Volume 3 Issue 9
January 2001

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PROJECTS . . . THEORY . . . NEWS . . .
COMMENTS . . . POPULAR FEATURES . . .

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Cover illustration by Jonathan Robertson

EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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Projects and Circuits

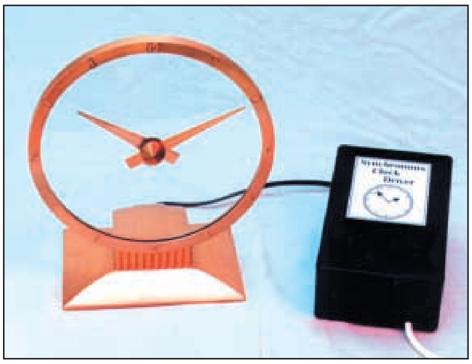
WATER MONITOR by John Becker 616
How costly is it to keep your garden watered?
Find out and control it

INGENUITY UNLIMITED hosted by Alan Winstanley 626
Wien Bridge Audio Generator; Precision Stereo Volume Control

L.E.D. SUPER TORCHES by Andy Flind 628
Two hi-tech (one super-hi-tech!) designs to brighten your nights

PERPETUAL PROJECTS – 3 by Thomas Scarborough 644
Three more solar-powered projects – **Loop Burglar Alarm, Touch-Switch Door-Light, Solar-Powered Rain Alarm** – plus seven suggestions for variants

SYNCHRONOUS CLOCK DRIVER by Andy Flind 660
By popular request – a dual-frequency, 50Hz-60Hz converter for mains operated synchronous clocks



Series and Features

NEW TECHNOLOGY UPDATE by Ian Poole 622
Small is efficient when it comes to packaging

CONTROLLING FLIGHT by Owen Bishop 638
An insight into how electronics helps to maintain aircraft safety

PRACTICALLY SPEAKING by Robert Penfold 654
A novice's guide to why some pins can be left unconnected

NET WORK – THE INTERNET PAGE surfed by Alan Winstanley 658

CIRCUIT SURGERY by Alan Winstanley and Ian Bell 666
Curious Decoupling; Some Like it Hot

Regulars and Services

EDITORIAL 615

NEWS – Barry Fox highlights technology's leading edge 623
Plus everyday news from the world of electronics

READOUT John Becker addresses general points arising 635

ELECTRONICS VIDEOS Our range of educational videos 642

SHOPTALK with David Barrington 650
The *essential* guide to component buying for *EPE* projects

PLEASE TAKE NOTE Shortwave Loop Aerial 650

BACK ISSUES Did you miss these? Some now on CD-ROM! 652

CD-ROMS FOR ELECTRONICS 656
Electronic Projects; Filters; Digital Works 3.0; Electronic Circuits and Components V2.0; Digital Electronics; Analogue Electronics; PICtutor; Modular Circuit Design; Electronic Components Photos; C for PIC Micros; CAD Pack

ELECTRONICS MANUALS 668
Essential reference works for hobbyists, students and service engineers

DIRECT BOOK SERVICE 670
A wide range of technical books available by mail order

PRINTED CIRCUIT BOARD AND SOFTWARE SERVICE 673
PCBs for *EPE* projects. Plus *EPE* software

ADVERTISERS INDEX ***676***

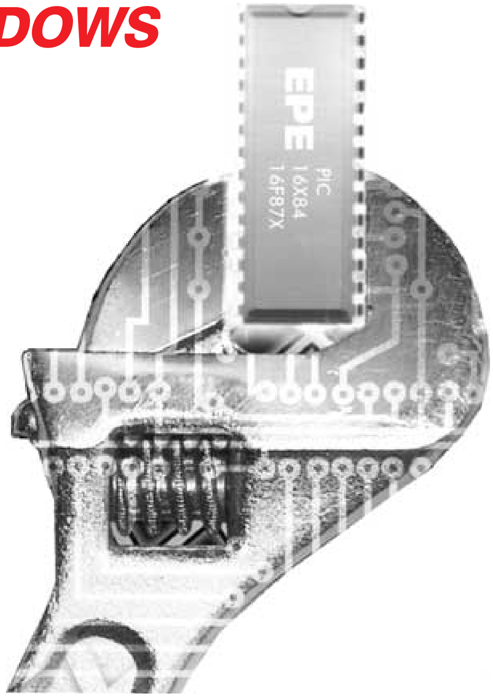
WE HAVE MOVED!
Please note our new address and phone/fax numbers – see page 615

Our October 2001 issue will be published on Thursday, 13 September 2001. See page 607 for details

Readers Services • Editorial and Advertisement Departments 615

NEXT MONTH

PIC TOOLKIT TK3 FOR WINDOWS



Designed explicitly for running in the "desk-top PC" environments of Windows 95 and 98, the software for Toolkit TK3 is intuitively easy to use, fast in operation, has many extra features that are probably not found elsewhere, and is the ideal programming aid for all who love to play with reprogrammable PICs. It is equally suited to TASM and MPASM programming dialects.

The accompanying p.c.b. caters for 8-, 18-, 28- and 40-pin PIC sizes. These can be hard-wired not only to integral on-board hardware, but also to external components in conjunction with a plug-in breadboard. In this context, it is not only a programmer, but its options are also closely allied to the facilities available on the highly successful EPE PIC Tutorial *board of March to May '98.*

The PIC families catered for are principally the PIC16x84 and PIC16F87x EEPROM-based series. It is likely that the system can be used with other PICs that also have 14-bit program codes.

The new software can also be used with the Toolkit V2.4 *board, originally released in May/June '99.*

TWO-VALVE SW RECEIVER

Never let us be accused of lagging behind the times. Get right up to date with this Two-Valve Shortwave Receiver.

Well maybe it's not the very latest technology but this fascinating retro project is fun to build and use, and the components are still easy to obtain.

This battery powered set is of the type that was the norm in the 60s. It covers the range 5MHz to 30MHz and, although a bit of "chassis bashing" is involved, it is easy to build and use.

Go back in time next month – it will give you a warm glow!

TRAFFIC CONTROL

We hear much about air traffic controllers, but more important to our daily lives are those relatively inconspicuous systems and people who control the flow of traffic in our busy cities. This article describes how electronics and computers are used to make their work possible.

For instance, vehicles approaching many junctions are detected by inductive loops. Changes in inductance change the input to the control computer that is located beside the road junction. Information from the inductive loops can tell the computer the length of the traffic queue at the lights and also the speed and approximate size of vehicles approaching them. It's all explained in this feature article.

PLUS ALL THE REGULAR FEATURES

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DON'T MISS AN ISSUE – PLACE YOUR ORDER NOW!

Demand is bound to be high

OCTOBER 2001 ISSUE ON SALE THURSDAY, SEPTEMBER 13

£1 BARGAIN PACKS
Selected Items

PIEZO ELECTRIC SOUNDER, also operates efficiently as a microphone. Approximately 30mm diameter, easily mountable, 2 for £1. Order Ref: 1084.

LIQUID CRYSTAL DISPLAY on p.c.b. with i.c.s etc. to drive it to give 2 rows of 8 figures or letters with data. Order Ref: 1085.

30A PANEL MOUNTING TOGGLE SWITCH. Double-pole. Order Ref: 166.

SUB MIN TOGGLE SWITCHES. Pack of 3. Order Ref: 214.

HIGH POWER 3in. SPEAKER (1W 8ohm). Order Ref: 246.

MEDIUM WAVE PERMEABILITY TUNER. It's almost a complete radio with circuit. Order Ref: 247.

HEATING ELEMENT, mains voltage 100W, brass encased. Order Ref: 8.

MAINS MOTOR with gearbox giving 1 rev per 24 hours. Order Ref: 89.

ROUND POINTER KNOBS for flatted ¼in. spindles. Pack of 10. Order Ref: 295.

CERAMIC WAVE-CHANGE SWITCH. 12-pole, 3-way with ¼in. spindle. Order Ref: 303.

REVERSING SWITCH. 20A double-pole or 40A single pole. Order Ref: 343.

LUMINOUS PUSH-ON PUSH-OFF SWITCHES. Pack of 3. Order Ref: 373.

SLIDE SWITCHES. Single pole changeover. Pack of 10. Order Ref: 1053.

PAXOLIN PANEL. Approximately 12in. x 12in. Order Ref: 1033.

CLOCKWORK MOTOR. Suitable for up to 6 hours. Order Ref: 1038.

TRANSISTOR DRIVER TRANSFORMER. Maker's ref. no. LT44, impedance ratio 20k ohm to 1k ohm; centre tapped, 50p. Order Ref: 1/23R4.

HIGH CURRENT RELAY, 12V d.c. or 24V a.c., operates changeover cocntacts. Order Ref: 1026.

3-CONTACT MICROSWITCHES, operated with slightest touch, pack of 2. Order Ref: 861.

HIVAC NUMICATOR TUBE, Hivac ref XN3. Order Ref: 865 or XN11 Order Ref: 866.

2IN. ROUND LOUDSPEAKERS. 50Ω coil. Pack of 2. Order Ref: 908.

5K POT, standard size with DP switch, good length ¼in. spindle, pack of 2. Order Ref: 11R24.

13A PLUG, fully legal with insulated legs, pack of 3. Order Ref: GR19.

OPTO-SWITCH on p.c.b., size 2in. x 1in., pack of 2. Order Ref: GR21.

COMPONENT MOUNTING PANEL, heavy paxolin 10in. x 2in., 32 pairs of brass pillars for soldering binding components. Order Ref: 7RC26.

HIGH AMP THYRISTOR, normal 2 contacts from top, heavy threaded fixing underneath, think amperage to be at least 25A, pack of 2. Order Ref: 7FC43.

BRIDGE RECTIFIER, ideal for 12V to 24V charger at 5A, pack of 2. Order Ref: 1070.

TEST PRODS FOR MULTIMETER with 4mm sockets. Good length flexible lead. Order Ref: D86.

LUMINOUS ROCKER SWITCH, approximately 30mm square, pack of 2. Order Ref: D64.

MES LAMPHOLDERS slide on to ¼in. tag, pack of 10. Order Ref: 1054.

HALL EFFECT DEVICES, mounted on small heatsink, pack of 2. Order Ref: 1022.

12V POLARISED RELAY, 2 changeover contacts. Order Ref: 1032.

PROJECT CASE, 95mm x 66mm x 23mm with removable lid held by 4 screws, pack of 2. Order Ref: 876.

LARGE MICROSWITCHES, 20mm x 6mm x 10mm, changeover contacts, pack of 2. Order Ref: 826.

MAINS RELAY with 15A changeover contacts. Order Ref: 965.

COPPER CLAD PANELS, size 7in. x 4in., pack of 2. Order Ref: 973.

100M COIL OF CONNECTING WIRE. Order Ref: 685.

WHITE PROJECT BOX, 78mm x 115mm x 35mm. Order Ref: 106.

LEVER-OPERATED MICROSWITCHES, ex-equipment, batch tested, any faulty would be replaced, pack of 10. Order Ref: 755.

MAINS TRANSFORMER, 12V-0V-12V, 6W. Order Ref: 811.

THIS MONTH'S SPECIAL

IT IS A DIGITAL MULTITESTER, complete with backrest to stand it and hands-free test prod holder. This tester measures d.c. volts up to 1,000 and a.c. volts up to 750; d.c. current up to 10A and resistance up to 2 megs. Also tests transistors and diodes and has an internal buzzer for continuity tests. Comes complete with test prods, battery and instructions. Price £6.99. Order Ref: 7P29.

1mA PANEL METER. Approximately 80mm × 55mm, front engraved 0-100. Price £1.50 each. Order Ref: 1/16R2.

VERY THIN DRILLS. 12 assorted sizes vary between 0·6mm and 1·6mm. Price £1. Order Ref: 128.

EVEN THINNER DRILLS. 12 that vary between 0·1mm and 0·5mm. Price £1. Order Ref:129.

BT PLUG WITH TWIN SOCKET. Enables you to plug 2 telephones into the one socket for all normal BT plugs. Price £1.50. Order Ref: 1.5P50.

D.C. MOTOR WITH GEARBOX. Size 60mm long, 30mm diameter. Very powerful, operates off any voltage between 6V and 24V D.C. Speed at 6V is 200 rpm, speed controller available. Special price £3 each. Order Ref: 3P108.

FLASHING BEACON. Ideal for putting on a van, a tractor or any vehicle that should always be seen. Uses a Xenon tube and has an amber coloured dome. Separate fixing base is included so unit can be put away if desirable. Price £5. Order Ref: 5P267.

MOST USEFUL POWER SUPPLY. Rated at 9V 1A, this plugs into a 13A socket, is really nicely boxed. £2. Order Ref: 2P733.

MOTOR SPEED CONTROLLER. These are suitable for D.C. motors for voltages up to 12V and any power up to 1/6h.p. They reduce the speed by intermittent full voltage pulses so there should be no loss of power. In kit form these are £12. Order Ref: 12P34. Or made up and tested, £20. Order Ref: 20P39.

BT TELEPHONE EXTENSION WIRE. This is proper heavy duty cable for running around the skirting board when you want to make a permanent extension. 4 cores properly colour coded, 25m length. Only £1. Order Ref:1067.

LARGE TYPE MICROSWITCH with 2in. lever, changeover contacts rated at 15A at 250V, 2 for £1. Order Ref: 1/2R7.

BALANCE ASSEMBLY KITS. Japanese made, when assembled ideal for chemical experiments, complete with tweezers and 6 weights 0·5 to 5 grams. Price £2. Order Ref: 2P44.

CYCLE LAMP BARGAIN. You can have 100 6V 0-5A MES bulbs for just £2.50 or 1,000 for £20. They are beautifully made, slightly larger than the standard 6·3V pilot bulb so they would be ideal for making displays for night lights and similar applications.

DOORBELL PSU. This has AC voltage output so is ideal for operating most doorbells. The unit is totally enclosed so perfectly safe and it plugs into a 13A socket. Price only £1. Order Ref: 1/30R1.

INSULATION TESTER WITH MULTIMETER. Internally generates voltages which enable you to read insulation directly in megohms. The multi-meter has four ranges, AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50 each, yours for only £7.50 with leads, carrying case £2 extra. Order Ref: 7.5P4.

REPAIRABLE METERS. We have some of the above testers but slightly faulty, not working on all ranges, should be repairable, we supply diagram, £3. Order Ref: 3P176.

TWO MORE POST OFFICE INSTRUMENTS

Both instruments contain lots of useful parts, including sub-min toggle switch sold by many at £1 each. They are both in extremely nice cases, with battery compartment and flexible carrying handles, so if you don't need the intruments themselves, the case may be just right for a project you have in mind.

The first is **Oscillator 87F**. This has an output, continuous or interrupted, of 1kHz. It is in a plastic box size 115mm wide, 145mm high and 50mm deep. Price only £1. Order Ref: 7R1.

The other is **Amplifier Ref. No. 109G**. This is in a case size 80mm wide, 130mm high and 35mm deep. Price £1. Order Ref: 7R2.

HEAVY DUTY POT

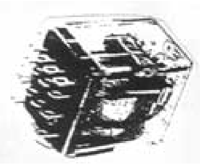
Rated at 25W, this is 20 ohm resistance so it could be just right for speed controlling a d.c. motor or device or to control the output of a high current amplifier. Price £1. Order Ref: 1/33L1.

STEPPER MOTOR

Made by Philips as specified for the wind-up torch in the Oct '00 Practical Electronics is still available, price £2. Order Ref: 2P457.

SOLDERING IRON, super mains powered with long-life ceramic element, heavy duty 40W for the extra special job, complete with plated wire stand and 245mm lead, £3. Order Ref: 3P221.

RELAYS



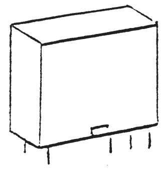
We have thousands of relays of various sorts in stock, so if you need anything special give us a ring. A few new ones that have just arrived are special in that they are plug-in and come complete with a special base which enables you to check voltages of connections of it without having to go underneath. We have 6 different types with varying coil voltages and contact arrangements. All contacts are rated at 10A 250V AC.

Coil Voltage	Contacts	Price	Order Ref:
12V DC	4-pole changeover	£2.00	FR10
24V DC	2-pole changeover	£1.50	FR12
24V DC	4-pole changeover	£2.00	FR13
240V AC	1-pole changeover	£1.50	FR14
240V AC	4-pole changeover	£2.00	FR15

Prices include base

MINI POWER RELAYS

For p.c.b. mounting, size 28mm x 25mm x 12mm, all have 16A changeover contacts for up to 250V. Four versions available, they all look the same but have different coils:



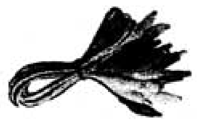
6V Order Ref: FR17
12V Order Ref: FR18
24V Order Ref: FR19
48V Order Ref: FR20

Price £1 each less 10% if ordered in quantities of 10, same or mixed values.

NOT MUCH BIGGER THAN AN OXO CUBE. Another relay just arrived is extra small with a 12V coil and 6A changeover contacts. It is sealed so it can be mounted in any position or on a p.c.b. Price 75p each, 10 for £6 or 100 for £50. Order Ref: FR16.

RECHARGEABLE NICAD BATTERIES. AA size, 25p each, which is a real bargain considering many firms charge as much as £2 each. These are in packs of 10, coupled together with an output lead so are a 12V unit but easily divideable into 2 × 6V or 10 × 1·2V. £2.50 per pack, 10 packs for £25 including carriage. Order Ref: 2.5P34.

FOR QUICK HOOK-UPS. You can't beat leads with a croc clip each end. You can have a set of 10 leads, 2 each of 5 assorted colours with insulated crocodile clips on each end. Lead length 36cm, £2 per set. Order Ref: 2P459.



BIG 12V TRANSFORMER. It is 55VA so that is over 4A which is normal working, intermittently it would be a much higher amperage. Beautiful transformer, well made and very well insulated, terminals are in a plastic frame so can't be accidentally touched. Price £3.50. Order Ref: 3.5P20.

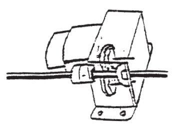
BUY ONE GET ONE FREE

ULTRASONIC MOVEMENT DETECTOR. Nicely cased, free standing, has internal alarm which can be silenced. Also has connections for external speaker or light. Price £10. Order Ref: 10P154.

CASED POWER SUPPLIES which, with a few small extra components and a bit of modifying, would give 12V at 10A. Originally £9.50 each, now 2 for £9.50. Order Ref: 9.5P4.

3-OCTAVE KEYBOARDS with piano size keys, brand new, previous price £9.50, now 2 for the price of one. Order Ref: 9.5P5.

1·5V-6V MOTOR WITH GEARBOX. Motor is mounted on the gearbox which has interchangeable gears giving a range of speeds and motor torques. Comes with full instructions for changing gears and calculating speeds, £7. Order Ref: 7P26.



MINI BLOWER HEATER. 1kW, ideal for under desk or airing cupboard, etc., needs only a simple mounting frame, price £5. Order Ref: 5P23.

TERMS

Send cash, PO, cheque or quote credit card number – orders under £25 add £4.50 service charge.

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VARIETY

I have commented on the variety this job offers in past Editorials, what is also of interest is the variety of projects we are able to offer. We can take little responsibility for the wide range of designs – these are mostly down to the inventiveness of contributors. Sometimes we will ask authors for a particular project, but very often the ideas will come from them and, as you can tell, they are an inventive lot.

This month is no exception – one project, from our long-standing regular contributor Andy Flind, has been designed following a request from a reader, this is the *Synchronous Clock Driver*. Andy also designed the *L.E.D. Torches* for his own use – see his introduction in the article. John Becker, our Technical Editor, has come up with another PIC-based project which develops some previously published designs. In addition to these, Thomas Scarborough has come up with a range of solar-powered projects as part of the *Perpetual Projects* series.

NEXT MONTH

Next month the variety is stretched even further with a *Two-Valve Shortwave Receiver* from Robert Penfold and perhaps the ultimate, up-to-the-minute design of *PIC Toolkit TK3 for Windows* from John Becker; together with new Visual Basic software with extensive facilities. There will also be some more *Perpetual Projects.*

THERE'S MORE

Just to whet your appetite even further we have the following unusual projects in the pipeline: *Ghost Buster* – experimental device for detecting low frequency standing waves; *Virus Zapper* – can a simple circuit kill the common cold? *Forever Flasher* – free power for an l.e.d. flashing circuit. Don't miss them.

