open sale in the country's largest surplus PC market, a ramshackle collection of huts.

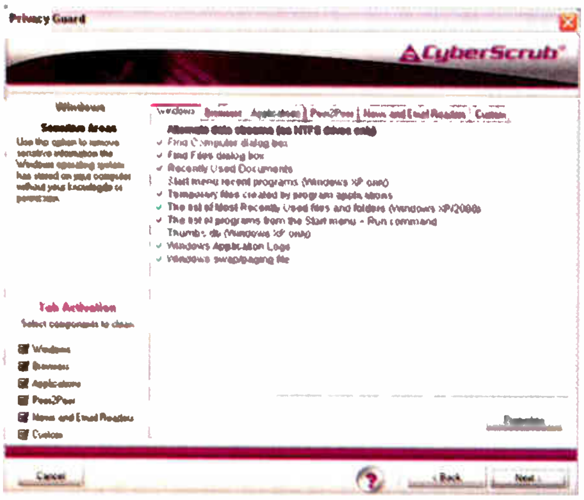
The BBC presenter bought several used hard disks for £15 each and had them analysed by a data recovery specialist. A wide variety of highly confidential data was successfully recovered. One local authority (Essex County Council) reportedly denied any wrong-doing or negligence on its part, which begs the question of how discarded equipment found its way abroad to start with.

Deleting a file from a hard disk only removes the reference to it, rather like throwing away a library card index but the book remaining on the shelf, the computer file itself may remain intact. Neophyte PC users had no idea about File Allocation Tables or the insecurity of dumping files into the Recycle bin.

One obvious source of personal data is the email database and address book, but there could also be a wide range of reports, spreadsheets, word processor documents and family photographs. There may even be CVs, job applications, scanned copies of birth certificates, work contract details, log-ins and bank details. And if you use a form-filling program such as the excellent Roboform (**www.roboform.com**), then you would be giving thieves and fraudsters unfettered access to many secure websites if your disk fell into the wrong hands.

Smash and Grab

The address book data is worth money as well: it contains highly prized live addresses that can be sold to spammers. The TV program showed Nigerian armed police and computer specialists 'busting' an Internet café that was used by an army of '419' fraudsters (the sort that entice you to send advance fees, in return for a split of a multi-million dollar bounty). The police faced a possible riot and had to shoot their way out after arresting the villains and confiscating dozens of modern Dell computers. It was evident that email extraction programs were being used to build lists, with millions of spam mails being generated per day in this most lucrative scam. As a genial Nigerian detective said, it certainly pays well.



Cyberscrub is a configurable privacy program that erases your tracks and destroys deleted data

If you have an old PC or Mac to dispose of, without doubt the best way of erasing data is to physically destroy the hard disk: open it up, remove and smash up the platters with a hammer, or take a high speed twist drill or angle grinder to it. (Some glass-like disk substrates will shatter, so wear suitable eye protection.)

Software products are available that will overwrite data with any combination of random characters, making data pretty much unrecoverable. Even so, the pattern of magnetic data can leave clues behind and the State University of New Jersey claims that specialised forensic software can recover data [or incriminating parts thereof], after more than 100 overwrites. You can never verify that data is completely unrecoverable of course, so the writer's advice is not to dump drives or sell them on eBay but drill them full of holes instead. The same applies to floppy, Zip and other removable media. Cheap electric CD destroyers can mechanically dapple a DVD or CD's surface, rendering them totally unreadable. USB Flash drives and memory cards often carry recoverable data, as well.

Scrub Those Disks

Software products that wipe hard disks include Cyberscrub Privacy Suite from **http://www.cyberscrub.com**. It will take care of cookies, temporary Internet files and many 'last used' file drop-down lists in popular applications. The pattern of overwriting is configurable to exceed Dept. of Defense (DoD) standards if desired. For total disk deletion, their Cybercide program wipes a hard drive to USA corporate-accepted levels.

The well regarded Eraser 5.7 program can be downloaded free from **www.heidi.ie/eraser/** whilst the user-friendly Acronis Privacy Expert Suite 9.0 includes a Disk Cleanup utility, and a 30 day trial is downloadable from **www.acronis.com**. Alternatively, East-Tec Eraser 2006 is available from East Technologies at **www.east-tec.com**.

If you need to *undelete* some lost data, O & O Software (**www.oo-software.com**) supplies a number of interesting data recovery programs including Media Recovery, Disk Recovery, Format Recovery and UnErase.

To make life harder still for those trying to salvage disk data, you could consider using a data on-the-fly encryption system: even if someone managed to undelete your data, the encryption renders it as good as impossible to decipher anyway. Whole disk encryption programs include Pretty Good Privacy (PGP) Desktop Professional 9.0 from **www.pgp.com**, or how about applying steganographic (hidden code) techniques and embedding important messages into, say, an innocent-looking JPG graphic file? For example, 4Hit Mail Privacy Lite is free from **www.4t-niagara.com**.

Once you have weighed up the risks, you can decide on the level of protection you need. A wide range of free and paid-for software utilities is available that offer varying levels of credibility, but using any of the major software titles mentioned will help ensure that your personal data really is gone for good, or 'tracked' for ever!

You can email the writer at **alan@epemag.demon.co.uk**

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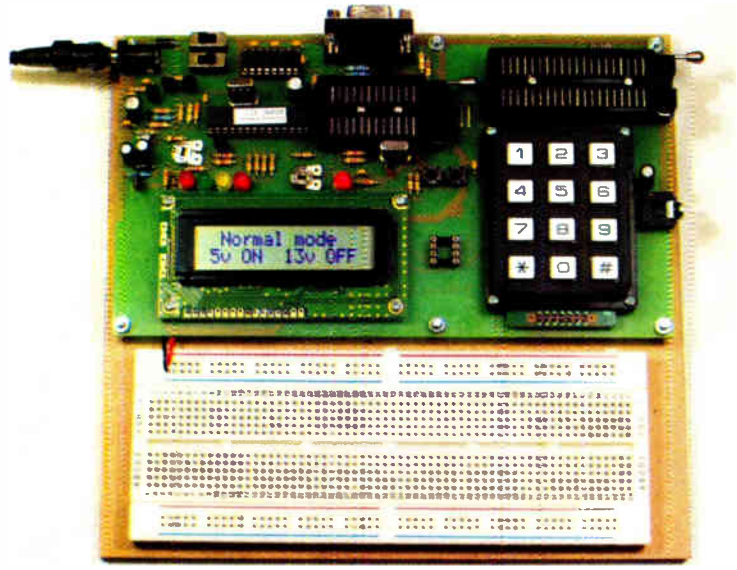

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Which Language to Learn

Everyone should start programming PICs using assembly language. That is the only way to fully understand what happens. Then there are good arguments in some applications to change over to using a high level language, but, BASIC or C? At the beginning BASIC is easy to learn while C can seen very strange, but the weakness of BASIC comes from its ease of use, while the power of C lurks in its strangeness. Once the early stages are past programmes are easier to write in C than in BASIC.

Experimenting with PIC Microcontrollers

This book introduces PIC assembly language programming using the PIC16F84, and is the best way to get started for anyone who is new to PIC programming. We begin with four easy experiments, the first of which is explained over ten and a half pages assuming no starting knowledge of PICs. Then having gained some practical 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*. Finally there are two projects to work through, using the PIC16F84 as a sinewave generator and investigating using the PIC16F88 (from the PIC16F877 family) to monitor the power taken by domestic appliances. In the space of 24 experiments, two projects and 56 exercises the book works through from absolute beginner to experienced engineer level.

Web site:- www.brunningsoftware.co.uk

PIC C Language

The second book *Experimenting with PIC C* starts with an easy to understand explanation of how to write simple PIC programmes in C. The first few programmes are written for a PIC16F84 to keep continuity with the first book *Experimenting with PIC Microcontrollers*. Then we see how to use the same C programmes with the PIC16F627 and the PIC16F877 family.

We study how to create programme loops using C, we experiment with the IF statement, use the 8 bit and 16 bit timers, write text, integer and floating point variables to the liquid crystal display, and use the keypad to enter numbers.