And, oh yes, we have *Teach-In 2002* starting in the November issue, it's a bit different to previous series and will be of interest to a very wide range off readers – more details next month.

Mike Kenward

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see below), from all UK newsagents (distributed by COMAG) and from the following electronic component retailers: Omni Electronics and Yebo Electronics (S. Africa). *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just $9.99(US) per year available from **www.epemag.com**

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BINDERS

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COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers (see *Shoptalk*). **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 imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

Constructional Project

WATER MONITOR

JOHN BECKER

How costly is it to keep your garden watered? Find out, and control it!

MUCH water has "flowed under the bridge" since the author's original *Digital Water Meter* was published in *EPE* June 1994. Indeed, in many parts of the UK, probably far too much has flowed this year!

Interestingly, that meter was designed at a time of great drought in Southern England and there were concerns that water should be conserved for ecological reasons. This too was a time when UK households were in the process of going over to paying for water by quantity used rather than according to a fixed annual charge.

In this respect, people were wondering whether they would be better or worse off by going over to Water Company metering. The meter was designed to enable readers to pre-assess their consumption before taking the irreversible step of allowing the Water Company to install their own meter.

These days most households probably have water metering installed as standard. It is still beneficial, though, to keep track of how much the water bill has been clocked up by watering the garden.

WATER CONSUMPTION

It is worth noting, however, that garden watering is not the only cause of significant water use. The UK Government's Office of Water Services (OFWAT) quotes the following domestic water supply statistics:

Appliance	Average use (litres)	Percentage of average total use
Household per day	380	100%
Washing machine	110	12%
Dishwasher	55	1%
Bath	80	17% (Bath and Shower)
Shower	35	
WC	9·5	32%
Garden hose	540 per hour	3%
Drinking/cooking	–	2·5%
Miscellaneous	–	32·5%

WATER MONITOR

Terry de Vaux-Balbirnie tackled one aspect of garden watering consumption with his *Hosepipe Controller* of June '01. His design allowed watering to be automatically cut-off after a preset period.

The Water Monitor presented now also allows preset water cut-off, but has the additional benefit of actually telling you the cost of the water that has been used to keep the grass green.

The design is PIC controlled and includes a 32-digit alphanumeric liquid crystal display (l.c.d.). The Water Company's charge per cubic metre of water used is entered via pushbutton switches and is automatically stored for future recall. The l.c.d. shows the elapsed time since watering started (24-hour clock), the number of litres used (99999 max.) and their cumulative cost (£99.99 – or $ etc. – max.).

The original intention had been to provide only this information. Editor Mike, however, made the valid suggestion that it would be useful if the meter could also control the duration of water flow. This facility has been added as a simple optional extra, although it is not used in the author's prototype shown in the photographs.

The duration can be set in steps of 10 minutes up to a total period of nine hours 50 minutes. It can be manually terminated earlier than the preset period if desired. The facility can be bypassed to allow unlimited water flow. The preset time is also stored for future recall.

Additionally, the meter allows the litres and cost count to be reset each time it is used, or to continue counting from the previous values reached when the meter was last used.

Cut-off duration and Water Company price per cubic metre can be changed as often as you require.

CIRCUIT DESCRIPTION

Not only has the UK experienced a change from drought to frequent flood conditions since the author's original water meter was published, but electronics technology has improved dramatically. This has allowed a much simpler and yet more sophisticated design to be published now – it is also cheaper to build!

The original meter used 14 integrated circuits and a 4-digit 7-segment l.c.d. The new design uses two i.c.s (the PIC microcontroller and a voltage regulator) and an "intelligent" alphanumeric l.c.d. The water flow sensor is the same as previously used.

Whereas the original cost about £70 to build, the new one costs about £35.

The circuit diagram for the Water Monitor, without the optional water control feature, is shown in Fig.1.

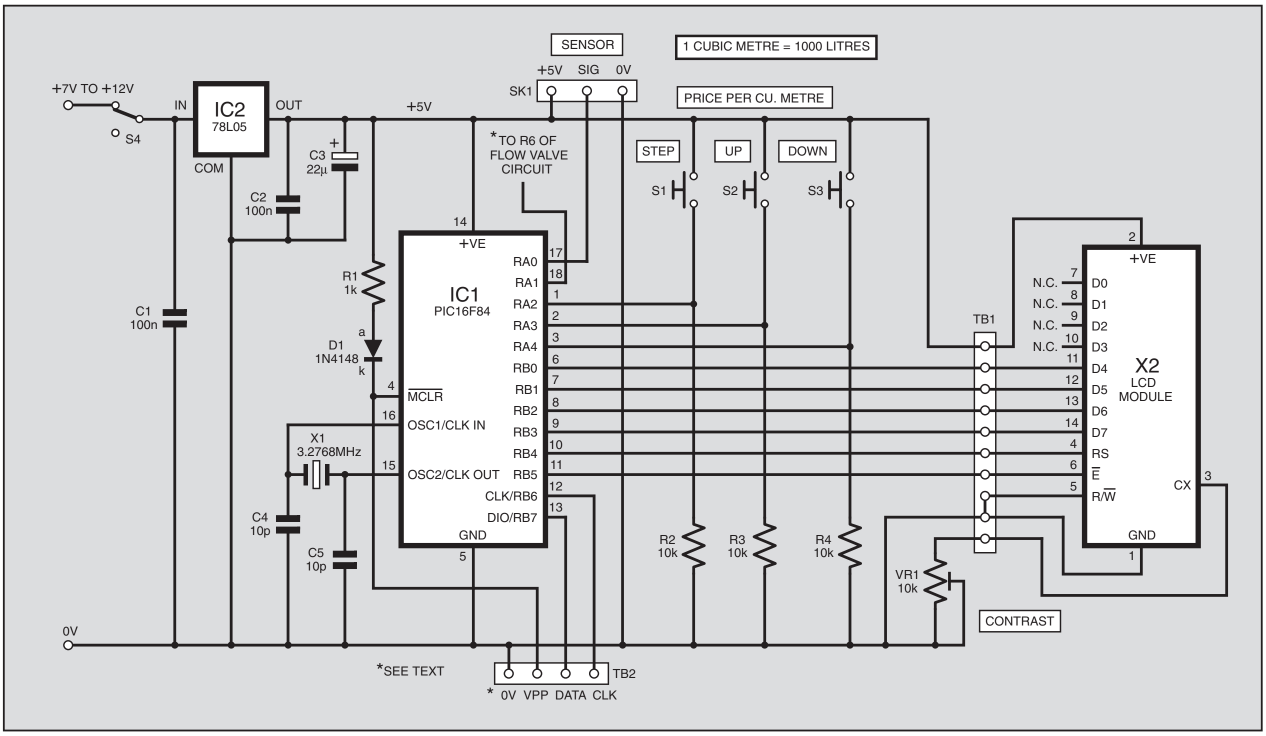


Fig.1. Circuit diagram for the Water Monitor control and display.

A PIC16F84 microcontroller is used, designated as IC1. It is operated at 3·2768MHz, as set by crystal X1. Pulses are input to the PIC from the water sensor (discussed presently) via socket SK1 to port pin RA0. Processed data is output to the l.c.d., X2, which is operated under conventional 4-bit mode. Preset VR1 allows for l.c.d. contrast adjustment.

Switches S1 to S3 are used to set the cost per cubic metre and the water cut-off duration. They are operated in push-to-make mode, with PIC pins RA2 to RA4 normally biased to 0V via resistors R2 to R4. When the switches are pressed, the relevant PIC pin is taken high (+5V). Port pin RA1 is used to control the optional water flow valve described later.

The PIC may be programmed *in situ* via connector TB2. The pins are in the author's standard order for use with *EPE* PIC programmer *Toolkit Mk2*. Resistor R1 and diode D1 prevent regulator IC2 from being "distressed" by the voltages involved during programming.

The unit may be powered at between about 7V and 15V d.c. The prototype draws 32·5mA with the sensor connected, 8·7mA without. It is not intended to be battery operated (unless a heavy duty battery is used, external to the unit). The prototype is powered from a bench power supply, although a mains powered d.c. "battery adaptor" may be used instead.

DO NOT use the control unit outdoors or anywhere near the water supply if it is in any way connected to the electrical mains, however remotely. Normal mains electricity safety considerations must be observed.

The controlling PIC software is available on 3·5-inch disk (for which a nominal handling charge applies) or free via the *EPE* web site. The files include the source code (TASM grammar) and both OBJ (TASM) and HEX (MPASM) format program codes. Pre-programmed PICs are available through an independent supplier. See this month's *Shoptalk* column for details of all options.

WATER FLOW SENSOR

As previously said, the water flow sensor (transducer) is the same as used in the original design. It is manufactured for use with heating and mains water supplies up to a temperature of about 70°C. It *must not*, however, be used to monitor drainage water sources, such as the outputs from kitchen sinks, baths, washing machines or similar, since it could become blocked.

In essence, the sensor comprises a pipe containing a small turbine mounted on sapphire bearings. Attached to the turbine, in a water-resistant housing, is a small electronic circuit, as shown in Fig.2.

Water flowing through the pipe causes the turbine to rotate at a rate proportional to the flow. Within the housing are a light emitting diode (l.e.d.) and a light sensitive diode. As the turbine blades rotate, they repeatedly interrupt the light path between the l.e.d. and the photodiode. The resulting voltage changes across the diode are amplified by the sensor's op.amp, shaped by the Schmitt trigger buffer and output at the transistor's collector.

The maximum output pulse level is that of the supply line which, in other applications, may be between about +4·5V and +16V d.c. For this monitor, the level is nominally +5V. An internal regulator drops the supply voltage to a fixed level suitable for the photodiode, op.amp and Schmitt trigger. The transistor's collector load resistor is connected to the supply line, so in this application, the pulsed output swings between +5V and 0V.

The sensor's l.e.d. has to be used with an external series resistor, R5, whose value is chosen to suit the supply line. The maximum l.e.d. current is 30mA, although with the test model a current of about 22mA, as set by R5 at 220 ohms, was satisfactory.

Note that the sensor's circuit housing is not totally light-proof and that too high an l.e.d. current in the presence of high ambient light levels could cause the output to stay high.

A graph of the sensor's output pulse rates plotted against water flow is shown in Fig.3. It also shows the typical output pulse waveform which, it should be noted, does not have an equal mark-space ratio, i.e. it is not a square wave.

The sensor is capable of monitoring flow rates of about 1·5 to 30 litres per minute. Full scale frequency output is approximately 600Hz. Typically, the number of pulses per litre of flow is 1200. It is this figure that is used in the calculations made by the PIC microcontroller.

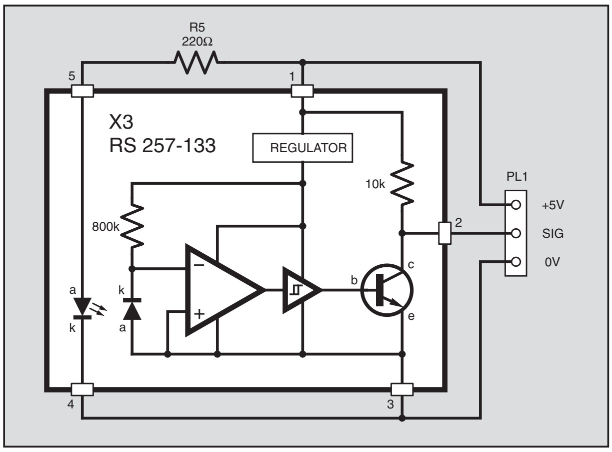


Fig.2. Diagram for the flow sensor's integral circuit.

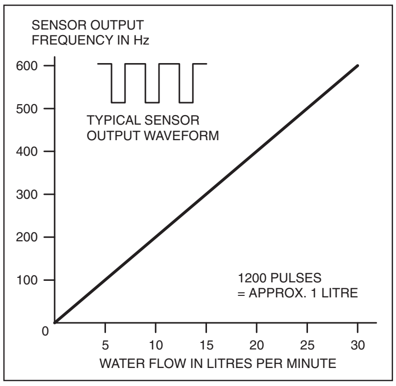


Fig.3. Sensor output pulse rates in relation to water flow.

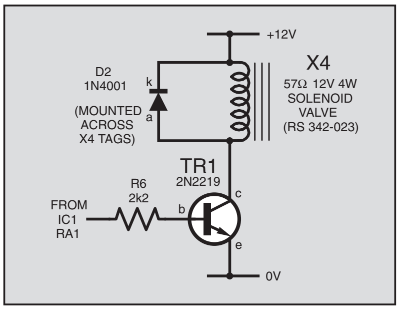


Fig.4. Optional water flow duration control circuit.

COMPONENTS

Approx. Cost Guidance Only £35
excl. case and solenoid

MONITORING UNIT

Resistors

R1	1k
R2 to R4	10k (3 off)
R5	220Ω

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometer

VR1	10k min. round preset

Capacitors

C1, C2	100n ceramic disc, 5mm pitch (2 off)
C3	22µ radial elect. 10V
C4, C5	10p ceramic disc, 5mm pitch

Semiconductors

D1	1N4148 signal diode
IC1	PIC16F84-4 microcontroller (pre-programmed)
IC2	78L05 +5V 100mA voltage regulator

Miscellaneous

S1 to S3	min. push-to-make switch (3 off)
S4	min s.p.d.t. toggle switch
SK1	3·5mm stereo jack socket (see text)
PL1	3·5mm stereo jack plug (see text)
TB1	10-way 1mm pin-header strip
TB2	4-way 1mm pin-header strip
X1	3·2768MHz crystal
X2	2-line 16-character (per line) alphanumeric l.c.d. module
X3	flow sensor module (RS 257-133 – see text)

Printed circuit board, available from the *EPE PCB Service*, code 317; plastic case, 150mm x 80mm x 50mm; 3-way sensor connecting cable, small diameter, length to suit application; power input socket to suit; 18-way d.i.l. socket; p.c.b. supports, self-adhesive (4 off); nuts and bolts to suit l.c.d. module (4 off); plumbing connectors to suit (see text); connecting wire; solder, etc.

FLOW CONTROL

Resistor

R6	2k2 0·25W 5% carbon film

Semiconductors

D2	1N4001 rectifier diode
TR1	2N2219 *npn* transistor (see text)

Miscellaneous

X4	flow control solenoid valve 12V d.c. 57Ω coil (RS 342-023 – see text)

Cable, plug and socket, plus plumbing connectors to suit (see text); connecting wire; solder etc.

SOLENOID VALVE

The optional facility which allows water flow to be switched on and off by the PIC is shown in Fig.4.

It consists of the solenoid valve, X4, and a controlling transistor, TR1. A high output level from PIC pin RA1 turns on the transistor via current limiting resistor R6. This causes the solenoid valve to turn on, allowing water to flow. When pin RA1 goes low, the valve is closed and water flow ceases.

The maximum flow rate for the valve is 17 litres per minute and its input water pressure must be between 0·2 and 10 bars (the author's domestic water pressure is about four bars).

Diode D2 is connected across the solenoid's coil to inhibit the generation of high voltage pulses (back-e.m.f.) at the moment of switching off the solenoid.

The solenoid requires a d.c. power supply of between 11·8V and 13·5V. It is nominally rated at 4W and has a coil resistance of 57Ω ±10 per cent. Typically, it will draw about 330mA.

A 2N2219 *npn* transistor is suggested for TR1 as this can switch a current of about 800mA. Any other similar transistor can be used instead. It is not in the least bit critical.

This control facility must only be used in conjunction with garden hose monitoring. It could cause damage to other water-fed equipment.

CONSTRUCTION

Printed circuit board (p.c.b.) component and track layout details are shown in Fig.5.

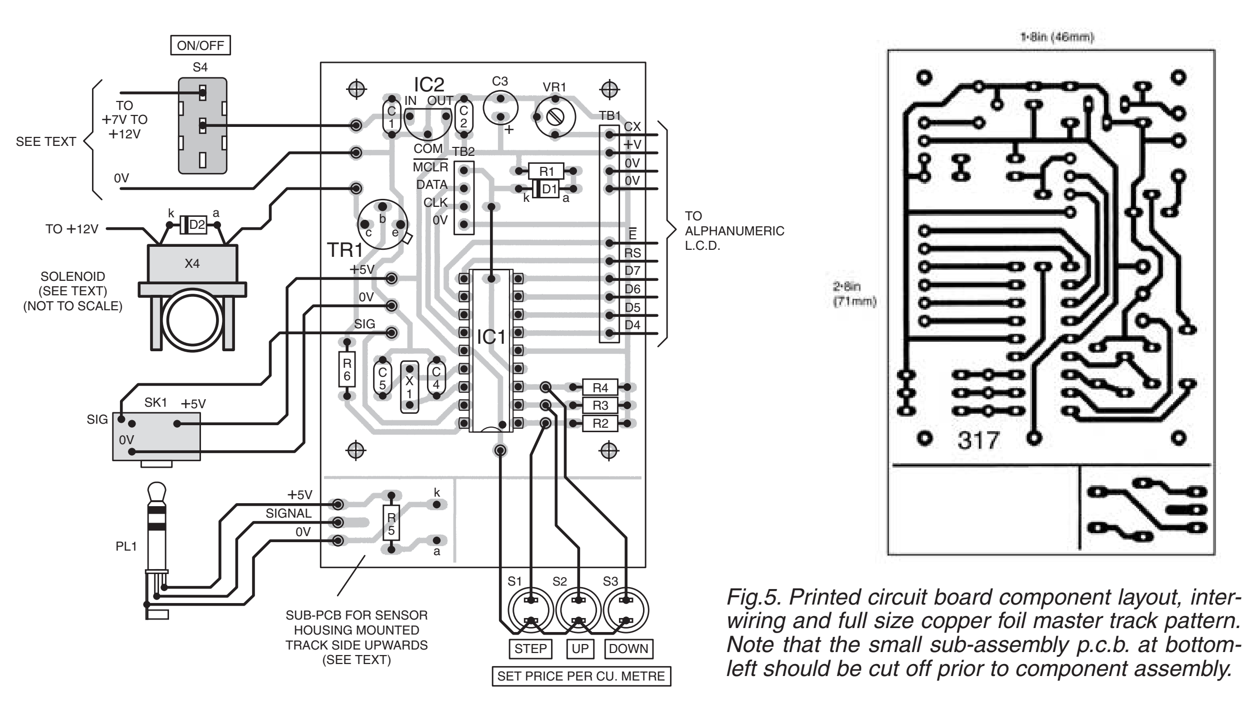
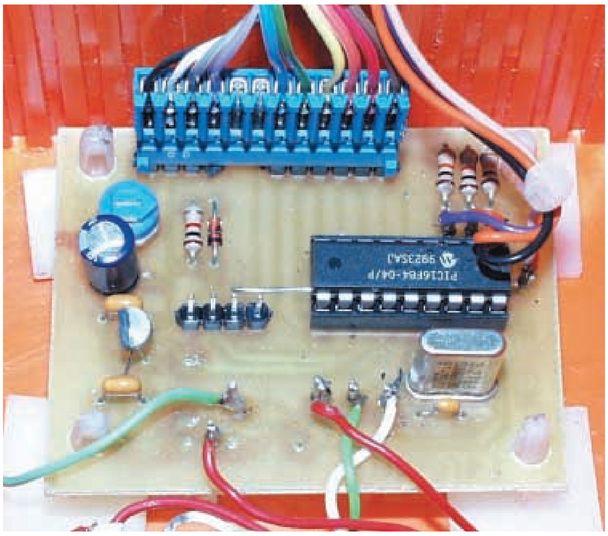
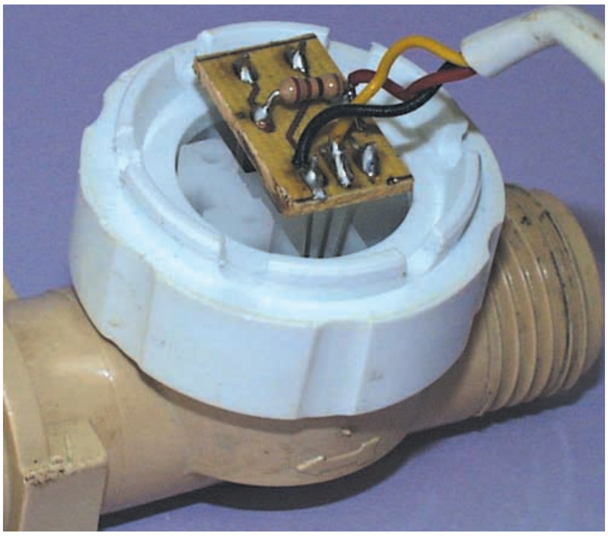


Fig.5. Printed circuit board component layout, interwiring and full size copper foil master track pattern. Note that the small sub-assembly p.c.b. at bottom-left should be cut off prior to component assembly.