Then its time for 25 pages of pure study, which takes us much deeper into C than is directly useful with PICs as we know them - we are studying for the future as well as the present. We are not expected to understand everything that is presented in these 25 pages, the idea is to begin the learning curve for a deep understanding of C.

In chapter 9 we use C to programme the PIC to produce a siren sound and in the following chapter we create the circuit and software for a freezer thaw warning device. Through the last four chapters we experiment with using the PIC to measure temperature, create a torch light with white LEDs, control the speed of one then two motors, study how to use a PIC to switch mains voltages, and finally experiment with serial communication using the PIC's USART.

Some of the programmes towards the end of *Experimenting with PIC C* are shown in assembler and C to enable the process to be fully explained, and in the torch light experiments, due to the fast switching speed, the programmes are written only in assembler.

As you work through this book you will be pleasantly surprised how C makes light work of calculations and how easy it is to display the answers.

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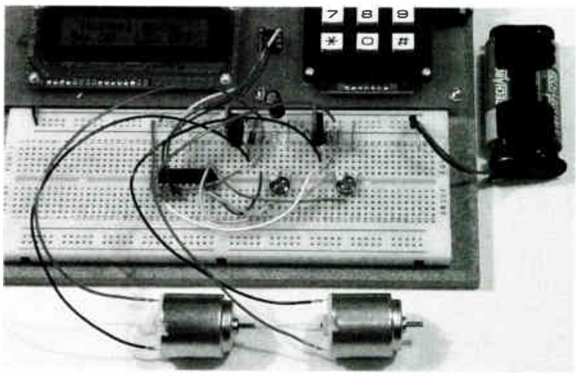

White LED and Motors

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.

We use a PIC16F627 as a freezer thaw monitor, as a step up switching regulator to drive 3 ultra bright white LEDs, and to control the speed of a DC motor with maximum torque still available. A kit of parts can be purchased (£30) to build the circuits using the white LEDs and the two motors. See our web site for details.

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READOUT

Email: john.becker@wimborne.co.uk

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

Alphanumeric LCD Types

On our Chat Zone (access via ***www.epemag.co.uk****) recently, the subject of LCD types and their chip sets came up, the suggestion being that different chip sets require different programming protocols. Over the years I have received very rare reports of readers having difficulty with their LCD failing to initialise properly.*

Obiwan said he'd had an LCD for which he'd had to alter my "standard" LCD initialisation program code (as used in my various PIC Tutorials and in my constructionals) to get it to work. I went on to request info from Obiwan and anyone who knew of LCD types which are different to those I regard as "industry standard".

A number of readers replied, and I entered into private discussion with Obiwan and Epithumia (George and Rob). I think Rob may have hit the nail on the head when he said his interpretation of the datasheet for his LCD was that a minimum 39µs delay is needed between sending the two nibbles of the configuration code for setting the LCD into 4-bit operation mode. This is a timing factor which I had overlooked with my code, which had it's origins in pre-PIC days, when I controlled LCDs purely through logic devices (EPROMS and things).

Rob's code is inserted between his new LCDOUT2 routine and the SENDIT routine:

```
LCDOUT2        movwf STORE
               call SENDITDELAY
               call SENDITDELAY
               return

SENDITDELAY movlw 50
               movwf LOOPA
SENDDELAY      decfsz LOOPA,F
               goto SENDDELAY
SENDIT         swapf STORE,F
;SENDIT         continues as before
```

This delay is only needed wih the LCD initialisation routine, not for data sending once the LCD has been initialised.

I agree with Rob's suggestion. Thank you to everyone who entered into the discussion.

But I would emphasise that the reported LCD problems in the past have been very rare indeed, and the failure of an LCD to work correctly may be down to a constructional problem in some way, and such should be checked for first.

My future designs using LCDs will automatically have Rob's delay built in.

Rob deserves this month's Letter of the Month for his help.

Extreme Electronics

Dear EPE,

In response to Frank Adams' comments (Extreme Electronics, *Readout* Aug '06), I remember when I was a child I used to stay with my aunt on the farm in Norfolk for my summer hols. On hot muggy summer evenings when I was ready for bed, she used to take me upstairs to a window overlooking the marshes as it became dark to look for the "will of the wisp".