Main p.c.b. in the prototype. The pin-header connector shown is optional and l.c.d. connections may be soldered if preferred.



Sub-assembly p.c.b. mounted inside the water flow sensor module.

This board is available from the *EPE PCB Service*, code 317.

At one corner of the p.c.b. is a small sub-assembly board which is for use with the water flow sensor. It should be carefully cut off before component assembly.

Assemble the main board in any component order you wish, but note that a link wire must be inserted before mounting the (*essential*) socket for IC1. Do not insert IC1 or the l.c.d. until you have checked that the output voltage from regulator IC2 is at +5V (within a few per cent).

The l.c.d. connections to the p.c.b. are, as usual, in the author's "standard" order. Connections to the l.c.d. itself could take one of two possible formats, as shown in Fig.6. The most likely is that on the left.

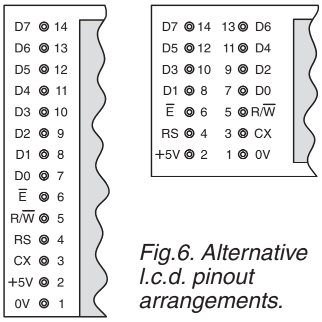


Fig.6. Alternative l.c.d. pinout arrangements.

A schematic drawing of the sensor housing is shown in Fig.7. Gently, but firmly, prise off the cap on the housing using a thin-bladed tool. Inside will be seen five rigid wires. Carefully push these into the holes of the small sub-p.c.b., which should be *trackside* upwards, and solder them in position.

Now solder resistor R5 to the *trackside*, having first pushed its trimmed leads through the holes (see photo).

The sensor, of course, will be outdoors and the control unit some distance away indoors. Solder a suitable length of 3-core cable to the board and solder plug PL1 to the other end.

Do not connect the sensor to the water supply or main p.c.b. yet.

CHECKING OUT

With the programmed PIC in place and the l.c.d. connected, switch on the power supply. Adjust l.c.d. preset VR1 until a reasonable display contrast is shown. At this time the information displayed will be "garbage", having been generated in relation to unknown values within the PIC's data EEPROM.

The first thing you need to do is to get some sensible data into the EEPROM. The process about to be described is that required whenever you wish to change the water price or flow duration, or to reset the cumulative values to zero.

Switch off the power supply, and wait a few moments to allow the capacitors to fully discharge. Now press switch S1 (Step) and hold it down while you again switch on the power. Once the display is again active, release S1.

On the display's top line should be seen the message "SET PERIOD" towards the right. At the left, the first and third digits could be anything (actually the l.c.d.'s interpretation of any ASCII value between 48 and 63). Digits 2, 4 and 5 should show *h* (for hours), *0* units of minutes, and *m* (for minutes)

On line two below this digit will be seen a flashing asterisk. This indicates the digit that can be changed, in this case the first digit.

Pressing S2 (Up) will cause the first digit's value to increment, rolling over to 0 after 9. The rate of change while the switch is pressed is about twice per second. Pressing S3 (Down) causes the value to decrement, rolling over to 9 following 0.

This digit sets the number of hours for which you want the water turned on once the unit is activated. Set it for zero at the moment.

To select the next digit, press switch S1 again to cause the asterisk to move under digit 3. This shows the tens of minutes for which the water should remain on. It too can be varied between 0 and 9 using S2 and S3. Try it, but return to 0 for now.

That completes the water-on duration setting. In this particular instance the duration has been set for zero. The PIC has been programmed to never turn off water if the value is zero.

For a non-zero value, the PIC monitors a clock routine which commences when the unit is powered and any value changes (if any) have been completed.

PRICE SETTING

Next the Water Company's cost per cubic metre value has to be entered. Press S1 again, causing the display to change.

The top line will now show the message "SET PRICE" at the left, and four random values plus a decimal point to the right. This asterisk will now be seen under the first random digit.

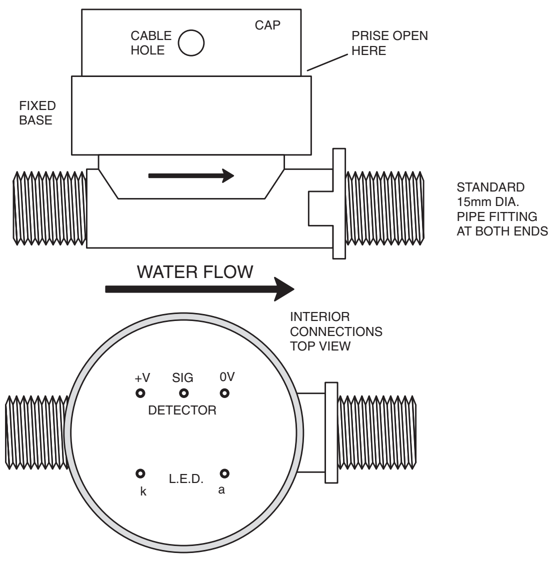


Fig.7. Schematic details of the water flow sensor module.

The righthand values show the price per cubic metre, in pence (or cents etc.) to the left of the decimal point, and tenths of a pence after it. The maximum value that can be set is 999·9 pence (or cents etc.) per cubic metre.

At the time of writing the author's Water Company charges 60·9 pence per cubic metre. The company actually shows the price on its invoices as having three decimal places. Such fine detail in this application seemed irrelevant and the last two digits of the Company's price are ignored. Remember that one cubic metre is 1000 litres, a lot of liquid! In this instance, one litre costs a mere 0·0609 pence (compare that to your petrol costs – or your bar bill!).

Again the digits can be changed using S2 and S3, with S1 causing the asterisk to step to the next digit. Refer to your last water bill and enter the cubic metre price shown.

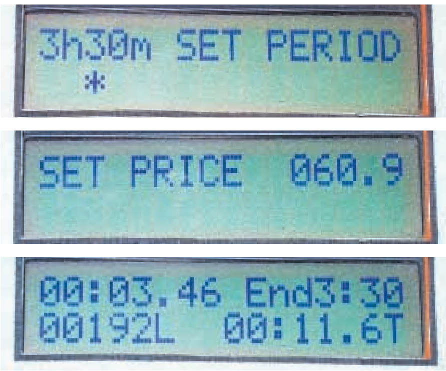
At the final digit position, the next press of S1 ends the value setting routine, storing the values in the data EEPROM for subsequent use and recall. They remain there until changed, even after the power has been switched off.

The confirmation word "STORED" briefly appears on the top line when the data has been stored. Then the monitoring commences, turning on the solenoid valve if in use.

RUN-MODE DISPLAY

The screen then shows its run-mode display, an hours-minutes-seconds count top left and the litres-consumed count bottom left, followed by letter L. Top right shows the word "End" plus the duration for which the water has been set to flow.

At the bottom right the cumulative cost of the litres used is shown, in the form "xx:yy.zT" where xx = pounds (or dollars etc.), yy = pence (or cents etc.) and z = tenths of a pence. Letter T simply means Total.



Example displays: Setting water flow duration period; setting price per cubic metre; during monitoring.

At present, only the clock value will be seen to be changing. There are no sensor pulses being input to affect the litres and cost values. These can be simulated, though, using a signal generator.

PULSE TESTING

Connect the output of a digital signal generator (0V/5V square wave) to the unit's Signal input point on the p.c.b. Set the frequency to around 1200Hz (the number of pulses per litre).

Power up the unit again and observe the litres count incrementing at roughly once per second. Varying the frequency will vary the litre rate. The total cost value will be seen to change in relation to this.

Restart the unit as described earlier. This time set the water-on period for 10 minutes. Repeatedly press S1 to bypass the digit settings for cost, and allow monitoring to restart.

It will be seen that the clock, litres count and cost have started from zero. This reset always occurs when the unit is powered up with S1 pressed. The function causes the cumulative flow and cost values to be reset and you can step past the preset duration and price values without changing them if you wish by using S1.

Observe the cumulative factors counting upwards again, until the clock reaches an elapsed time of 10 minutes. The PIC constantly monitors the clock in relation to the water-on duration set. When the two match, the message "FINISHED" is shown top right, monitoring stops, and port pin RA1 goes low, so shutting off the water solenoid if in use.

The litres count and cost values are automatically stored into the data EEPROM at this point. The software remains in this holding condition until power is switched off.

REPETITION

On next switch-on, the stored values are all recalled, but the clock value is always reset to zero. This allows watering to be started each time the unit is switched on and to continue for the same preset duration, day after day if required.

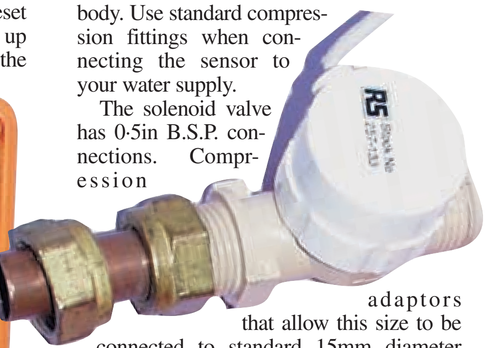
Note that the unit only goes into Reset mode if switch S1 is held pressed while power is being switched on. It otherwise goes straight into monitoring mode.

At any time during monitoring, you can store the current cumulative counts by pressing any of switches S1 to S3 and then to switch off manually before the preset duration ends. If you switch off without storing the data, the existing cumulative values will be lost and those stored previously will be recalled on next power-up.

PLUMBING

The water sensor has standard 15mm diameter plumbing fittings. It must be connected so that the water flows in the direction of the arrow moulded into its body. Use standard compression fittings when connecting the sensor to your water supply.

The solenoid valve has 0·5in B.S.P. connections. Compression



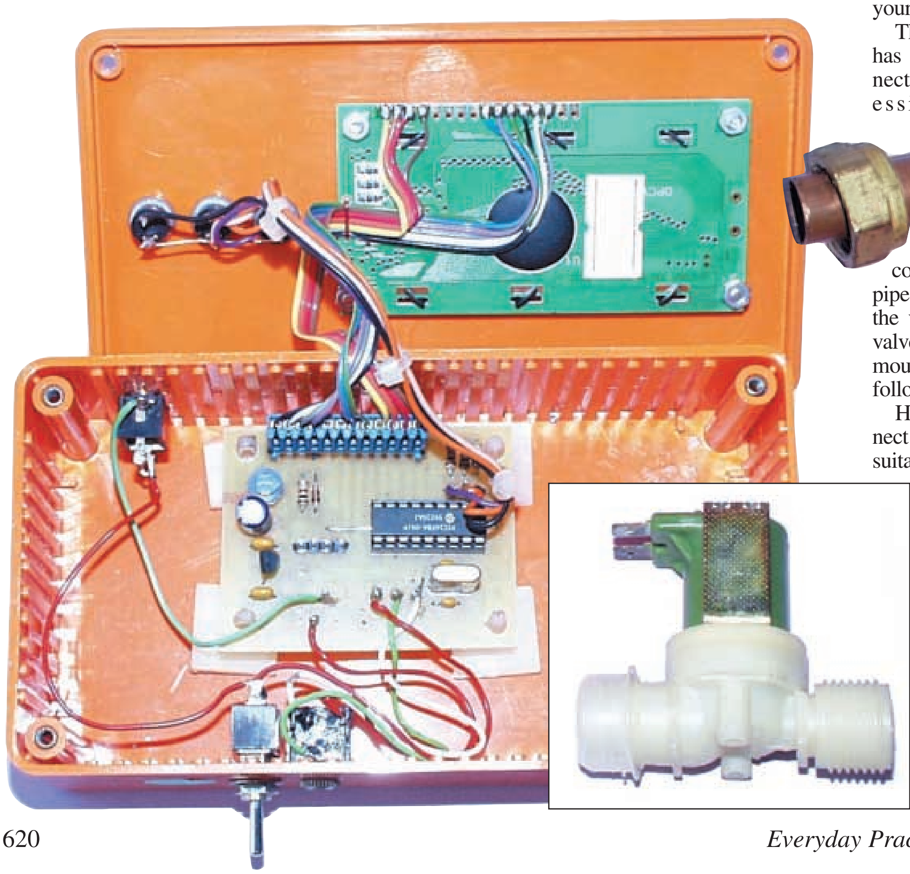
adaptors that allow this size to be connected to standard 15mm diameter pipes are available from the same source as the valve, or from plumbing retailers. The valve also has a water flow direction arrow moulded into its body and which must be followed.

Having "plumbed-up", electrically connect the solenoid to the control unit, via a suitable length of colour-coded cable plus its own plug and socket (not illustrated).

Alternatively, the entire system may be operated at 12V d.c., in which case it would be acceptable to connect the solenoid and water sensor to the unit via a single 4-core cable (+12V, 0V, signal, coil control), using a 4-pin plug and socket.

Solder diode D2 directly across the solenoid coil's terminals, ensuring the correct polarity. Wrap waterproof tape around the electrical connections.

The unit is now ready for use. □



New Technology Update

Not only do smaller i.c. packages reduce overall equipment sizes, but also help to reduce heat generation, reports Ian Poole.

COMPONENT packaging is a vitally important issue for electronics technology. It has been investigated in this column before (see May 2000). Whilst component packages may seem on the surface to be comparatively low tech when compared to the silicon that is mounted inside them, they are equally important, and surprisingly high tech.

It has been said that the package itself is not the limiting factor in terms of performance, but it can be considered that it enables the full performance to be realised. As a result, much development is invested by manufacturers to ensure that packaging technology keeps up with the improvements being made in the silicon itself.

These developments span the whole breadth of the semiconductor industry ranging from the simple discrete devices right up to the large high-speed processors.

Small Packages

There is a steady trend to reduce the size of packages. To many people the fundamental driver for this is to reduce the size of electronic printed circuit boards. By reducing the area covered by the components it should be possible to reduce the board area required. However, the size reduction does not bear a linear relationship to the reduction in component size. Track routing becomes more difficult and if the same printed circuit board design rules are adopted there is a diminishing return on using smaller components.

There are other benefits of using smaller components. The main one is the increase in performance. This can manifest itself in a number of ways. One is an increase in speed. This is brought about by the fact that lead lengths are smaller and levels of stray inductance (ESL – equivalent series inductance), and to a lesser extent capacitance, are much reduced.

There are also other advantages. Thermal resistance can be reduced with careful package design, again because distances are smaller. In some instances optimised devices are able to dissipate over 50 per cent more in a smaller package purely as a result of the package design. In fact, over the past few years power devices have shrunk in size to the extent where many engineers who have been in the business for some time wonder whether these new components can handle the stated power!

A further advantage for power devices is that smaller packages bring shorter lead lengths and this can assist in reducing the levels of R_{DS}(ON). A further reduction can be brought about by using multiple bond wires in the package. In many packages it is found that the internal bond wires contribute significantly to the overall value of the ON resistance. Again this assists in the power handling capacity of the device because it means that the power dissipation within the device package is reduced.

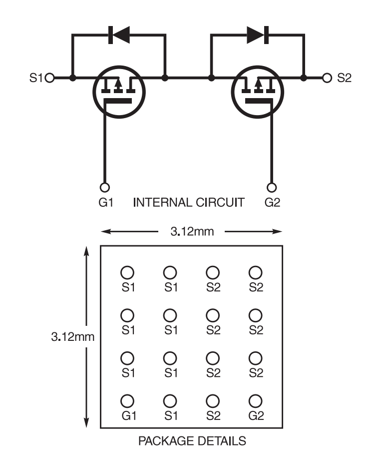


Fig.1. An example of a dual p-channel MOSFET in a chip scale package.

Other Aspects

Further improvements can be brought about by the current trend towards chip scale packages (CSP). These are particularly useful for power MOSFETs. Whilst they are not full scale integrated circuits in the traditional sense of the term, several components can be integrated onto a single chip. This has the advantage of saving a considerable amount of board space because only one package is needed instead of two or more.

One example of this is where a back-to-back MOS switch is encapsulated in a 16-bump CSP, as shown in Fig.1. This device is aimed at use in a battery pack to provide switching and protection. The chip scale package occupies only 3·2mm × 3·1mm and contains all the interconnections, whereas a traditional package would require connections between the internal drain and source.

Typically this might be contained in a TSSOP (thin shrink small outline package) measuring about 3mm × 6mm, but additional tracks would be required on the printed circuit board that would take up additional space.

Integrated Circuits

Not only are developments occurring in the discrete component arena but, as would be expected, there are many major initiatives being undertaken that will improve i.c. technology.

One of the major areas where problems are being encountered is with the interconnections to the chip. No longer can the pin assignments be made to conform to what is easiest for the chip designer. With speed considerations being critical, a balance has to be made to find the best overall solution for the chip and printed circuit board design. Often the more critical inputs and outputs are allocated to areas that are more accessible to the tracks on the boards. In this way interference, ringing and other associated issues can be controlled.

Leadless Packages

Thermal issues are again of great importance. With the massive levels of heat that are generated in many chips, it is imperative that all the thermal issues are fully addressed to ensure full performance and long term reliability.

One area of concern is associated with the thermal coefficients of expansion of the different materials used, particularly between silicon and board or substrate materials. With leaded components this was not a major concern because sufficient expansion could be taken up in the leads. However, with leadless packages the stress must be taken up in other areas.

To overcome this problem, Fairchild mounts its die onto a substrate that has an almost equivalent thermal coefficient of expansion to that of silicon. Wire bonds are then taken to the external pads and then the package is encapsulated using an organic material. Using this concept any strain occurs at the substrate/encapsulant interface and this affects neither the performance nor the reliability.

Undercover

With chips becoming considerably more complex, far greater numbers of interconnects are required. In some cases 1000 or more may be needed, and this creates enormous problems as the chips become "pad bound". To overcome this, pads are placed under the chip to enable connections to be brought out from anywhere under the chip itself. This relieves the problems caused by having to bring out the connections to external bond points near the edge of the chip.

By removing the limitation of connection pad placement to be on the perimeter of the chip, or at least near to the edge, chip designers gain a considerable amount of flexibility, both in terms of the design itself and the number of connections that can be made.

Making connections under the chip is accomplished by a process involving the use of conductive "bumps" under the die. These bumps connect to equivalent connections on the carrier which can then be routed as required.

News . . .

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

YEDA 2001

The Young Electronics Designer Awards (YEDA) were made on 6 July at the Science Museum in London, during a special celebration dinner attended by 220 guests, including prizewinners, parents, teachers, local dignitaries and members of the business community.

Martin Rosinski (16) of Ponteland Community High School, Ponteland, Newcastle upon Tyne, scooped both the The Duke of York's Award and First Prize in the Intermediate category for the second year running, with his rail axle safety assessment device. This tiny unit has already attracted the interest of Railtrack and other major international rail network operators. Martin's device has the potential to prevent tragic accidents occurring as the result of broken or buckled rails, by using sophisticated electronics.

The Duke's Award resulted in cheque for £1000 to be shared between Martin and his school, together with a crystal trophy to be retained for one year and a hand painted certificate signed by His Royal Highness, plus a DVD player courtesy of Philips Electronics UK Ltd. Martin's Intermediate Prize was £750 plus a YEDA Trophy.

Amongst the other winners were Johnny Will and Harry Mustard (both 14) of Murchiston School, Edinburgh. Their childproof lock for power tools was deemed to be the most commercially viable project which earned them and their school £1000. Johnny and Harry also won the Junior Category (under 15 years) with their design, receiving a further £500 and a YEDA trophy.

The IEE Award for the best new entrant to YEDA went to Michael Porton (16) of Fitzalan High School, Leckwith, Cardiff, again with £1000 to be shared by himself and his school. Also highly motivated by safety aspects was Tammy Crawford-Rolt (16) of St Margaret's Senior School, Midhurst, West Sussex, who invented a variable temperature alarm for use with cooking and won £150.

The YEDA competition is open to students between the ages of 12 to 25 in secondary schools, colleges and universities. It challenges young designers to produce a novel electronic device that meets an everyday need. The overall objective is for contestants to have fun putting their ideas into practice and in doing so discover the exciting opportunities which a career in the electronics, communications and IT industries can offer.

More information and the full list of winners and their designs can be obtained from The YEDA Trust, 60 Lower Street, Pulborough, West Sussex RH20 2BW. Tel: 01798 875559. Fax: 01798 873550. E-mail: yeda@cix.co.uk.

B.A.E.C. SEEKS AUTHORS

Some while ago we reported that the British Amateur Electronics Club was in need of authors. Seemingly the situation has not been resolved and recently received B.A.E.C. information states that "continued publication of the Newsletter is in doubt" through shortage of articles.

The Club requires articles telling members what you know, passing on information which you may have acquired in years of experience or recently acquired in college. Any electronics-related subject will be of interest.

If an adequate supply of articles is not forthcoming, the Club says that it will have no choice except to wind up. That would be a great shame for an organisation that has existed for many decades and provided help, advice, information and interest for many hobbyists.

If you have knowledge to share and can put more than two words together on paper, for goodness' sake write something for the Club and help its continued existence!

For more details about the Club contact George Burton, Editor and Chairman, 581 Fishponds Road, Fishponds, Bristol BS16 3AA. Tel: 0117 965 4800. E-mail: prontaprint.bristol@cableinet.co.uk. Mention *EPE* when contacting him.

Bowood Cat

Bowood Electronics have sent us their 28-page A4 mail-order catalogue. It includes batteries, telephone accessories, boxes, buzzers and connectors, along with passive components such as capacitors and resistors. There is a useful selection of p.c.b. manufacturing materials and a pretty substantial list of semiconductors. It appears to be well worthwhile having this "catalist" on your bookshelf.

For more information contact Bowood Electronics Ltd., Dept EPE, 7 Bakewell Road, Baslow, Derbyshire DE45 1RE. Tel/Fax: 01246 583777.

E-mail: sales@bowood-electronics.co.uk.
Web: **www.bowood-electronics.co.uk**.

ILP Disk Cat

ILP, who are renowned for their high-power amplifier modules, have sent us a disk containing the datasheets and prices for their HY2000 series. These cover eight modules ranging from HY2000 30W to HY2007 240W. They typically include their own power supply and heatsinks, can be used with 4Ω or 8Ω loads and have automatic adjustment of input sensitivity. Usefully, the data sheets include mounting dimensions and connection details.

A selection of ILP transformer prices is given, and the company have also advised us that they are a source for customised toroidal transformers as well. ILP have been manufacturers of hi-fi audio modules and toroidal transformers since 1971. Their catalogue is free.

For more information contact ILP Direct Ltd., Dept EPE, Spong Lane, Elmsted, Ashford, Kent TN25 5JU. Tel: 01233 750481. Fax: 01233 750578. E-mail: ilp@btinternet.com..

OPEN-SKY FOR HOME VIDEOS

Barry Fox reveals how you could become renowned as a film director, with your home movies.

Nothing on TV tonight? Don't want to pay for a subscription movie channel? Soon you will be able to surf the Internet with a satellite dish to watch someone's home movies.

The catchy idea of Personal Broadcasting comes from European satellite organisation Eutelsat. Trials of the service, called Open-Sky, started in Italy this July. If the trials are a success Eutelsat will switch on the rest of Europe, North Africa and the Middle East next year. Eutelsat hit on the idea because many people now use digital camcorders and computer editing equipment to craft mini-epics which they would love more people to see.

Europe's Digital Video Broadcasting standard was designed to deliver a stream of high quality video and audio, encoded to the MPEG-2 standard and travelling at many megabits per second. Home satellite receivers can only decode MPEG-2 signals.

Home computers access the Internet by phone line using the quite different Internet Protocol, which splits data into small packets running at tens or hundreds of kilobits a second. Even the new and much more powerful MPEG-4 compression standard cannot deliver clear video pictures and sound at these low speeds.

Open-Sky builds a bridge between the two very different technologies by slotting packets of MPEG-4 video into the DVB bitstream so they can be broadcast by satellite to a home dish. The dish is connected to a Windows PC which is fitted with a DVD-IP decoder card, costing around 200 Euros (£125). The card strips IP packets from the DVB video signal; a conventional Web browser, with Windows Media Player, then decodes the video. Data speeds of 256 or 512Kbps – far faster than available from conventional phone lines – are used to deliver full screen video.

Because the PC cannot transmit signals back to the satellite, a conventional low speed modem and phone line are used to access the Internet and trigger the high speed delivery of selected material. Eutelsat will soon invite home movie makers to upload their videos at slow speed to a central server, using a modem and phone line, with the invitation that anyone with a dish and PC can stream and watch them, like a TV programme.

Eutelsat privatised in July and the populist idea steals a march on rival satellite operator Astra which has so far promoted its Astra-Net data service mainly as a business tool, for staff training and shareholder conferences. Astra says it is also now moving into the consumer market, with satellite Internet transmission of the Italian version of TV programme *Big Brother*.

ULTIBOARD 2001

Adept Scientific has announced the latest release of the p.c.b. layout software from Electronics Workbench, Ultiboard 2001. It is said to give "unprecedented functionality at unmatched prices".

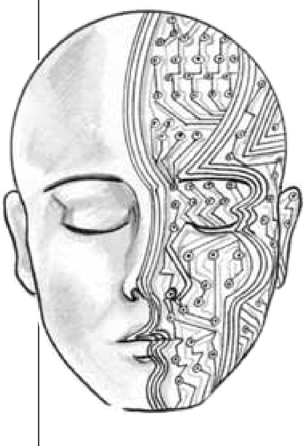
Ultiboard has been specifically redesigned after an extensive R&D programme in response to user feedback. The specific improvements includes a function known as Tight Integration with Software Capture, which works with Multisim, Electronics Workbench or Ulticap. There is a fully customizable user interface which makes it easier to view and navigate p.c.b. designs. A useful new facility is Push and Shove component placement, allowing users to place components in densely populated areas by automatically moving interfering parts aside.

For more information contact Adept Scientific plc, Dept EPE, Amor Way, Letchworth, Herts SG6 1ZA. Tel: 01462 480055. Fax: 01462 480213. E-mail: info@adeptscience.co.uk. Web: **www.adeptscience.co.uk**.

SMART METERS

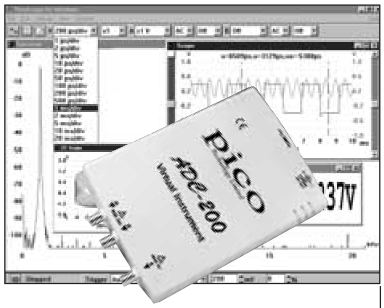
The Minister for E-commerce has announced that a new generation of "smart meters" could allow domestic users of electricity and gas to reduce their spending on fuel and connect homes to the Internet and cable TV.

"The Internet of the future will connect all kinds of services, not only PCs and TVs", says the Minister. "Technology already exits to allow telephone and TV services through utilities meters that could provide an Internet under the stairs".



INGENUITY UNLIMITED

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 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 full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited,* Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.)
Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE

- 50MSPS Dual Channel Storage Oscilloscope
- 25MHz Spectrum Analyser
- Multimeter • Frequency Meter
- Signal Generator

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 six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners-up.

Wien Bridge Audio Generator – Spot On

When testing audio amplifier and filter circuits, a source of high quality sinewaves is needed. The Wien Bridge oscillator is a suitable sinewave source, but its gain must be held at exactly three. Any less and the oscillation will die away, and any more and the oscillation amplitude will increase until the circuit clips the waveform to produce a square wave.

The usual method of stabilising the amplitude is to use a thermistor. Unfortunately, suitable devices are expensive, can be difficult to obtain and are temperature sensitive. It was, therefore, decided to try a different approach and use an automatic gain control (a.g.c.) loop to stabilise the oscillator, as shown in the circuit diagram of Fig. 1.

The op.amp IC1a is the oscillator proper. Positive feedback is provided through the Wien network comprising of the dual-ganged potentiometer, wired as a variable resistor, VR1a and VR1b, and the switched capacitor network (C1 to C8). The capacitors used came from an old, commercial signal generator, hence the odd values. Good quality, close tolerance (5% or better) capacitors are needed. The values specified cover the frequency range 5Hz to 50kHz.

Negative feedback is provided from pin 1 to pin 2 of IC1a. When the junction f.e.t. TR1 is biased off, the feedback resistors set the feedback at a value of 2·47. When TR1 is biased on, resistor R3 is in parallel with resistor R5 and the gain increases to 3·47. As the bias on the transistor changes it appears as a variable resistance. At the correct bias point a gain of exactly 3 will be achieved.

The circuitry around IC1c controls the j.f.e.t. bias. The oscillator output is rectified by the diode D1 and charges capacitor C9. The resultant negative voltage is amplified by IC1c and is applied to the gate (g) of TR1.

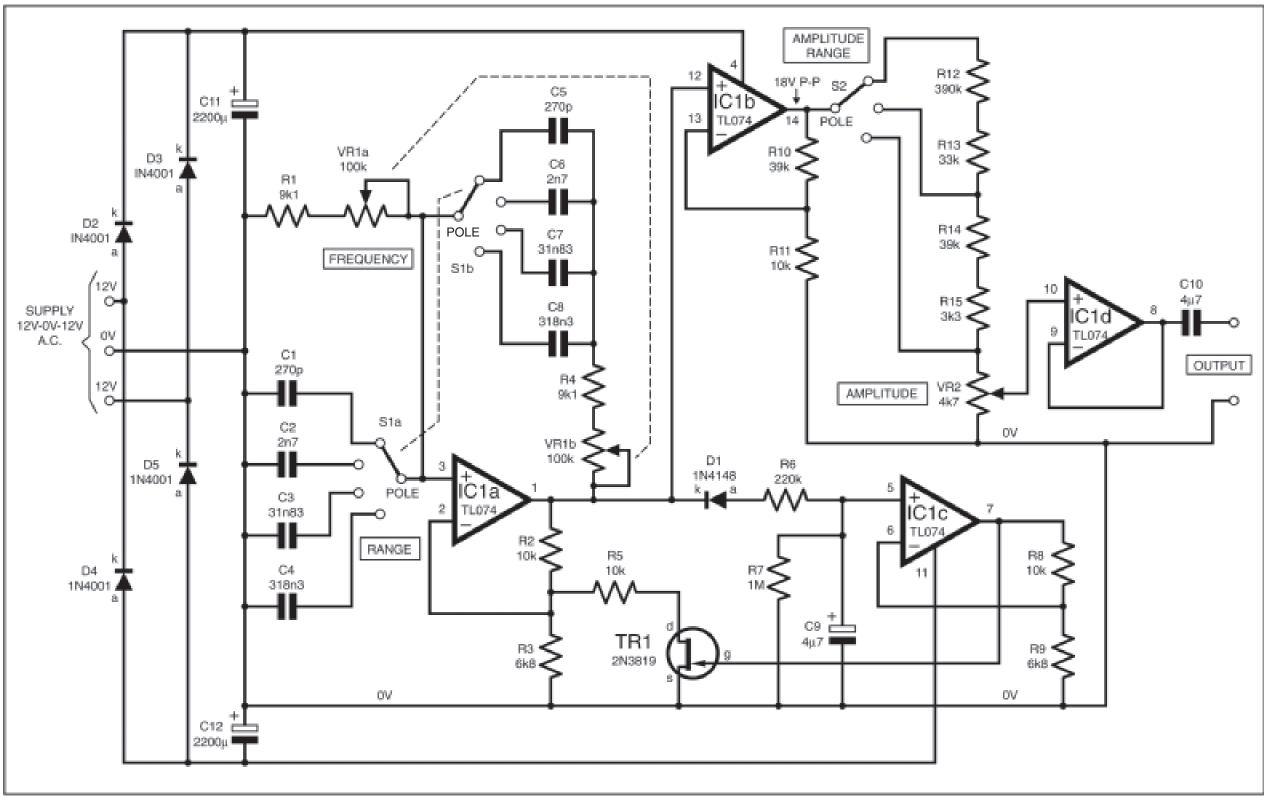


Fig.1. Circuit diagram for the Wien Bridge Audio Generator. Note capacitor C10 should be a non-polarised type.

Note the long time constants for charging and discharging capacitor C9: this stops the a.g.c. circuit from trying to follow the waveform and ensures any amplitude variations take place very slowly. It also means the oscillator takes about 15 seconds to settle down on start up but this is a small price to pay.

The sinewave output is amplified by 1C1b to approximately 18V peak-to-peak and then applied to the attenuator selected by switch S2 which gives 1, 10, 100 attenuation steps while the Amplitude potentiometer VR2 allows fine adjustment of the output level. Op.amp IC1d buffers the attenuator output and feeds the output terminals via a non-polarised d.c. blocking capacitor C10.

The author's circuit shares a ±12V d.c. regulated supply with several other items of test gear. The bridge rectifier, D2 to D5, and smoothing capacitors C11 and C12 shown are present on all the test items to prevent interference from being carried along the supply lines.

There is no reason why the unit should not have its own internal power supply but the power circuits must be kept well away from the signal circuits to prevent pickup of hum.

Paul Fellingham, Brighton, East Sussex.

INGENUITY UNLIMITED

BE INTERACTIVE

IU is *your* forum where you can offer other readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!

Precision Stereo Volume Control – Well Balanced

WHILST working on a hi-fi preamplifier project, the subject of potentiometers used as variable resistors for volume control arose. The specifications of available dual potentiometers were a bit disappointing for my application. The "gang error", the difference in level from each track resistance, was in the region of 2dB to 3dB (26% to 41%), which is unusable in a hi-fi application without a balance control.

For audio applications, variable resistors with a log resistance profile are required. This is hard to achieve in manufacture, so generally the log profile is made up from two or more linear profiles. This means that log conformance is not very good, and this is essentially the reason behind the poor gang error.

To obtain true balance from our hi-fi systems, it seems necessary to compensate by fiddling with the balance control every time the volume control is changed – not very practical. For my project I decided to use a ganged pair of 12-way switches to make my own variable resistor in the circuit of Fig.2.

The log conformance of this arrangement is better than 0·2dB and the gang error comes down to the tolerance of the resistors used. The overall value of the resistance is 47k and the step size is 4dB.

Duncan Boyd, Blackburn, W. Lothian.

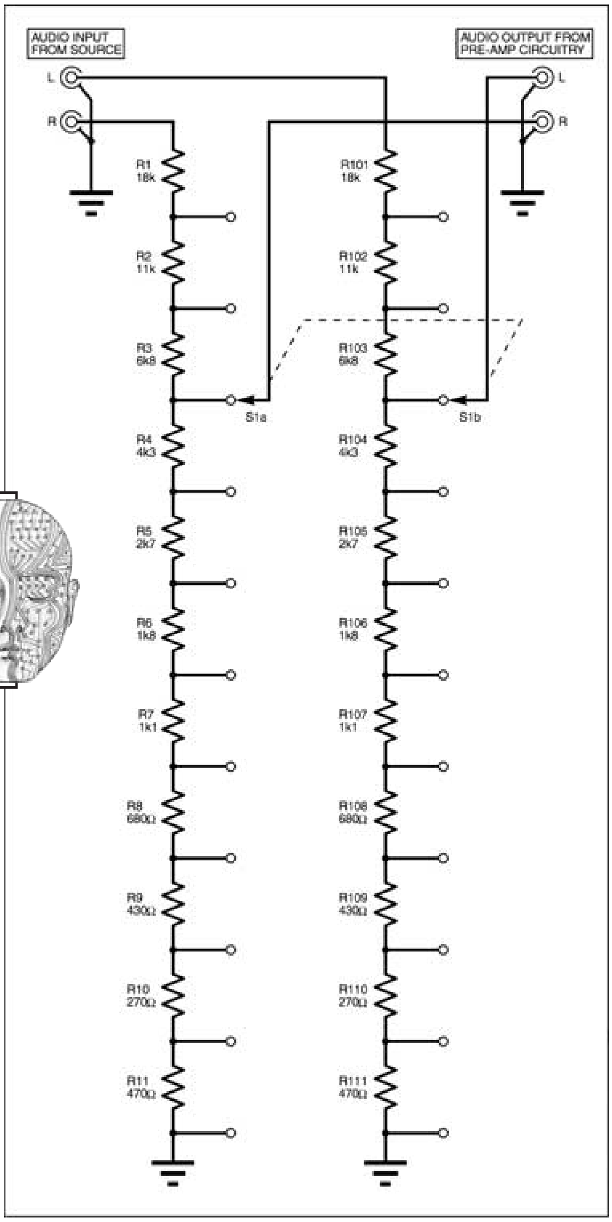
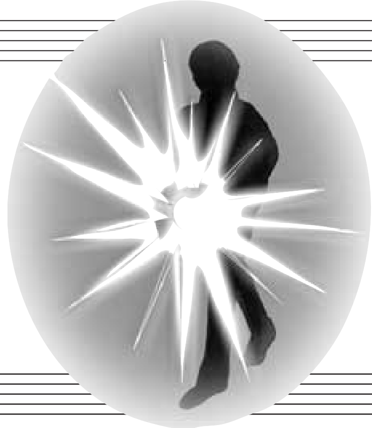


Fig.2. Circuit diagram for a Precision Stereo Volume Control.

Constructional Project

L.E.D. SUPER TORCHES



ANDY FLIND

Two brilliant ways of lightening your darkness – one of them really "state-of-the-art"!

THE idea for the first of these two torches took hold last summer whilst the author was contemplating a camping trip to Scotland. The Scottish weather and insect life can lead to long evenings confined to the tent (especially if the campsite doesn't have a bar!) so it was felt that an economical reading light might prove useful.

The first design was put together using parts which happened to be available in the workshop. Many readers will have similar components to hand, with the possible exception of the very bright red l.e.d.s which were left over from the construction of goggles for a "Mind Machine" project.

The resulting torch subsequently proved very useful as some unpleasant weather was indeed encountered north of the border. Readers acquainted with the famous Scottish midge will know how swarms of these can also prevent any kind of outdoor activity, and the ability to read for long periods without incurring heavy battery replacement expenses was well worth the constructional effort.

HI-TECH UPGRADE

On return it was felt that the torch might make a useful constructional project. However, *EPE*, as we all know, is right at the cutting edge of technology and our Editor indicated that it would only be acceptable if it used the latest and brightest white l.e.d.s.

Unfortunately this was not just a case of replacing the original ones as the new high intensity white types exhibit around twice the forward voltage of the familiar red ones and required the development of a circuit capable of handling this.

The resulting torch using white l.e.d.s is impressive though, as it really is extraordinarily bright for l.e.d.s and with three brilliant sources of cold, bluish-white light it looks like no other torch currently on the market. It definitely has novelty value, as well as being very useful.

However, it is more expensive to construct and slightly more difficult to test if problems are encountered following construction, so it would seem that both designs have applications. Because of this it was decided to present both versions so prospective constructors can make a choice.

RED L.E.D.

The Red L.E.D. Torch is relatively cheap and simple to construct using inexpensive l.e.d.s and semiconductors. The circuit is easy to follow and faults can be traced and cured readily. The red light may be more pleasing to some users as it has a "warmth" which is lacking in the white version.

It's actually better as a reading light since the pure red light heightens the apparent contrast between black print and a white page. Although not so bright as the white version it is more than sufficient for many purposes.

Finally, for those who like to listen to shortwave radios in bed, it doesn't produce any r.f. (radio frequency) noise. The white l.e.d. version does to a small extent, for reasons that will be explained. One small disadvantage is that it can be difficult to distinguish colours with the pure red light. Red text on a white page, for example, is practically invisible.