Some evenings there was nothing but on other occasions faint glowing soft white balls of light appeared. They hovered and sometimes appeared to bob along a few feet above the ground and then disappear like they had popped. It was very exciting and my aunt looked on them as being good omens and nature's guardians, like fairies, although I've never seen one of those!

I asked her many years later if they were still there. She said no, because people had destroyed their home. I didn't think anything more of it at the time. Thinking about it now she was kind of right, the area was a water meadow with wild flowers and a high water table if you pushed a stick in a dyke bubbles of gas (methane) were released. This area is now mainly drained and under arable cultivation. The large amount of street lighting and general background light pollution would make it difficult to see anything. Perhaps progress is not such a good thing.

Dave Larner, Caister-on-Sea, via email

Dave, how lovely that you've seen the will 'o the wisp, but sad that Will's now lost his home. I wonder if in due course the phenomenom may reappear in areas which are now being reflooded in places like East Anglia? But it may take generations for the conditions to become suitable again.

I'm originally from the fens and marshes of Lincolnshire, but it was not known in my areas – perhaps too many dykes had also drained and dried the region.

Mysterious Lights

I have just read Frank Adams' letter in Aug '06 about the mysterious lights. After watching a recent TV programme about lightning I was reminded of an incident like the one in Frank's letter, it was in the '40s too.

I was walking up a slope towards a bridge and there was a wall with those pointed glazed coping stones on top, and as far as I can recall the weather was dry, but I do not remember if it was cloudy or bright. This ball of blue light appeared suddenly and travelled along the tiles and then just vanished. There was no sound or smell or any tingling, just the ball that vanished.

Robert (anon), via email

That's weird Robert. Maybe it was "will of the wisp" again?

VB 2005 Express

Dear EPE,

Here are some sites that will be of help to the readers interested in VB 2005 Express, as discussed recently in *EPE*:

http://msdn.microsoft.com/vstudio/express/default.aspx

http://msdn.microsoft.com/vstudio/express/support/install/

http://www.smart-projects.net/recover.htm

I can also remember seeing something about free registration being only valid until mid-November 2006.

Mike Von Der Heyden, South Africa, via email

Thanks Mike. It's getting a bit late for registration, but I think it might still be OK if readers are quick.

Screwdrivers

Dear EPE,

Increasingly, imported far-Eastern electronic equipment is held together by special security/tamper-proof screws, notably recessed triangular heads. Do not confuse with tri-wing! The necessary screwdriver will be a triangular prism in shape, about a Phillips 0 in size. No, none of my regular suppliers have these (e.g. RS, Farnell, CPC, Maplin, Screwfix, Rapid). The 'security bit sets', now sold cheaply in vast quantities, do not contain these bits. Without them, you can't service the equipment! Where can they be obtained?

I attach a photograph, in which the two recessed-triangular-head screws are #4 self-tappers, I've also placed an ordinary M3 machine screw alongside for comparison of scale. As the heads are 4.5mm diameter and down a deep counterbore, bits (machined from 6mm hex shanks) are unlikely to be of help, a genuine screwdriver would be more useful.

Godfrey Manning, via email

I didn't know the answer, so I asked via our Chat Zone. Here are extracts from some of the replies:

These security screws are the types used in mobile phone technology especially in repeaters and base stations. Regular tool suppliers supplying BETA or USAG tools will help, also if you have a Yamaha Service Centre near to you will help because Yamaha and Sony and Panasonic are adopting these types of screws to mount PCBs on chassis. These sites explain better:

www.hudsonfasteners.com/sec/sec_tp3_trs_phsts.htm
www.hudsonfasteners.com/sec/sec_tp3_bit.htm

Bernard (CZ name Dsaint)

I checked all of my tool kits and I haven't got one either! It should be easy enough to make your own, filing down a big hexagonal or Pozidriv bit to fit. Unsure how strong it would be though.

Alan Winstanley (CZ name ARW)

I agree with ARW, I just grind some old screwdrivers down and make my own. Sometimes it can take a bit of work, but it can be done most of the time.