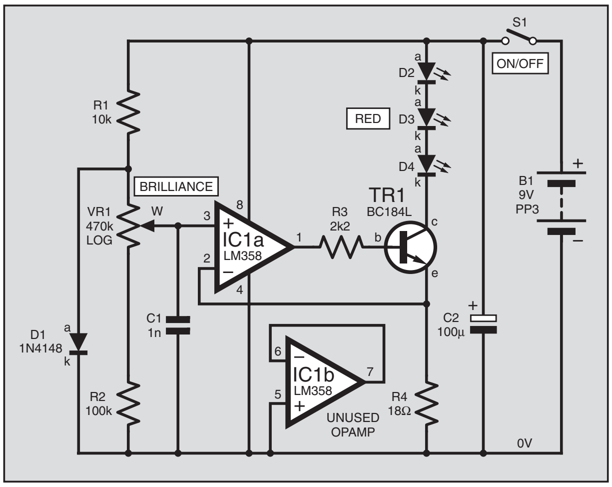


Fig.1. Full circuit diagram for the Red L.E.D. Torch.

RED CIRCUIT

The circuit diagram for the Red L.E.D. Torch is shown in Fig.1. In principle, it is simply an adjustable constant current circuit driving the three l.e.d.s, D2, D3 and D4 in series. Resistor R1 and diode D1 place a constant voltage of about 0·6V, the forward voltage drop of D1, across the "brilliance" control VR1 and resistor R2, which sets the minimum output.

Op.amp IC1a drives transistor TR1 until the voltage from the wiper of VR1 appears at TR1's emitter, causing a corresponding current to flow through the emitter resistor R4. Nearly all of this current is drawn from TR1's collector, passing through the three l.e.d.s on the way, so the current through these is effectively set by the control voltage from VR1.

Since the eye, like the ear, has a logarithmic response to stimulus intensity VR1 is a “log law” type.

An LM358 op.amp is used for IC1a in this circuit since its output voltage ranges right down to the negative rail. Many op.amps cannot go far enough in this direction to be used for directly controlling a transistor in the manner used here. The LM358 actually contains two op.amps, of which only one is used by this circuit.

The l.e.d.s have a typical forward voltage of less than 2V, usually about 1·7V so battery B1 will operate the circuit until its output drops to around 6V to 7V, by which time replacement is usually advisable anyway to avoid leakage.

An alkaline PP3 battery has a typical capacity of around 550mAh (mA-hours), so the full output current of about 35mA consumed by this circuit means that it will operate for about fifteen hours. At the other end of the scale it is perfectly possible to read by it with a current of less than 10mA, when the battery should last for over fifty hours!

Many older readers will remember childhood longings for a torch with performance like this for reading beneath the bedclothes!

HARDWARE CONSIDERATIONS

The general layout of this version of the torch can be seen from the photographs. The case used is not the cheapest available but it has the advantage of being compact, with a separate battery compartment having a snap-on cover and a recessed front panel which provides useful protection for the clear l.e.d. lenses.

Two small p.c.b.s were made to fit into the internal slots provided. One of these contains the circuit whilst the other provides mounting for the l.e.d.s and the brilliance control VR1, together with on-off switch S1. These boards are available from the *EPE PCB Service*, codes 313 (Main Red) and 314 (Display Red).

The boards should first be fitted temporarily to the case and trimmed with a file if necessary until the case fits neatly together over them.

The front panel should be drilled for the l.e.d.s and the shaft of VR1 using the template shown in Fig.2. The leads of the l.e.d.s used in the prototype were long

COMPONENTS

RED L.E.D. TORCH

Resistors

R1	10k
R2	100k
R3	2k2
R4	18Ω

All 0·6W 1% metal film.

See SHOP TALK page

Potentiometer

VR1	470k rotary carbon, with switch, log

Capacitors

C1	1n ceramic, resin-dipped
C2	100µ radial elect. 25V

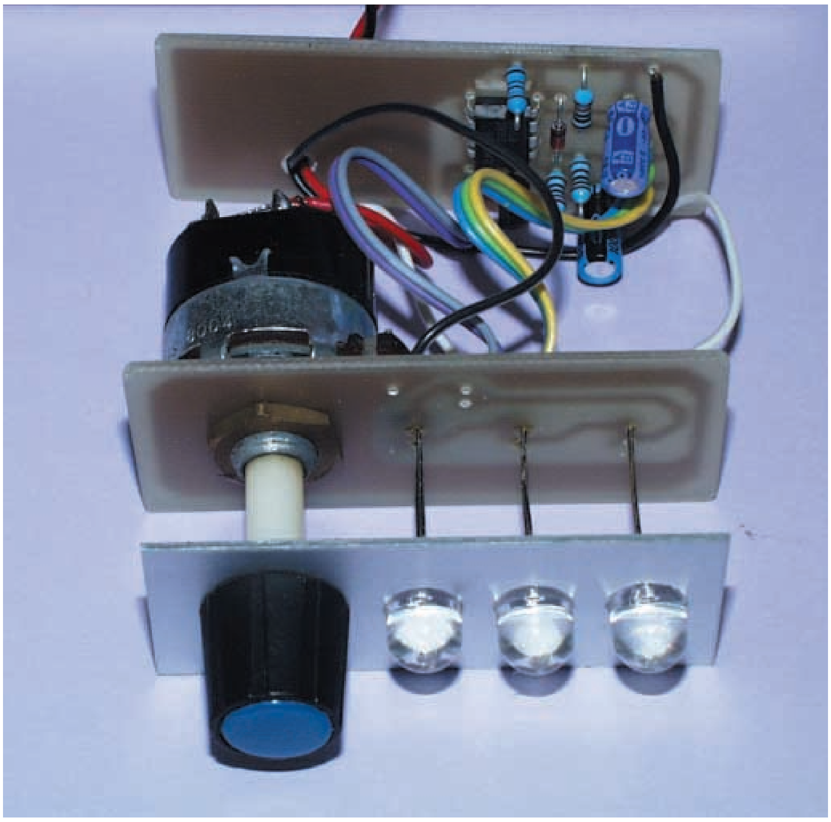
Semiconductors

D1	1N4148 signal diode
D2 to D4	ultrabright 8mm red l.e.d. (3 off)
TR1	BC184L *npn* silicon transistor
IC1	LM358 dual op.amp

Miscellaneous

Printed circuit boards, available from the *EPE PCB Service,* codes 313 (Main Red) and 314 (Display Red); 8-pin d.i.l. socket; PP3 battery connector; control knob, 15mm diameter; plastic case, 114mm x 72mm x 33mm with integral battery compartment; connecting wire; solder, etc.

Approx. Cost Guidance Only **£11** *excluding case.*



The “sandwich” of p.c.b.s and front panel removed from the case showing the method of mounting the l.e.d.s by using the full length of their leads.

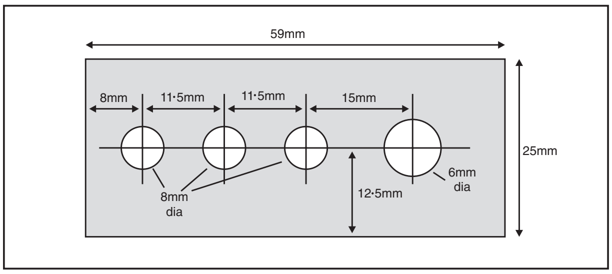
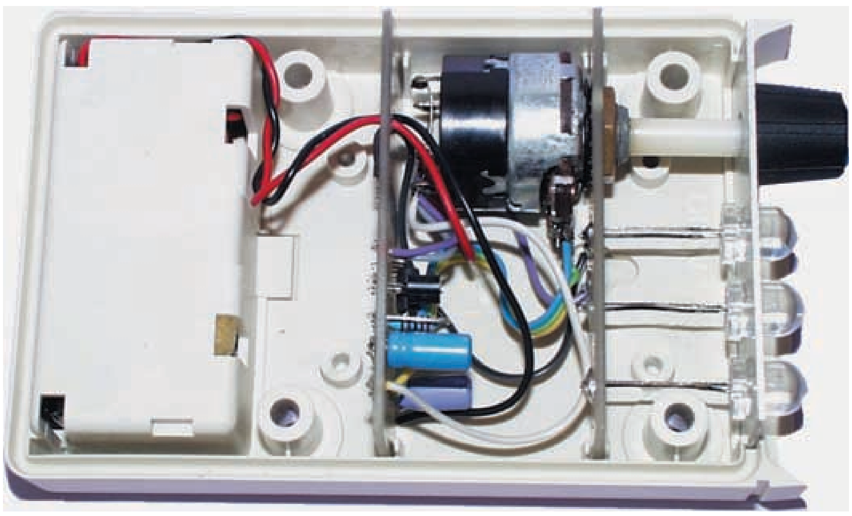


Fig.2 (right). Front panel drilling template, with dimensions.

(Below) The two p.c.b.s slotted into their guides.



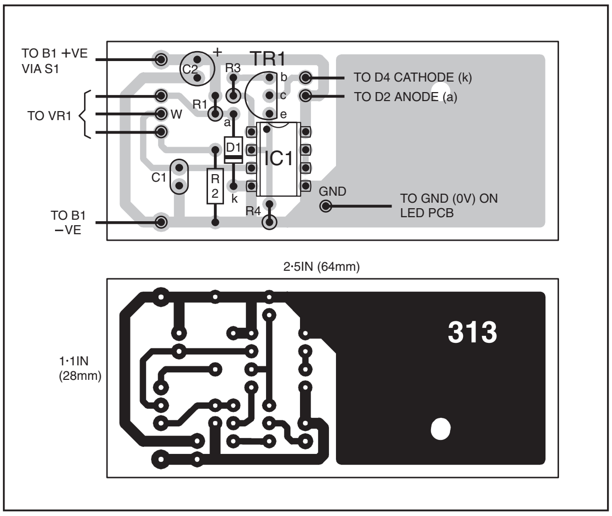


Fig.3. Red L.E.D. Torch main p.c.b. component layout and full-size copper foil master.

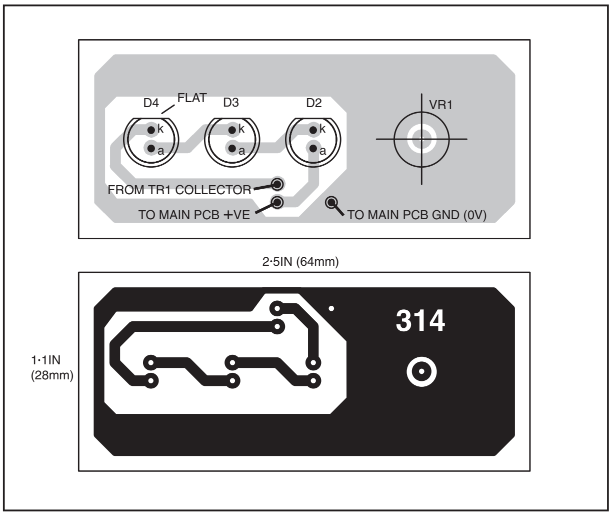
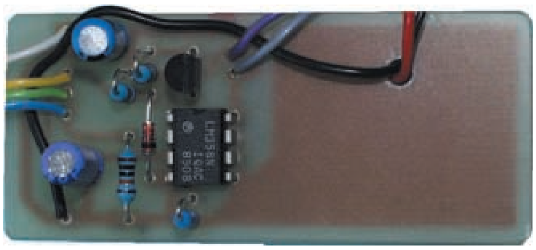


Fig.4. Red L.E.D. Display board component layout and copper foil master.

enough to extend back to the p.c.b. behind them so this was used as their mounting. If this is not the case, they can be glued to the panel and their connections made locally as shown for the second, white version of the torch.



Completed circuit board for the Red. L.E.D. Torch.

CONSTRUCTION

Most of the remaining components for this project are fitted to the p.c.b. as shown in Fig.3. There should be no problems in assembling this little circuit, but it should be noted that three of the resistors, R1, R3 and R4, are mounted in a vertical manner to save space. An 8-pin dual-in-line socket is recommended for IC1.

The method of fitting the three l.e.d.s D2, D3 and D4 is shown in Fig.4. It is useful to place the l.e.d. board and front panel into the case to hold the l.e.d.s in place for soldering, allowing them to project adequately through the case holes.

Connections between the various parts are shown in Fig.5. A hole in the main p.c.b. allows leads to be passed through it where necessary.

Testing should be just a matter of connecting a supply and checking that everything works, though if problems are encountered it should be simple enough to find and rectify them with a meter. If the l.e.d.s fail to light they can be checked by driving them directly in series from the battery using a 220 ohms resistor to limit the current to a safe value.

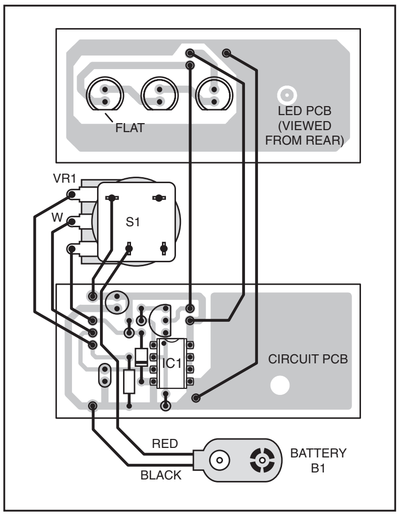


Fig.5. Interwiring between the p.c.b.s and the brightness control.

WHITE L.E.D. SUPER TORCH

A bright idea for lighting your way at night

WHITE L.E.D.S

THE NEW white l.e.d.s operate in a different way to the older red, yellow and green ones that have been around for some time. They are not a mixture of colours to obtain white as might at first be thought. Instead they consist of very high intensity blue l.e.d.s backed by a phosphor which glows brilliantly white under the stimulation of the intense blue light.

The resulting output is very bright for an l.e.d., in fact it's quite painful to look directly into one of these devices at full power, but it's a very "cold" light with a high blue content, unlike the warmer colour of a conventional white filament lamp. These l.e.d.s have a typical forward voltage of about 4V, around twice that of a red type.

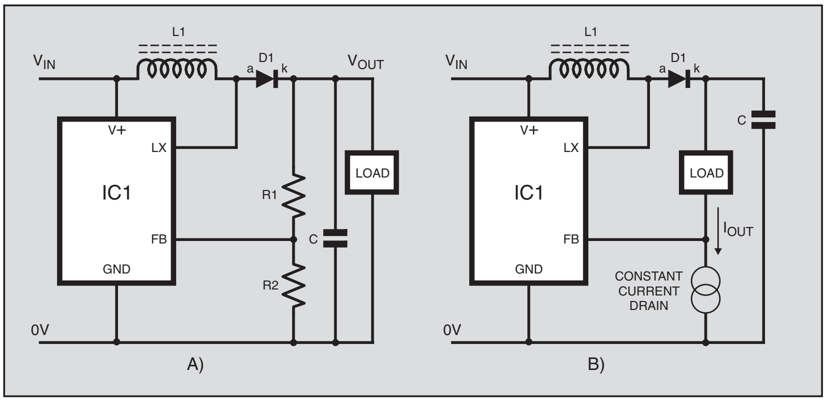


Fig.6. Operating principle of the White L.E.D. Super Torch circuit.

It was decided to retain the 9V PP3 type battery for this project as it fits easily into the available battery compartment. However, the 4V forward voltage of the white l.e.d.s is an awkward value for a 9V supply as one l.e.d. would be very inefficient. More than half the power used would be wasted in the current limiting circuit whilst two in series would lead to battery replacement at over 8V, which is also unacceptable. In any case, three l.e.d.s were preferred as in the red l.e.d. version.

SWITCH-MODE SOLUTION

The solution adopted was the use of a switch-mode inverter to raise the supply voltage, and by ingenious design it is possible to control the l.e.d. current and have the voltage adjust automatically to whatever is required by them.

The principle for this is shown in Fig.6. In Fig.6a, the usual way of using an adjustable step-up switch-mode converter is shown.

The inverter works by first switching the LX terminal to ground so that a current from V_{in} to ground builds up through the inductor L1. Then the LX terminal is made open circuit. Current attempts to continue flowing through L1 but now has to take the path through diode D1 to charge capacitor C.

This tendency of the inductor current to keep flowing when LX is turned off can lead to a high voltage developing across L1, which explains how the output voltage can become higher than the supply voltage. If LX switching continues unchecked and there is no load on the output, the voltage across C will simply increase until something breaks down, usually the internal transistor behind LX in the i.c.!

Control of the output voltage is therefore essential and is usually achieved by taking a proportion of the output to a feedback terminal (FB) through a resistive potential divider, shown here as R1 and R2. This is compared with an internal reference voltage, and when it exceeds this, the operation of LX is halted, thereby maintaining the output to a voltage set by the values of the two resistors.

VARIABLE POWER

In Fig.6b the circuit is used in a slightly different manner. The load is placed between the output and the feedback terminal, and a constant current is drawn from this terminal to ground. To maintain the feedback terminal at the internal reference voltage, an identical current must flow through the load, and the voltage across the load will automatically adjust to whatever is required to achieve this. This is the principle used by this project.

In the full circuit diagram of the White L.E.D. Super Torch is shown in Fig.7, the switch-mode device is a Maxim MAX761. This is a CMOS device with a very low operating current which accepts a wide range of inductors for L1, making it ideal for battery operated projects.

Inductor L1, a miniature ferrite type, and diode D1 are the voltage-raising components. D1 is a high-speed Schottky type as the long reverse recovery time of the more common 1N4000 series makes them virtually useless for this circuit. A 1N4148 worked quite happily during development but the 1N5817 is the type recommended in the MAX761 data sheet and is inexpensive.

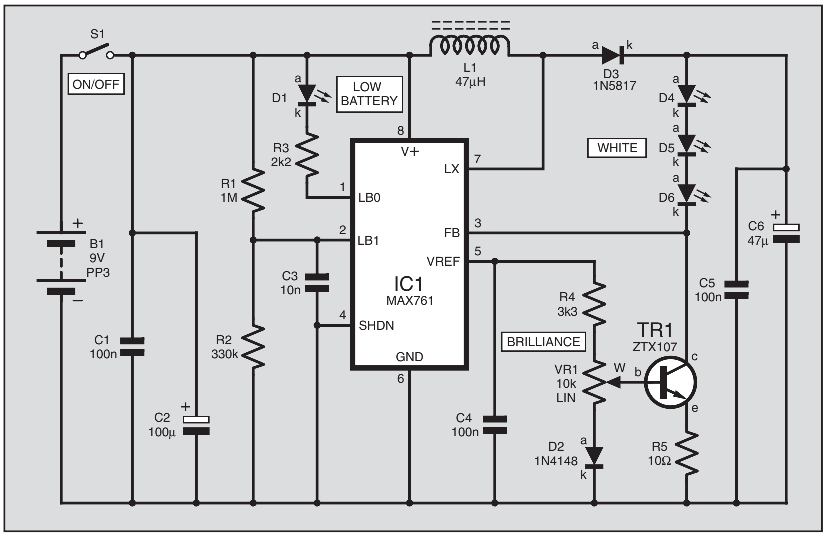


Fig.7. Complete circuit diagram for the White L.E.D. Super Torch.

The output current flows through l.e.d.s D4, D5 and D6 to the feedback terminal of IC1, and then to ground through a current controlling circuit built around transistor TR1 and associated components. This takes a reference of about 1·5V, which is conveniently provided by IC1, and applies it to the base of TR1 through the brilliance control VR1.

Diode D2 compensates for the base-emitter voltage drop of the transistor so that most of the voltage applied from VR1 is developed at the emitter and hence across resistor R5. As with the previous circuit, the current flowing through this resistor is now voltage-controlled and is drawn from the collector and so through the l.e.d.s.

ESSENTIAL NON-LINEARITY

The necessary non-linearity of the control is provided in a slightly different way in this circuit. A linear component is used for VR1, but the base current taken by transistor TR1 leads to non-linearity of the control action as the output current is increased, since it causes a drop in the voltage across VR1.

In practice the value of R4 should be chosen to provide a maximum current output of about 30mA, but the value of 3k3 shown should normally prove to be about right.

This circuit can actually operate from supplies down to about 3V, by which time the average PP3 may be expected to be leaking to some degree, so a low-battery indicator is essential. Fortunately the MAX761 also provides a facility for this. A voltage on pin 2, LB1, is compared with the internal reference and when it falls below this the output LB0 from pin 1 can be used to turn on an l.e.d.

With the values of R1 and R2 shown, this occurs when the supply drops to about 6V, illuminating D1, a low-current red l.e.d.

In comparison with the red version of the torch, this is a more complex circuit. Because it turns current on and off at high frequency through an inductor it generates a small amount of r.f. noise. This is not detectable at ranges of more than a couple of metres at most, but users planning to use it whilst operating sensitive radio equipment should be aware of this effect.

COMPONENTS

WHITE L.E.D. TORCH

See SHOP TALK page

Resistors

R1	1M
R2	330k
R3	2k2
R4	3k3
R5	10Ω

All 0·6W 1% metal film.

Potentiometer

VR1	10k rotary carbon, with switch, lin

Capacitors

C1, C4, C5	100n ceramic, resin-dipped (3 off)
C2	100µ radial elect. 25V
C3	10n ceramic, resin-dipped
C6	47µ radial elect. 25V

Semiconductors

D1	3mm red l.e.d., low current
D2	1N4148 signal diode
D3	1N5817 Schottky diode
D4 to D6	5mm extreme brightness white l.e.d. (3 off)
TR1	ZTX107 *npn* transistor
IC1	MAX761 switch-mode voltage converter

Miscellaneous

L1	47µH ferrite bobbin choke

Printed circuit board, available from the *EPE PCB Service*, code 315 (White L.E.D.); 8-pin d.i.l. socket; PP3 battery connector; control knob, 15mm diameter; plastic case, 114mm x 72mm x 33mm, with integral battery compartment; l.e.d. mounting plate (see text); connecting wire; solder, etc.

Approx. Cost Guidance Only **£23** *excluding case.*

Front panel layout
of the White L.E.D. Torch.

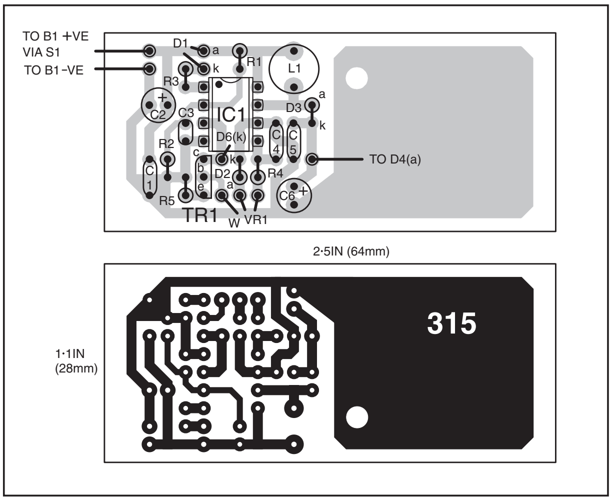
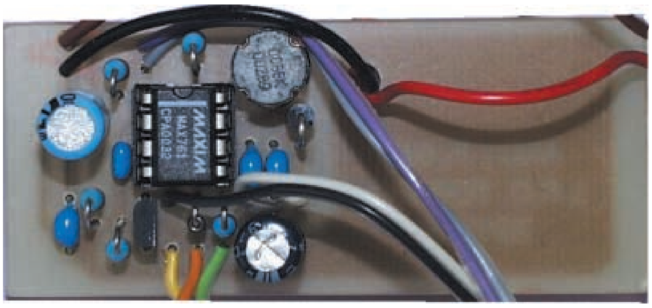


Fig.8. White L.E.D. Torch component layout and foil master.



Components mounted on the white l.e.d. circuit board.

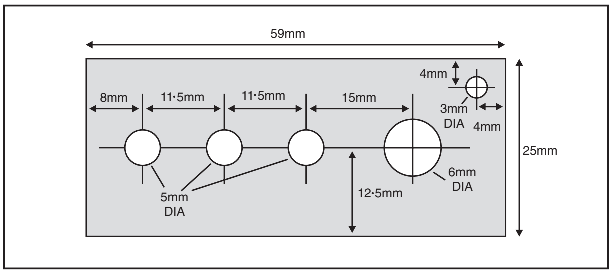


Fig.9. Front panel drilling template, with dimensions.

COLD BRILLIANCE

The light produced is somewhat cold in nature, as it contains a lot of blue light. The clear lens casing tends to separate the colours slightly, so that a circle of bluish light can sometimes be seen in the output beam.

The current drain depends on the supply voltage as IC1 draws more current to supply the output as the input voltage falls. However, at full power it takes about 50mA, so an alkaline PP3 should manage over ten hours at this setting. It is possible to read with the torch quite comfortably at supply currents of little more than 10mA, making for a very long battery life.

The torch is much brighter than the red version and it really would be possible to walk along a rural footpath at night with it, and it would be far more economical to run than a conventional torch. Unlike the red version, colours are clearly visible in its light.

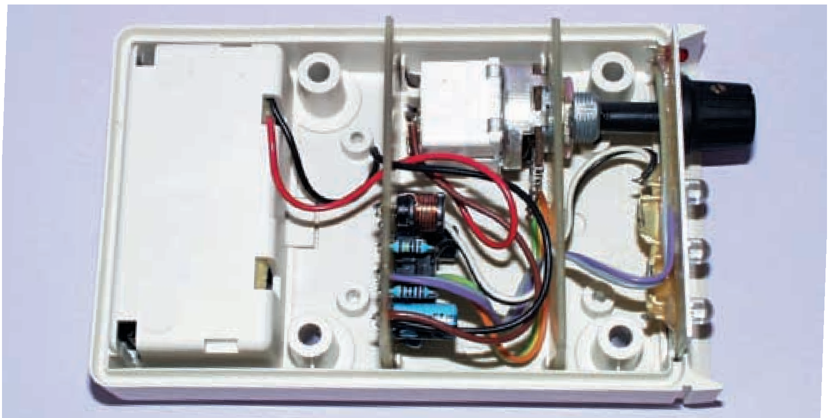
Finally, white l.e.d.s are still "state-of-the-art" so many people have not actually seen one and are usually astonished by their brilliance. This is the version to build if you want to impress your friends!

CONSTRUCTION

The printed circuit board for this version is also available from the *EPE PCB Service*, code 315.

Once again, the board should be checked for a fit in the case first, and adjusted by filing the edges if necessary.

Following this all the components can be fitted as shown in Fig.8. The board is rather compact, with all the axial-leaded resistors and diodes mounted vertically to save space, so some care will be needed in assembly. An 8-pin d.i.l. socket should be used for IC1.



Completed unit showing the internal layout of the torch.

Testing should be carried out with care since if it is not correctly loaded on power up, the output voltage may exceed the rating for the output transistor "behind" IC1 LX and cause damage. It is suggested that the board is tested with a 330 ohms resistor in place of the l.e.d.s.

The supply current should vary between 2mA and 45mA depending on the setting of VR1, and the voltage across the test resistor which, unlike the l.e.d.s, is directly dependant on the current, will vary from 0V to about 10·25V.

A second p.c.b. is not used in this project as the l.e.d. leads were not long enough. A spare piece of fibreglass p.c.b. material was used for mounting the brilliance control VR1, but a piece of aluminium sheet would do as well. A hole should be drilled in this for the wires to the l.e.d.s to pass through from the circuit p.c.b.

Once again the front panel was drilled to take the shaft of VR1 and the l.e.d.s, but in

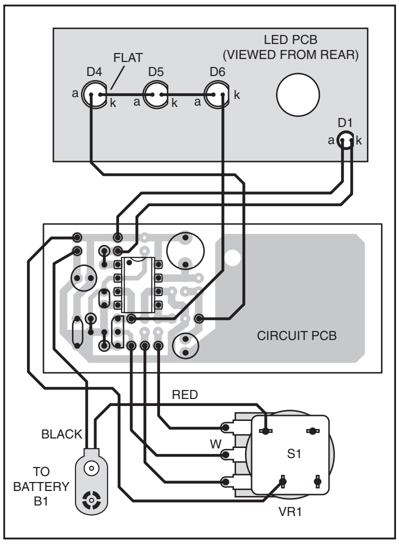


Fig.10. Interwiring details for the White L.E.D. Super Torch.

this version there is also a 3mm red l.e.d. for the low battery indication. This is placed in a corner by the control, away from the main l.e.d.s, to make it more visible. A template that can be used for drilling the panel is given in Fig.9.

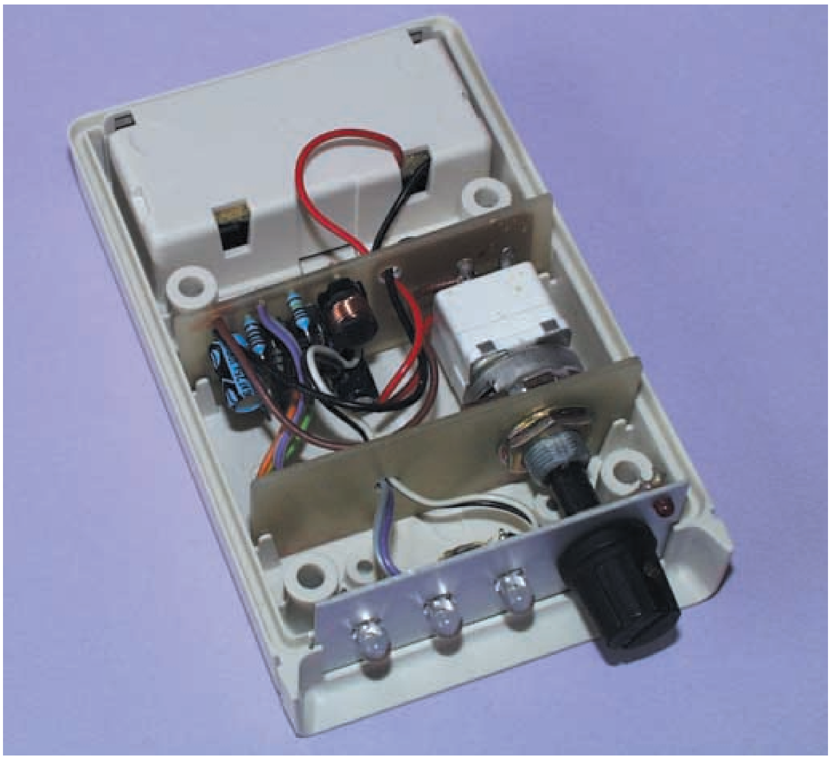
The l.e.d.s are connected as shown in Fig.10 and secured with two applications of Evostik, although an epoxy adhesive might be better.

TESTING AND ASSEMBLY

The l.e.d.s can be tested if a suitable supply is available to ensure the correct path for the current exists through them. Two PP3 batteries in series will provide an 18V supply which can be applied through a series resistor of 560 ohms to limit their current to just over 10mA for testing. If they all illuminate it's a safe bet they are connected correctly and working.

Following this, the project can be assembled into the case for a final operational check. Adjustment of VR1 should control the brilliance from almost zero to full power. On switch-off the three white l.e.d.s will glow for a short period as capacitors C2 and C6 discharge, and the low battery l.e.d. D1 should flash briefly as the supply drops through 6V, showing this feature is working correctly.

If a variable voltage bench supply is available this can be used to check the action more precisely.



Completed White L.E.D. Super Torch. Note the 3mm "low battery" monitor l.e.d. in the top right-hand corner of the front panel.

IDEALLY SUITED

Both these torches make ideal reading lights with low battery consumption. The red one is cheap to construct and has a pleasant warm light. The white one is more expensive (principally due to the cost of the l.e.d.s), but just as cheap to run and considerably brighter, and quite unique in appearance.

It is also a better replacement for a normal incandescent lamp torch. They both have their advantages, so the choice is a matter of individual preference. □

READOUT

E-mail: editorial@epemag.wimborne.co.uk

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

WIN A DIGITAL MULTIMETER

A $3^1/_2$ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

Every month we will give a Digital Multimeter to the author of the best *Readout* letter.

★ LETTER OF THE MONTH ★

CONTROL PLATFORMS

Dear EPE,

First, let me congratulate you and Owen Bishop for an excellent article in the June '01 issue, *Controlling Jodrell Bank*. I personally find articles like this most enlightening and hope you continue to publish similar articles in the future. The side bars on Grey and incremental encoders were most fascinating, especially if you've ever wondered how a PC mouse works.

I'd also like to throw my penny's worth into the development language/operating system debate. I've read with interest peoples' comments, their pros and cons for each respective environment and am of the conclusion that there is no "perfect" solution. Price, performance, cost, ease of use and minimum hardware specifications etc., all play a factor in people choosing which is the better environment for them and their specific project.

I'm sure that some readers, myself included, have written their own versions of software for some of your projects for various reasons, and I would like to suggest that *EPE* make available a web page so that software developers could either post *their* versions of software or perhaps links to web sites where alternative versions of software can be found. Perhaps this way people can try out different versions of software that they feel are more appropriate to their situations.

If developers included the source code there would be no need to place executables on the site and problems with viruses could be eliminated. Also, some development languages, like Visual Basic, require quite hefty runtimes. However, if you only store the source code on the site, then perspective users of the software would require the actual development environment to compile the code so you wouldn't need to store rather larger runtime files or setup kits.

As a professional Visual Basic software developer, I feel that the above approach would eliminate a lot of the problems some seem to encounter. *EPE* project authors could continue to develop software in their preferred development toolset and the *EPE* community would port the software to other platforms giving the less experienced developers chance to use different versions.

Joe Farr, via the Net

Thank you Joe. Owen's article in this issue should interest you just as much.

We have previously discussed having a reader's software portal on our site but the problem is that someone at our end has to monitor and regulate it, time which none of us have available on a regular basis, although we can certainly see the merits of the idea.

However, we have just introduced a PIC TRICKS folder on the ftp site that contains some useful code sections that have been published in Readout.

Regarding source code provision, we already do this (and it is one of the requirements of project acceptance that authors must provide source code for general dissemination to readers who require it).

Executables we shall continue to provide for the sake of those who do not wish to modify code, allowing them to directly make use of the code as it stands. All software is checked for viruses before being placed on our ftp site.

PIC BANKS AND INTERRUPTS

Dear EPE,

I have just read through John Becker's *PIC16F87x Extended Memory* piece in June's *EPE*. Very good – explaining things so thoroughly and simply for beginners, with all the useful tables etc.

The thing I missed in the article was any mention of interrupts. If you're both using interrupts and playing with different banks then you have to be additionally careful because you can find yourself in interrupt code (ISR) with RP0/RP1 and/or the IRP/FSR bit 7 incorrectly set for accessing the ISR's data locations.

Thus it is necessary to locate (at least) the ISR's state saving locations in the $70 to $7F region so that they can be accessed independently of the RPx bit settings before the ISR has been able to set them up how it wants.

Resetting of RPx and IRP on exit from the ISR will generally happen automatically as a consequence of preserving the STATUS register by means of the standard ISR entry/exit sequence, but in the (probably unlikely) case that the ISR changes FSR bit 7, this will need to be saved and restored specially.

Malc Wiles, via the Net

Hello again Malc, and thank you!

Readers, Malc makes a very valid point and indeed interrupts are something that has not been significantly discussed in EPE. In fact, Malc and I have since been in frequent discussion about this. The upshot is that Malc has written a "semi-tutorial" on interrupt use with PICs.

We know there are many PIC users who will appreciate more insights into using interrupts and the potential problems if they are not used correctly. As a programmer familiar with many software disciplines and dialects, Malc is well qualified in this matter. His script is excellent and we look forward to publishing the final version in due course – no date fixed yet.

TUNING FORK

Dear EPE,

I was very interested in the *Electronic Tuning Fork* in May's *IU*.

Some years ago, I bought some ancient Moog synthesisers and needed to build a crystal based 440Hz sounder to tune them by. It needed to be stable and all the back issues off *EE* I had only showed RC oscillators, which I presumed would drift as much as the old synths. So I had to build my own gadget. However, I couldn't work out how to divide a crystal generated frequency into the required 440Hz.

So, remembering how one used to tune organ circuits by filing a notch in a resistor, I took a 400Hz ceramic resonator from a dead VCR, built a standard oscillator circuit around it followed by three 4017 divide-by- tens. Then, I opened up the ceramic resonator and very carefully filed down the sliver of material inside on all four sides, which increased the resonant frequency, replacing it and repeating until I got the required reading on my frequency meter.

Amazingly, this actually worked. I had wondered if air getting to a once sealed component would affect stability but it still works properly!

Nigel Rushbrook, via the Net

Alan, who is Master of Ceremonies for IU comments:

Nice story Nigel. Well, that's one way of fulfilling the design requirement I suppose, though it's a bit unofficial!

It also proves there is plenty of mileage to be had out of good old discrete logic without having to program a PIC microcontroller, though I fear the MCU is the way everything will go.

Alan Winstanley

PIC16F877 AND PICTUTOR

Dear EPE,

Can I plug a 16F877 into the *PICtutor* board, given I make an appropriate plug adaptor, in order to program it? I assume the high programming voltage is the same as that for the PIC16F84.

John Waller, via the Net

Yes, John, it is certainly possible to program other PICs using PICtutor. *Simply connect leads from* PICtutor *for +5V, 0V, RB6 and RB7 to the other PIC's appropriate pins. However, you must be aware that the* PICtutor *guarantee becomes invalid if you do so.*

C TUTOR?

Dear EPE,

I get the impression that in the commercial world programming of PICs in C is becoming the norm. Microchip's most recent range of microcontrollers, the PIC18Cxx2, boasts a "C-compiler optimised architecture/instruction set", with "Source code compatible with the PIC16Cxx instruction set".

Whilst general tutorials on the all purpose programming languages Visual Basic or C would be inappropriate in *EPE*, I would welcome an introduction to this field by someone who has investigated the available compilers, and settled for one at a hobbyist price.

Michael Stewart, via the Net

Thanks Michael, and you will no doubt be interested by Alan Bradley's informative "C Source" letter published in Readout *June '01, and in Mike Kenyon's letter on the next page.*

You will probably also find our "C" for PICmicro Microcontrollers *CD-ROM will be of great interest (see the CD-ROM pages). It also includes a "virtual" code development screen.*

C POWER

Dear EPE,

Whilst I must applaud the desires of several of your readers to learn "C" programming, I must agree with the sentiments you expressed in the May edition. Furthermore, C (and C++) is a complex and extremely powerful language with the capability to do horrible (and nice!) things to not only the operating system but indeed to the BIOS. It gives access to all aspects of the computer but relies heavily on the programmer keeping very close tabs on what he (or she) is doing at all times. A misplaced comma or semicolon could easily bring the operating system down with the resultant mess being sprayed around the hard drive!

Having said that, please don't be put off (just be careful!) – I understand that the Microsoft team wrote the various versions of Windows in C – an indication of the versatility of the language.

If anyone wants to learn C programming, an excellent primer is *Learning to Program in C* by Noel Kantaris (B. Babani – ISBN 0-85934-203-4). I feel that in any subject, knowing the tools and materials available is half the battle, and to this end I have no hesitation in recommending *C The Complete Reference* or the newer version *C++ The Complete Reference* – both by Herbert Schildt (Osborne Books ISBN 0-07-881538-X and 0-07-882123-L respectively).

I believe that Kemighan and Ritchie (the inventors of the language) have also written tutorial books on the subject. The various PC magazines give away versions of C compilers (and Linux software!) from time to time on their cover disks, in addition to running tutorials, and there are many C and C++ programming forums (fora?) on the web. No excuses!

With reference to your question about the USB, most new PCs are equipped with USB capability, simply requiring the addition of a hub card, while others will already have the port built in to the main board. A (limited) power supply is available, though the necessary driver software may be a problem for the home constructor.

Mike Kenyon, via the Net

You have provided some very useful advice, Mike, thank you.

SNUG BUG SENSOR

Dear EPE,

I noticed the *Snug Bug* article (April '01) mentions that the active temperature sensors used have the disadvantage of requiring three wires. One which does not is the IC590kH (RS order code 308-809). This a current source whose current is proportional to temperature (1μA/°C) and so is resistant to the problems of long cables and only requires a two-wire cable. A simple op.amp current-to-voltage converter circuit will read it.

Alan Bradley, via the Net

Thanks Alan.