George (CZ name Obiwan)

The following link (a reference from the *Wikipedia* article on screws) has pretty much every tamper-proof screw bit on offer. Godfrey's triangular widget is the next-to-last one on the list, I think:

www.lara.com/reviews/screwtypes.htm

Graham (CZ name Grab)

Thank you kindly folks, I passed all your info on to Godfrey. Does anyone have info on UK suppliers?

OEM Datasheets

I would be interested to know if anybody is able to get circuit diagrams for OEM (Original Equipment Manufacture) electronic equipment these days, because in my experience the whole system has been shut down to the amateur and even the professional has to pay through the nose to get any information at all. All blamed on the Health and Safety Act, but I would have thought the Freedom of Information Act should come first.

George Chatley, via email

*George, ordinary (component) datasheets I just find generally by searching on the topic by name through Google (**www.google.com**), followed by the word "datasheet", and usually find what I want without problems.*

There used to be companies who specialised in OEM product data, Mauritron for instance, but I don't see them now looking at a random copy of EPE. *Again, Google might provide an answer about them. Anyway, let's see if readers can offer help.*

Fluorescent Lighting

We had a few replies to David Howton's fluorescent lighting problem quoted in Readout *Aug '06. The replies were sent on to David. Thank you everyone.*

Is the starter correct? The 6ft and 8ft fluorescent fittings have a different glow starter to all the other fittings.

Check the capacitor. On all of the 6ft and 8ft fittings that I have come across the capacitor is an essential part of the circuit. Yes, is does perform the function of power factor correction but it is also part of the main circuit. When the only function of a capacitor is to correct the power factor then it is connected directly across the mains supply. In the 6ft and 8ft fittings it is usually wired in series with the choke.

I have replaced these capacitors by the dozen, they appear to 'dry out' – capacitance value can fall to less than half the declared value. Replacing the capacitor with a new one is the best way out, but a rough and ready way to check is as follows:

Remove the capacitor from the fitting. Connect a 230V live wire to one capacitor terminal and a 13·8Ω 5W resistor (5R6 + 8R2) to the other capacitor terminal. The other resistor wire connects to the neutral of the supply (all in series). Connect a multimeter, on the AC volts range, to read the voltage across the resistor, see Fig.1. The reading will be 1V per microfarad, therefore a 6·8μF capacitor will read 6·8V. **Beware – the capacitor may remain charged after the mains is disconnected. It is not always the case that it will self-discharge.**

The supply voltage should not affect a fluorescent too badly. In England I guess we buy fittings to the same specification as Ireland but since we became harmonised with Europe we are now on 230V ±10% which is not so good as Ireland.