SOLDER TYPES

Dear EPE,

Having read Alan Winstanley's *Basic Soldering Guide* (downloaded from your web site), and as a service-technician constantly trying to improve his soldering, I would like to ask what the advantages are of using solder containing two per cent silver or two per cent copper over the usual 60/40 tin/lead alloys. When and where are they best used?

Erik Hens, via the Net

Alan replies:

Solder containing silver (two per cent typical) tends to produce better quality results when soldering by hand. It has a better "wetting" characteristic, meaning that it flows more easily over the joint than ordinary Sn/Pb solder does. It also has better conductivity, which might be important with low power, high frequency circuits. I know an engineer who exclusively uses silver-loaded solder for all his manual soldering.

The only copper-based solder I know of, is 99·7 per cent tin, 0·3 per cent copper. Such solders are described as "lead-free" which is supposedly better for the environment. Some countries are banning the use of lead solder altogether, so everyone is actively looking for alternatives. Water-based fluxes are also becoming popular for environmental reasons. For more info browse **www.weller.com**.

NOTETAB TEXT EDITOR

Dear EPE,

Regarding text editors and file sizes, I too have had problems with Windows Notepad (and similar). May I recommend NoteTab, available as a free download from **www.notetab.com**. The highly featured, freeware version is excellent. It is a text editor (as opposed to a wordprocessor), and is very fast. It also has a huge host of other clever features... well worth a try.

I have used it with a PIC '871 datalogger project that I am working on, both for the ASM source code (too large for Notepad), and to view/edit the data files the PIC generates, which are 2·5MB in size.

Richard Niell, via the Net

You are right, Richard, it is good. I downloaded it when I first read your E-mail and am very impressed. So much so, that I have actually put a link to the NoteTab site into my forthcoming Toolkit TK3 For Windows *so that users can import the editor and use it through* TK3 *(which allows programmers to use any text editor of their choice).*

Incidentally, I was amused to see the vast quantity of web "smilies" that NotePad has as "library" symbols for use in text messages – I had no idea there were so many! Interestingly, NoteTab also has hyperlinking facilities.

PCB MASTERS

We have several times discussed the merits of various techniques of outputting CAD-generated p.c.b. artwork to a form suitable for use as the track master when making p.c.b.s via photosensitive copper-clad fibreglass.

Such techniques have included the use of sprays that transparentise paper printouts (including the use of WD40 – actually very successful as long as track thicknesses and spacings are adequate).

Until recently, I have favoured the use of translucent (but not transparent) drafting film. This works best with dot-matrix printers but can be difficult with inkjets unless good quality (and expensive) ink is used. It it still prone to smudging before it dries, and on occasions can "spread" across the film (especially if the wrong side of the film is used).

However, let me share with you my pleasure at discovering Overhead Projection (OHP) film. This clear film has been manufactured for use when creating computer generated colour images that are suitable for overhead projection displays, which are commonplace when "presentations" are made by Public Relations departments in a multitude of industries.

PC World was my own source and there are several manufacturers. Not knowing what I was destined to achieve with it, I bought from a cheaper range, but which was said to be suitable for Epson inkjet printers. It is brilliant to use!

Subsequent exposure time in my UV printer, using Mega photosensitive board, is down to two and half minutes, whereas it had been four minutes with the drafting film. The definition is great and even tracks a mere "15 thou" (about 0.4mm) wide retained their width perfectly. The image is the best I have had since I ceased using a plate camera to photograph hand-drafted tape and pad masters (before CAD became affordable).

I heartily recommend OHP film to anyone making their own track masters using an inkjet printer (as I write, another EPE author has also discovered it, sending his latest p.c.b. design printed on it).

ELECTRONICS SHORTAGE

Dear EPE,

Reading the News item in June's issue about the Electronics Labour Shortage, I could not help but laugh out aloud. I have been trying to get a job in the electronics industry for the past twenty years but to no avail. At first I would phone for jobs and send for application forms and would get some replies stating that they need people with qualifications. This was back in the late 70s.

I thought, OK, go to college and get some qualifications. So for four years I attended my local college and gained the City & Guilds 2240 Electronic Servicing and various other certificates, but having these qualifications did not make any impact on prospective employers.

I was also interested in the assembling side of electronics. I trained at various establishments to gain experience and knowledge to increase my chances of gaining work in this field. It did not make any difference to the outcome. My last interview was several weeks ago at a large Japanese company that makes electronic parts for the automotive industry. Despite the experience I had obtained working on a full time placement for an electronic scales builder, I was turned down again. So how can you state there's a skills shortage when companies are so picky?

Brian Wintle, via the Net

We are sorry to learn of your difficulties, Brian, but it is very difficult for us to comment. The item was a News report about a survey by KPMG – we did not produce the results they reported from the electronics industry.

We do hope you have better success with your next application.

ACTIVE JAVA

Dear EPE,

While C is certainly one of the dominant languages for embedded systems today, Java is definitely getting in on the act, being suitable for PC-side user interface applications, and there is a lot of activity on making Java runtime environments small enough for microcontroller applications.

Java has a number of advantages for the hobbyist, the main one is that it is free and available on all the common platforms including Windows and Linux – write the application for one and it will run on all. Compare this with C which varies slightly across different platforms and Delphi which I believe may only be available on Windows.

One potential drawback is that Java is interpreted and so slower than C, for example. However, it is fast enough compared with Visual Basic and compilers are available, GCJ for instance, to support more demanding applications. Having programmed in C++ I've also found object oriented programming is far easier and more intuitive with Java than C++ to the extent that I now use Java almost exclusively.

Java has a very active community developing both the language and application libraries and there are numerous books at all levels. The best place to start is **www.javasoft.com**, this is the home of Java and the source for all API documentation, software development kits and an excellent on-line/downloadable tutorial.

Other useful sites include; Gamalan at: **softwaredev.earthweb.com/java** and *The Java Developer's Journal* at: **www.svs-con.com/java/index2.html**

David Price, Reading, Berkshire, via the Net

Interesting, David, but we are not sure that Java is actually a language that would suit the type of projects that we publish.

Opinions, anyone?

Personally, having got to grips with VisualBasic (VB6), I find it superb to use and love playing with it. (Watch out for my Spectrum Analyser that I've written in VB6!)

Special Feature

CONTROLLING FLIGHT

OWEN BISHOP

An insight into how electronics helps to maintain aircraft safety.

AIRCRAFT safety is of paramount importance to us all, whether we are flight passengers or simply ground-based below a flight path. This article highlights how electronics is used to control and monitor aircraft performance and help to ensure safety.

FLIGHT SURFACES

The primary flight surfaces that control the attitude and direction of an aircraft are the ailerons on the trailing edge of the wings, the elevators at the trailing edge of the tailplanes (which may themselves be trimmable) and the rudder behind the tail fin.

The secondary flight surfaces include the flaps or slots, which are narrow strips at the leading or trailing edges that are moved out from the wing when the aircraft is flying at low speed so as to prevent the aircraft from stalling. Also included with the secondary flight surfaces are the spoilers or speed brakes. You can often see these rather wider strips angled sharply up from the upper wing surface just after a landing. They are used to decelerate the aircraft rapidly prior to taxiing to the terminal.

In the early days of flying, the primary flight surfaces were moved into position by a purely mechanical system of levers, cranks and cables. The pilot physically wrestled with the joystick and the foot-propelled rudder bar. Later, hydraulic systems were introduced so that the safety of the aircraft was no longer dependent on the brute strength of the pilot. Nowadays there is still a joystick in the cockpit, but it is reduced in size and delicately adjustable. It is very similar in appearance to the joystick commonly used for computer games.

MOVING A SURFACE

A flight surface is usually moved by an electric motor with reduction gearing to decrease the rate of rotation and to correspondingly increase the torque. Alternatively, the surface is moved by electro-hydraulic actuators, consisting of solenoid-operated valves and an assemblage of pistons and levers.

Moving an aileron, for example, is not just a matter of switching on the motor and then switching it off again when the aileron has reached the required angle. Flight surfaces are subject to strong forces from air streams and their motion must be closely monitored and tightly controlled. Feedback from position sensors is used to ensure that the surface has actually moved to where it should be.

Another requirement is that the motion from the current position to the new position must take place as quickly as possible. Fig.1 shows a profile of the kind of motion needed. At time A, the aileron is at a given angle to the wing. During the period A to B it is accelerated at the maximum rate (a rate that will not cause it or the mechanism any mechanical damage) until it reaches its maximum angular velocity.

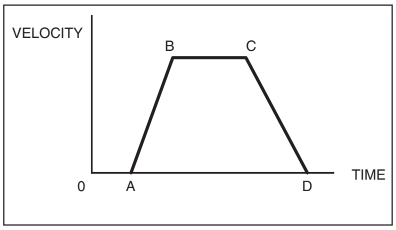


Fig.1. A plot of a trapezoidal velocity profile.

The curve is level for the period B to C, showing that the aileron is now turning as fast as possible. The final stage is to decelerate it, again at the maximum safe rate, so that it comes to rest (that is its velocity is zero) at the exact moment at which it reaches the desired new angle. The length of the curve from B to C has to be calculated so as to bring this about.

Deceleration begins at time C and the aileron comes to rest at time D. Because of the shape of the curve, this is known as a trapezoidal control profile. If the change of angle is small and the aileron has to start decelerating before it has attained maximum angular velocity, the profile becomes a triangle.

MECHANICAL INERTIA

There are mechanical problems to be dealt with as well as electronic ones. However robust the control mechanism, there is always a certain amount of inertia to be taken care of. It is impossible to stop motion without exerting some mechanical counter-force.

In the case of an aileron or other movable flight surface, it is essential for it to stop dead when it lines up with the fixed surface of the wing. To allow it to move even as little as 1mm beyond the stopping point is to invite distortion of the moving surface or of the wing itself. Various materials have been tried to absorb the closing impact but none have been found satisfactory. The current solution is to incorporate a slipping clutch into the drive.

The algorithm for calculating the required angular velocity moment by moment is moderately complex. It depends on the original and required aileron angles and on certain parameters such as the maximum allowable acceleration and deceleration and the maximum allowable velocity. Variations in airflow over the wings will exert forces on the aileron. The calculations must compensate for these.

MICROCONTROLLING MOTORS

Calculations of this degree of complexity need a microcontroller or microprocessor. Then, putting the calculated motion into effect is not simply a matter of switching the motor on or off. The torque required from the motor must be calculated on a continuous basis in terms of current to be sent to its coils. This stage too needs a processor of some kind.

Motors used in these LEMACs (Large Electro-Mechanical Actuating Systems) are generally of the variable reluctance type. A variable reluctance motor comprises a coil-less multipoled rotor, spinning within a multipoled stator, which has electromagnetic coils.

The number of poles of the rotor differs from that of the stator. Typically, the rotor has six poles angled 60° apart, and the stator has eight poles angled 45° apart. This means that only one pair of poles of the rotor can be aligned with a pair of poles of the stator at any one time.

The rotor is made to turn by applying a sequence of pulses to the coils of the stator. The action is similar to that of a stepper motor but it is not a stepping action. It is a continuous action, and the driving circuits are required to supply a sequence of precisely timed and carefully shaped pulses to the coils. A microcontroller is used to produce these pulses.

SLAVE PROCESSORS

As explained, there are several operations in moving a flight surface that can be achieved only with the help of a processor. In the most up-to-date systems, the processor is a microcontroller and is situated very close to the actuator. The microcontroller receives a general instruction from the flight computer to move the aileron to a specified new angle. From then on, the microcontroller takes over the control of the aileron, leaving the flight computer free to deal with other flight surfaces or with other aspects of flying the aircraft.

Using stored data and feedback from sensors in the wing, the microcontroller moves the aileron to its new position. Then it reports back to the flight control computer that the task has been completed. It may also report back at intermediate stages, if interrogated by the flight computer.

Many of the sensors referred to above incorporate a microcontroller to supervise their activities and to process the data they produce. For example, the angular position of a mechanical part, such as an aileron, may be sensed by a linear inductive position sensor (LIPS).

The input to the sensor is a 1MHz signal of fixed amplitude. The amplitude of the output signal is proportional to the present position of the moving part. The output signal is sampled at the same phase in each cycle, giving a d.c. voltage proportional to the position of the part. The interface circuit is small enough to be contained within the casing of the sensor.

FLY-BY-WIRE

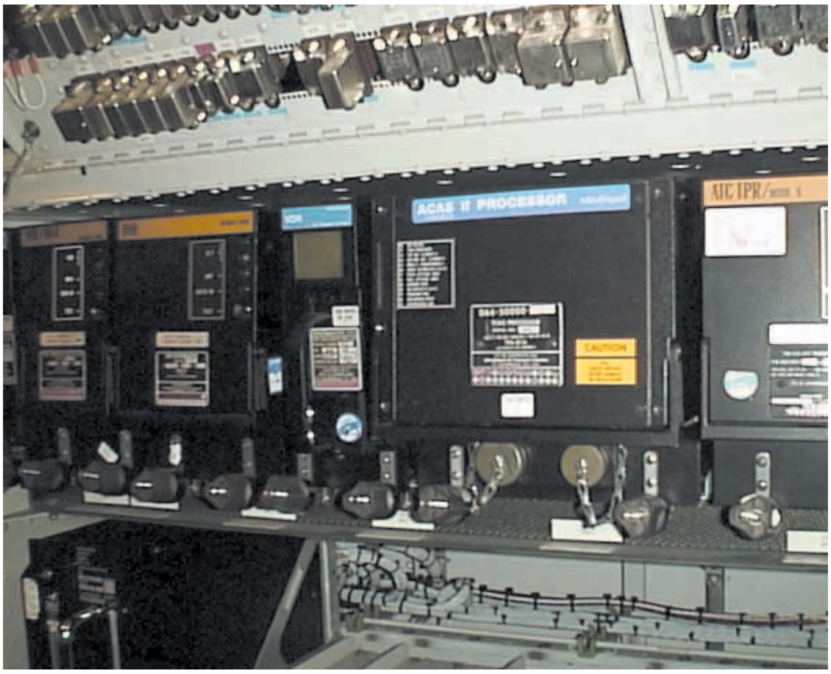
The control of flight surfaces as described in the previous paragraphs is part of the “fly-by-wire” system developed by Lucas Aerospace for the Airbus 320 and 330. The official name for this system is Integrated Modular Avionics (IMA). The dictionary defines avionics as the application of electronics to aviation.

The concept of localising much of the computing within the wings does a lot to simplify the cabling of the system. It also leads to a modular approach to the flight systems. There are many such systems in the Airbus, each functioning autonomously, yet each sharing data with certain other systems so that the control of the aircraft as a whole is coordinated. The controllers for most of these systems are located in a special hold below the flight deck – see photograph above.

The whole fly-by-wire system is digital except in the final links connecting it to the sensors and actuators. The modular approach includes specialised processing cards for handling the data and gateway cards for routing data through the system.

One of the more recent developments is the use of multi-purpose modules. These are able to perform a wide range of functions. When a multi-purpose card is plugged into the rack, it automatically reads the configuration of the contact terminals in the socket. From this information it is able to deduce what function it is expected to perform there. It then configures itself to perform that function.

These Generic Smart Actuator Controllers (GSACs) greatly simplify the problem of stocking spares, since only one type of module need be stocked.



Control cabinets below the flight deck of an Airbus 330.

SAFETY

As might be expected, safety aspects loom large in all the systems and routines connected with flight. At one time, avionics circuits were built from devices having military specifications. These have the advantage of high reliability and guaranteed performance, but are very expensive and often difficult to obtain. Now the trend is to use the standard specification types that are readily available commercially. Circuit builders rely on rigorous design of the circuit to provide the required reliability and margins of safety.

Redundancy is a widespread way of making a system reliable. Redundancy on the small scale is exemplified by replacing a single component by two or three identical components, usually wired in parallel. If one fails, the others continue to operate.

For example, if a voltage is to be regulated by a Zener diode, three such diodes wired in parallel will give virtually the same regulation, even if two of the three fail. The laws of probability show that if the chance of one component failing in a given period is one per cent, the chance of all three failing at the same time is one per cent of one per cent of one per cent, which is one in a million.

Another example of redundancy is the use of two or three sensors to measure the same quantity. If their outputs agree, all is well. If there is a discrepancy between their outputs, a warning is generated to call attention to the failure.

MULTIPLE MEASUREMENTS

A more subtle approach is to use different techniques to measure the same quantity. For example, the speed of a motor may be measured by using a magnetic or optical sensor driving a tachometer circuit. At the same time, the speed may be calculated from measurements of the back e.m.f. of the motor. The output of the tachometer circuit is compared with the back e.m.f. measurements and any disagreement results in an alarm signal or corrective action by the computer.

An example of large-scale redundancy is illustrated in the photograph on the next page. Toward the top of the photograph there are duplicate control panels. The panel on the right is normally used by the pilot while that on the left is used by the co-pilot. If they should accidentally try to operate their controls differently, a warning signal is heard and the pilot’s panel takes priority. If either panel fails, the aircraft can be flown using the other panel. If both fail, the third panel at the bottom of the photograph can be used.

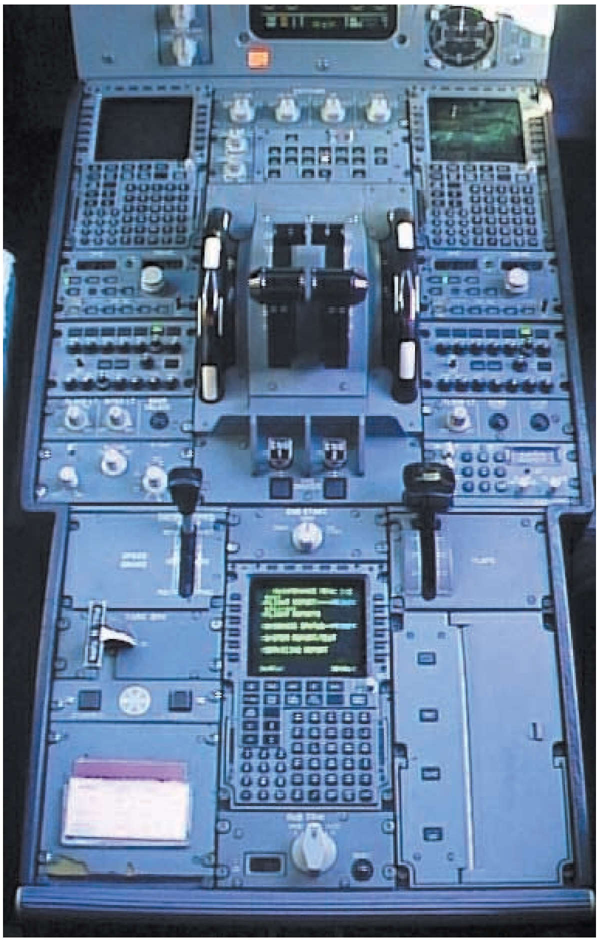
With more and more control functions being implemented in software, it is not only the avionics that must be reliable. Software must not fail to act as expected. For this reason, the software is often written in a rigorous high-level language, such as ADA. A proprietary language known as LUCOL is used by Lucas Aerospace and, for the control of Rolls Royce engines, they have cooperated with Rolls Royce to produce a language known as FADEC (Full Authority Digital Engine Control).

TESTING

Thorough testing at the design stage is another contributor to safety. When testing the mechanical parts of an aircraft, it is no longer a matter of “taking her up for a spin”! Every part of a modern aircraft is exhaustively tested well before the day of the first take-off.

An example of the close scrutiny given to all the parts of the mechanism is the test bed designed and built by Machines and Systems (Design) Ltd. for testing a gearbox made by Lucas Aerospace (Fig.2).

The gearbox being tested is a tee gear used for linking a motor with an aileron. Motor 2 is the motor normally used as the



Triplicate control panels on the flight deck of an Airbus 330.