Robert Powell, via email

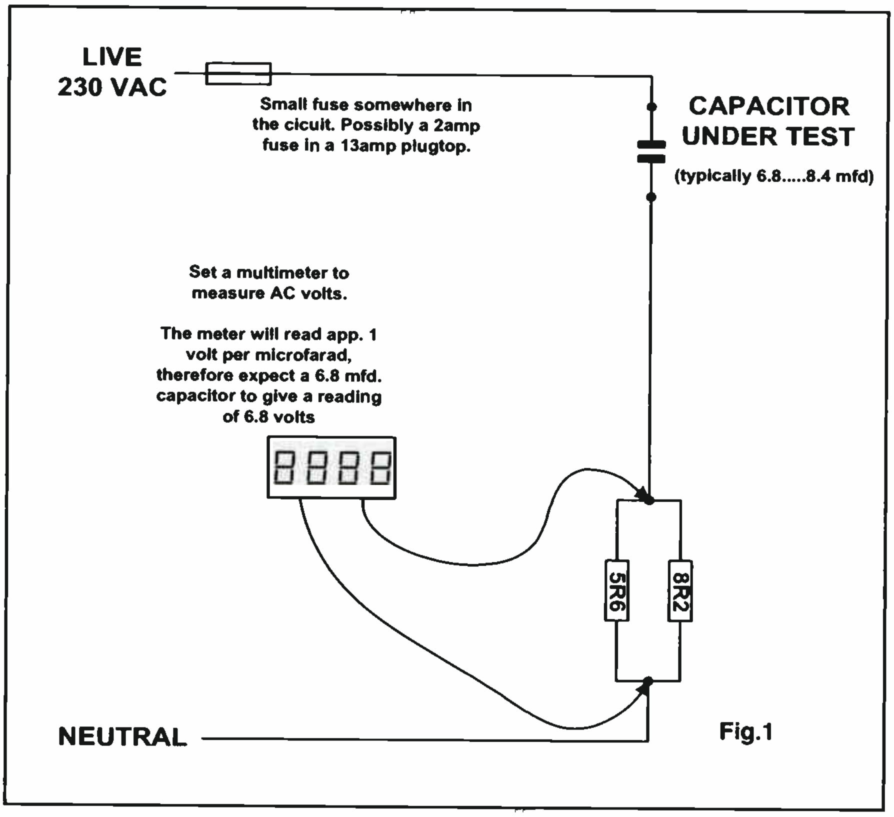

Fig.1

More Fluorescent Lighting

This is a bit of a long shot, but I suspect that David Howton has a mains supply with a large superimposed 3rd and/or higher harmonic content. A poor quality choke will be sensitive to higher harmonics and will result in a reduced current for the same voltage. This can be checked by measuring the current change with a good quality RMS voltmeter across a suitable non-inductive resistor in series with the choke.

Remedy? Ask the supply authority to check the supply earthing, confront them with a request for harmonic content at or near the house, or try a good quality light fitting.

Leon van der Merwe, via email

Most of us in the UK have a high mains supply – it's not been dropped back to 230V from 240V, although the European "harmonised" supply is 230V.

Has David replaced old "fat" 1.5in diameter tubes by modern 1in tubes? These have a slightly different gas mix from the fat ones, which means they're more difficult to start (but more current goes through the mercury vapour when running, and less through the "starter" gasses that are needed to strike the tube and vapourise the mercury).

The modern thin tubes don't work reliably in what was called "resonant start" circuits where the power factor capacitor is wired between the tube heaters (cap and choke in series resonate at about 50Hz, doubling the line voltage across both cap and choke. With the high resonant current flowing through the tube's heaters, the tube lights, damping the resonant current and bringing the current down to the normal running value.)

The answer is to replace the power factor cap with a starter switch and put the power factor cap across the mains. Incidentally, it's worth paying quite highly for electronic starter switches – they don't shorten tube life like the cheap glow starters.

Or, is David using the right starters? Assuming they're switch-start fittings, 6ft tubes run at a higher voltage than the 3ft to 5ft (all about 100 -105V across the lit tube) and a starter for a 5ft can re-ignite (i.e. re-start) on a 6ft tube. Try a starter for an 8ft tube (they run at 150V or so).

Switch-start 8ft fittings normally have the power factor cap in series with the tube and choke – this gives a greater degree of stability in operation, when the tube voltage is more than about half the mains voltage. So try rewiring the 6ft fitting to a series cap circuit.

Alternatively, if you want to be shot of the electricity supply company completely, the ability of compact fluorescents to operate at about 160V – and on DC – makes it possible to run solar cells in series to charge a bank of cells and, in effect, store sunlight for the dark hours – rather better than trying to recover it from cucumbers, like the mad scientist in *Gulliver's Travels*! The capital cost is horrendous, but running cost almost nil.

Dick Oliver, via fax

Smart Mixture

Dear EPE

I feel I must make some comments regarding the *Smart Mixture Display* project in September's *EPE*. With an automotive background of over 20 years, many of them spent in powertrain control system development, I believe I am in a position to give an informed view.

Basically, it's always been been frowned upon if anyone suggests the addition of extra wiring to any engine management system (EMS) component on a road-going vehicle, particularly a sensor that's involved in fuelling control. And especially the oxygen sensor(s)!

The measurement components generally have unique supply and ground circuits back to the EMS ECU, and wiring is optimised with extensive EMC testing to ensure that interference is at an absolute minimum. Adding extra wiring can only compromise this process and new ground connections (which are required for the Mixture Display project) could lead to conditions that upset the balance of differential input measurement systems.

So – why are EMS designers so particular about their input circuitry?

Fuelling measurement is at the heart of the control of tail pipe emissions. Vehicles are extensively tested to ensure that these meet very strict limits and unless these are achieved, the manufacturer is not permitted to sell, and can be fined heavily if they then release vehicles that cannot conform in the 'real' world!

There are also implications for the components. For example, it's fascinating to see a catalyst that's caught fire because an engine was running too rich...not cheap either! The oxygen sensors not only control the fuelling process, but are also used to measure the levels of polluting gases that are coming out the rear end! If emissions limits are exceeded, the dreaded OBD light comes on in the instrument cluster, and manufacturers start to panic! The vehicle might even go into a limp-home mode.

The sensor signals are also used to take account of the 'ageing' of an engine during it's lifetime, and can adapt the calibration to account for this, keeping the performance up to scratch and the emissions in line.

So – any errors in the signals can have wide-reaching (and expensive) effects on the car.

Air flow meters – some are PWM output, not voltage, and often have a thermistor incorporated to measure inlet air temp – another crucial fuelling parameter.

Oxygen sensors – sometimes there are four on a car – in the exhaust manifold for direct fuelling and downstream to measure catalyst performance. How do you know you're picking the right one? Many different types too, especially the universal type (definitely not cheap) that give an actual air fuel ratio rather than the 'simple' ones that switch rich/lean. Heater profiles are critical as well, especially considering the current they draw during warm-up.

OK – you may want to fit your own unique sensor(s) and keep clear of the car components. But, positioning of the oxygen sensor is another significant process – you have to know the gases composition map on the exit from the exhaust valve(s) and into the manifold, as you might end up in an area that has a gas mix that is totally unrepresentative of the actual air/fuel ratio. This could require extensive experimentation – even the professionals get it wrong. On one occasion, the 'mechanical' guys were blaming an air meter for 'dodgy' signals... then it was discovered that it was mounted in an area of the inlet manifold that was experiencing all sorts of turbulence over the engine speed range. They went away and did some flow modelling, moved it, and all was fine!

I'm not trying to put the dampers on experimentation and measurement here... many of my published circuits have been related to car systems monitoring. But – I've been very careful to ensure that none have had the potential to interfere with the car's basic systems, which I'm worried may happen with this circuit.

If you're really into the monitoring of car fuelling parameters, why not borrow a SCAN tool from your 'friendly' local dealer? Most vehicles built post-'96 are fitted with a J1962/OBD connector easily accessible under the fascia by the driver's or passenger's feet and this is where you can plug into the car systems in a way that is much safer! If this connector is fitted, the manufacturer must have provided a fixed set of measurements for the local garage to measure what's going on (and download fault codes, freeze frame data, etc.) without having to invest in a system unique to that model.

If you're thinking of doing a dedicated system such as something like the *Smart Mixture Display*, why not get your PIC development kit out and play with an 18F248 which has CAN capability – CAN is the network on the vehicle where you'll find messages that you can decode to give such signals as air flow and oxygen sensor output. Then play from there....

Steve Dellow, via email

Thank you for this information which we are happy to bring to readers' attention. Steve has also informed us that in the USA it is illegal to modify the engine management system.

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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.

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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** **£23.99**

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.

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Computing & 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.

268 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.

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288 pages – large format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision Command System

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using Lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with '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.

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**

PIC YOUR PERSONAL INTRODUCTORY COURSE SECOND 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 second edition covers the popular reprogrammable EEPROM PICs: P16C84/16F84 as well as the P54 and P71 families.

270 pages **Order code NE36** **£16.99**

INTRODUCTION TO MICROPROCESSORS
John Crisp

If you are, or soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors, 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 microprocessors.

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** **£21.99**

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 **Order code BP542** **£8.99**

NEWNES PC TROUBLESHOOTING POCKET BOOK – THIRD EDITION
Howard Anderson, Mike Tooley

All the essential data for PC fault-finding and upgrading. This book provides a concise and compact reference that describes, in a clear and straightforward manner, the principles and practice of fault-finding and upgrading PCs and peripherals. The book is aimed at anyone who is involved with the installation, configuration, maintenance, upgrading, repair or support of PC systems. It also provides non-technical users with sufficient background information, charts and checklists to enable the diagnosis of faults and help to carry out simple modifications and repairs. In order to reflect rapid changes in computer technology (both hardware and software) this new edition has been completely revised and rewritten.

256 pages **Order code NE41** **£19.99**

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Tony Fischer-Cripps

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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.

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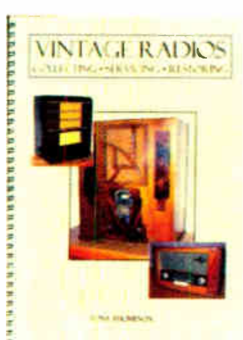
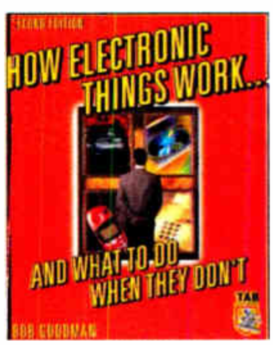
Over 800 pages in Adobe Acrobat format — **Order code BEB2 CD-ROM** — **£21.95**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.
96 pages — **Order code BP239** — **£5.49**

OSCILLOSCOPES – FIFTH EDITION
Ian Hickman
Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.
This handy guide to oscilloscopes is essential reading for anyone who has to use a 'scope for their work or hobby; electronics designers, technicians, anyone in industry involved in test and measurement, electronics enthusiasts . . . Ian Hickman's review of all the latest types of 'scope currently available will prove especially useful for anyone planning to buy – or even build – an oscilloscope.
The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscillocopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3). storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.
288 pages — **Order code NE37** — **£22.99**

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
To be a real fault finder, you must be able to get a feel for what is going on in the circuit you are examining. In this book Robin Pain explains the basic techniques needed to be a fault finder.





Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.
The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.
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Steve Money
In most applications of electronics, test instruments are essential for checking the performance of a system or for diagnosing faults in operation, and so it is important for engineers, technicians, students and hobbyists to understand how the basic test instruments work and how they can be used.
The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bridges, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of these instruments are also examined.
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DIGITAL GATES AND FLIP-FLOPS
Ian R. Sinclair
This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.
Topics such as Boolean algebra and Karnaugh mapping are explainend, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.
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Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.
Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.
The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.
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Project Building

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Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

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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.

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R. A. Penfold
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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.

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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.

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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** **£10.99**

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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.

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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.

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Theory and Reference

THE EMERGENCE OF BROADCASTING IN BRITAIN
Brian Hennessy
The beginning of any great enterprise should be recorded for posterity. Few knew that the *Children's Hour* "Uncles", Arthur, Jeff and Caractacus, were also the engineers who struggled by day to develop technical equipment – and would soon become Assistant Controller, Station Director and Organiser of Programmes for the BBC.

This is a very human account, from the dawn of radio to the attainment of a Royal Charter in the late 1920s. It tells of the struggles and frustrations of engineers in developing innovative equipment and of the great John Reith who battled with everyone to bring the BBC from a staff of four up to a Corporation of several hundred.

Brian Hennessy's book also describes the devlopment of broadcasting equipment, the search for premises and looming bankruptcy before ending with the emergence of a firmly established Chartered Corporation – the BBC.

Meticulous research over many years, over a hundred photographs, plans and diagrams as well as interviews with many of those who were there at the time, make this a valuable and original work for those involved in media studies, for radio enthusiasts or simply for those interested in radio and the fascinating story of the emergence of broadcasting.

436 pages **Order code EBB** **£26.00**

COIL DESIGN AND CONSTRUCTIONAL MANUAL
B. B. Babani
A complete book for the home constructor on "how to make" RF, IF, audio and power coils, chokes and transformers. Practically every possible type is discussed and calculations necessary are given and explained in detail. Although this book is now twenty years old, with the exception of toroids and pulse transformers little has changed in coil design since it was written.

96 pages **Order code BP160** **£4.49**

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.

The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.

Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.

188 pages **Order code BP299** **£5.49**

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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 our website.

Boards can only be supplied on a payment with order basis.

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