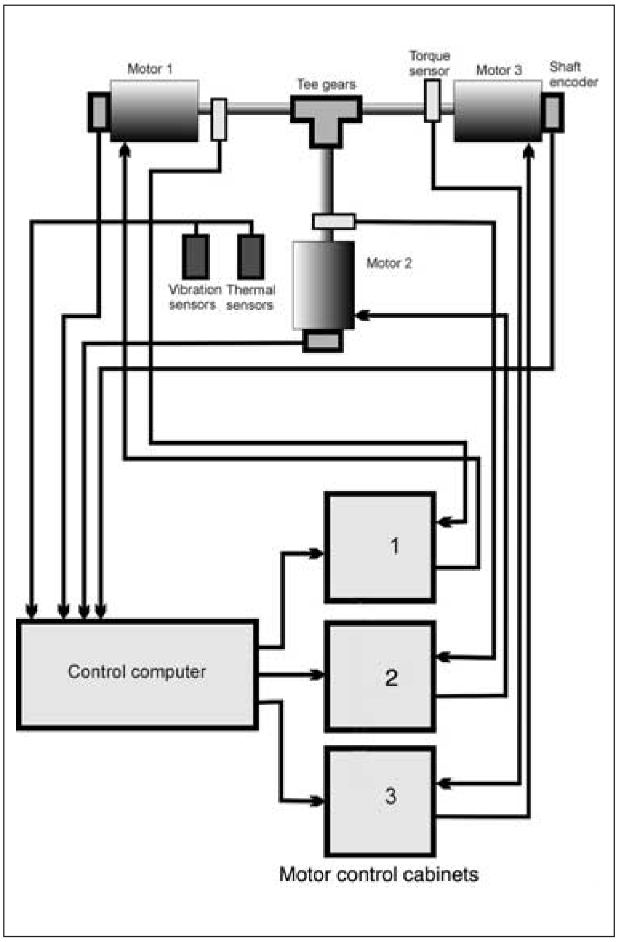


Fig.2. A block diagram of a test-bed designed for testing actuator gearboxes.

aileron actuator. Motors 1 and 3 drive the cross-shaft and are intended to simulate the action of airflow on the aileron.

Each motor has its own control circuitry housed in a motor control cabinet. The whole system is under computer control. The computer is normally programmed in VEE, a language specially intended for control systems. This is a visual language by Hewlett Packard in which the programmer drags symbols representing functional blocks on to the screen, and joins them by "wires". VEE then produces the program to give the required control action.

The motors receive a d.c. drive current from their control cabinets and data from each motor is fed back to the cabinets and to the computer from a shaft encoder and a torque sensor. The shaft encoder is similar to those used in the Lovell telescope, described in the June '01 issue. This gives a measure of the angular position of the shaft.

TORQUE SENSING

Two types of torque sensor have been used in this test bed. The simplest and cheapest consists of a double flanged shaft with strain gauges set at 45° so as to measure the shear stress in the shaft. The principle of the strain gauge is that its resistance changes when the thin metal foil of the gauge is subjected to strain. The filaments of the gauge become stretched, and thus become longer and thinner.

As a result, their resistance increases. The change in resistance is relatively small so a sensitive measuring circuit is required. This usually takes the form of a bridge, with a gauge in each arm.

In the case of the torque sensors, the bridge must have an electrical connection for the alternating drive current and a connection to the instrumentation circuit that buffers and amplifies the output signal. The connections are made by way of silver contact slip rings to allow the shaft to rotate freely while torque is being measured.

More recently, a new type of sensor dispenses with the slip rings. The supply current is generated in the bridge electromagnetically, using an inductive loop. On the output side, an f.m. signal is transmitted to a loop receiver. There are integrated electronics on both the stator and rotor to deal with signal processing. These new sensors are more expensive but are more robust and can deal with very high rates of revolution.

Most of the signal links in this system are by optical fibre to avoid electromagnetic interference from the motors. The system also includes sensors to detect overheating and excessive vibration. These are connected to the main computer by one-bit digital lines. In an emergency, signals from these sensors can automatically shut down the system.

Under computer control, and in real time, the gearbox can be taken through a prescribed regime of driving force and the resulting reaction from simulated effects of airflow. The computer records the torque and angular position of the shafts at each stage. In this way, the ability of the gearbox to function correctly under all possible operating conditions is exhaustively tested.

ACKNOWLEDGEMENTS

The author thanks the following for helpful advice and information used in this article. At Lucas Aerospace Ltd., Actuators Division, Wolverhampton: Carl Maxwell, Principal Electronics Systems Engineer and R&D Team Leader, Chris Whitley, Principal Electronics Systems Engineer, and Karl Barker, Electronic Systems Engineer. At Machines and Systems (Design) Ltd.: Roger Doyle and John Bugge, Engineering Directors. At Cathay Pacific Airways, Perth International Airport, Western Australia: Colin Myers, Engineering Manager. □

TRAFFIC CONTROL

Whilst air traffic control in relation to electronics and computing is too complex to discuss simply, road traffic control is a subject of equal importance (and arguably more so) to our daily lives, and which will be highlighted in a future article.

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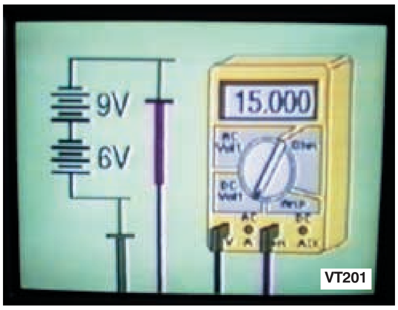

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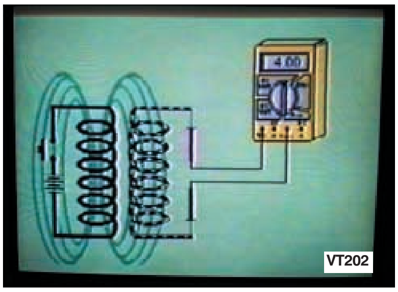

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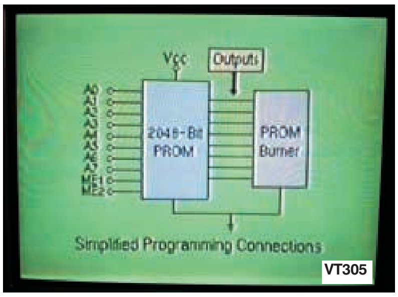

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09/01

Perpetual Projects – 3

LOOP BURGLAR ALARM

THOMAS SCARBOROUGH

● Solar-Powered – no batteries ● Uses a common – Uniboard – p.c.b. ●
● Will run indefinitely, without attention ● Ideal for the novice ●

THIS month, in the penultimate of our four-part series of "perpetual" projects, we give details of a further three circuits that will find many possible uses in and around the home. We also include suggestions for some interesting variations.

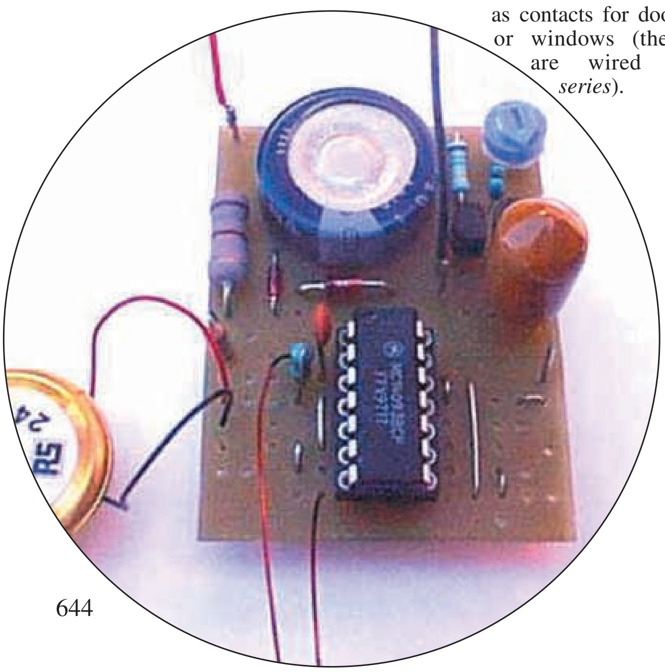
All are based on the same Uniboard p.c.b. introduced in Part One (July '01) and are all powered by the *Solar-Powered Power Supply and Voltage Regulator* described in the same issue. Each is designed to run unattended for months at a time without attention – in fact for years!

It only remains for you to select which of the following solar-powered Perpetual Projects most appeals to you! You can, of course, elect to build all the projects, provided you purchase additional p.c.b.s.

☆ *Loop Burglar Alarm* ☆
☆ *Touch-Switch Door-Light* ☆
☆ *Rain Alarm* ☆

Besides these projects, suggestions are made for seven variations – a Broken Beam Beeper, a Power Failure Alarm, a Soil Moisture Monitor, a Thermostat, a Timer, a Liquid-Level Alarm, and a Wake-up Alarm.

In all the projects which follow, only the specifications of IC1 and the l.e.d. are critical. Rough equivalents should work in most other instances without trouble.



LOOP ALARM CIRCUIT

The simple Loop Burglar Alarm circuit diagram is shown in Fig.1. Note that the component references follow on from the *Solar-Powered Power Supply and Voltage Regulator* circuit published in the July '01 issue.

There are various manufacturers of the 4093 i.c., and the one used throughout this series is the Motorola MC14093BCP. This does make a difference – the make significantly affects both the power consumption and characteristics of the 4093 i.c.

Any unused inputs of IC1 should not be left "floating" (unconnected), otherwise an input may not know what to do, and is likely to behave erratically. By "tying inputs high'', a significant amount of power (as much as one third) can be saved.

The circuit works on the principle that when a continuous electrical loop is broken, an alarm is triggered. The loop may include a thin wire snare which would be snapped by an intruder or by the removal of an object through which the loop-wire is threaded.

The "loop" in Fig.1 could also include contacts which would be broken by, for example, a gate or a window opening. Normally-open magnetic switches (closes when a magnet is brought into close proximity to the switch), or microswitches (which are cheaper), would also serve well as contacts for doors or windows (these are wired *in series*).

However, it should be remembered that such switches can be closed again as quickly as they were opened! They might thus best be used to indicate, for instance, when a shop door has been opened. (See next month for a circuit which adds a *delay* before switching off the oscillator).

Normally-closed switches may be used if you swap the positions of resistor R5 and the loop in the circuit diagram. Such switches are then wired in *parallel*.

PUSH-PULL

In the circuit diagram of Fig.1, the oscillator (IC1a) causes an audible tone to be produced by piezo disc WD1. Note that instead of wiring the alarm's piezo disc between IC1b's output terminal and the 0V or $+V_E$ rails (which would work perfectly well), it is wired instead between the two output terminals (pins 3 and 4) of IC1a and IC1b.

Consider that IC1b inverts the output of IC1a. Therefore when IC1a's output goes high, IC1b's output will go low, and vice versa. This, in effect, constantly reverses the voltage across the leads of piezo disc WD1 in a push-pull fashion, and substantially increases the volume of the alarm.

While not sufficient to wake the neighbourhood, the break-contact alarm would hopefully be sufficient to unnerve a would-be intruder/thief!

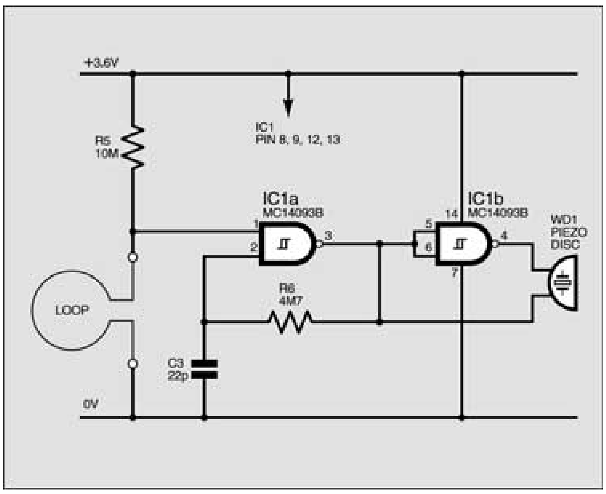


Fig.1. Circuit diagram for the Loop Burglar Alarm. Component numbering continues on from the Solar-Powered Power Supply and Voltage Regulator *published in the July '01 issue.*

CONSTRUCTION

The Loop Burglar Alarm is built up on the Uniboard p.c.b., as shown in the topside component layout details of Fig.2, together with the copper foil master. This board (*minus components*) is available from the *EPE PCB Service*, code 305.

Commence construction by soldering the link wires and the resistors in position, continuing with capacitor C3 and attaching the piezo disc WD1 as shown.

Finally, insert IC1 in its d.i.l. socket, being careful again to observe the correct polarity, as well as anti-static precautions. A one megohm (1M) resistor may be wired in series with the loop to protect the input at IC1 pin 1 from possible static, although in practice the circuit is unlikely to miss this.

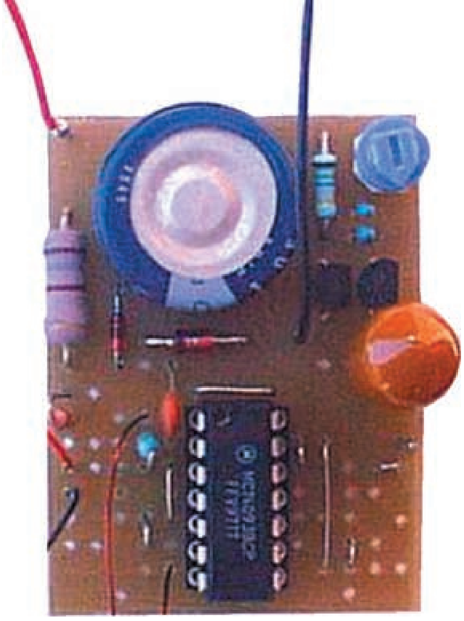
SETTING UP

Once the power supply capacitor C1 has been fully charged in the sun, via the solar cell (see Part One), adjust the regulator's preset trimmer VR1 until 3·6V is measured across electrolytic capacitor C2 (solder pins are provided on both sides of C2) – while the alarm is *sounding*. This it will continue to do as long as the loop is broken (or open circuit).

Remember that capacitor C2 in the regulator circuit causes a delay to any adjustments that are made to the voltage.

Current consumption was found to be less than 1µA on standby, and about 600µA when the alarm is sounding.

As soon as the regulator's "Goldcap" capacitor C1 has been fully charged up in the sun, the Loop Burglar Alarm will be on perpetual guard!



Completed loop alarm circuit board. Also includes solar-powered power supply components.

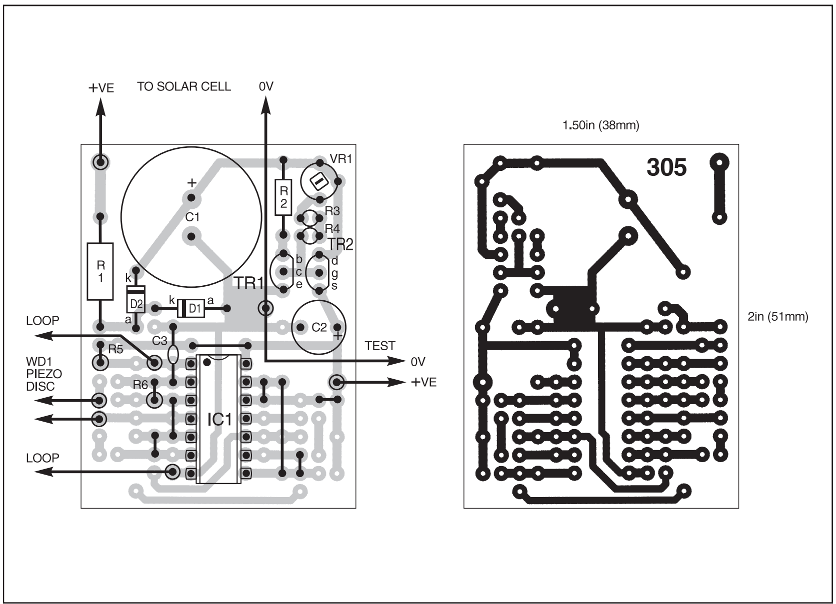


Fig.2. Uniboard component layout and full-size foil master for the Loop Burglar Alarm. Includes components for the solar-powered power supply (July '01).

COMPONENTS

LOOP BURGLAR ALARM

See SHOP TALK page

Resistors

R5	10M
R6	4M7

All 0·25W 5% carbon film

Capacitor

C3	22p ceramic plate

Semiconductor

IC1	MC14093BCP quad 2-input NAND Schmitt trigger

Miscellaneous

WD1	low profile wire-ended piezo sounder

Printed circuit board (Uniboard) available from the *EPE PCB Service*, code 305; multistrand connecting wire; link wires; solder pins; solder etc.

Note: Component designations run on from the Solar-Powered Power Supply and Voltage Regulator *described in the July '01 issue.*

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IT'S A LIGHT TOUCH

SUGGESTION 1 – BROKEN BEAM BEEPER

Try making a Broken Beam Beeper. This will sound when a person breaks a beam of light which shines across (for instance) a doorway. Use the Loop Burglar Alarm as a guide.

Unlike the Loop Burglar Alarm, this circuit draws about 10µA when on standby. If triggering is unreliable, experiment with the value of resistor R5 – a higher value for greater sensitivity to light, and vice versa.

- Substitute an *npn* phototransistor for the loop wire, mounting the phototransistor in a black tube so that it is not affected by ambient light. Wire the emitter (e) to the 0V rail, and the collector (c) to IC1 pin 1 and R5.
- Illuminate the phototransistor with a focussed light-beam.
- Change the value of resistor R5 to 270 kilohms (270k) (this will suit most phototransistors and conditions).

When the resistance of the phototransistor rises above about 540 kilohms (this occurs when the light-beam is broken), the alarm beeps.

SUGGESTION 2 – POWER FAILURE ALARM

Mains voltages are lethal – do not attempt this unless you have a thorough experience of mains wiring.

A distinct advantage of this Power Failure Alarm is that it will *never* suffer power failure itself – it is perpetual. Wire up the Broken Beam Beeper (Suggestion 1) – but instead of using a light beam as a light source, use a miniature neon lamp which is powered by the mains. House both the miniature neon bulb and the phototransistor in a small dark enclosure.

- For 200V to 250V mains supplies, wire a 270 kilohm 0·5W resistor in series with the miniature neon lamp.
- For 110V mains supplies, wire a 100 kilohm 0·5W resistor in series with the miniature neon lamp.
- Wire a 1nF capacitor in parallel with the phototransistor

SUGGESTION 3 – SOIL MOISTURE MONITOR

Try modifying the Loop Burglar Alarm to become a Soil Moisture Monitor. Note that since current consumption in this case is up to about 60µA on standby (this was explained in *Part 1* of the series), the circuit is likely to shut down before sunrise. Nevertheless, it should serve its purpose well.

- Substitute two probes for the loop.
- Change resistor R5 to one megohm (1M).
- Wire a 10µF capacitor in parallel with resistor R5.

As the soil dries out, this "breaks the contact" between the two probes which are inserted a short distance from each other in the soil. The capacitor helps when you reset the alarm after triggering.

Can you see how it functions? When the alarm triggers, water the soil – remove the two probes from the soil, click them together to reset the alarm, and re-insert in the soil.

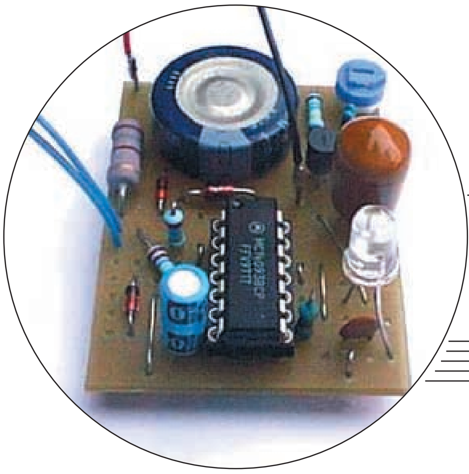
SUGGESTION 4 – THERMOSTAT

You might like to try designing a Thermostat to warn of impending frost. Once again, current consumption is up to about 60µA on standby, so that the circuit is likely to shut down before sunrise – this might defeat the purpose of this circuit in some applications. Use the Loop Burglar Alarm as a guide.

- Substitute a thermistor for the loop.
- Wire a 100pF capacitor in parallel with the thermistor (this effectively reduces the source impedance presented to the input, thus reducing current consumption – the "trick" is referred to in *Part 1*).
- Choose a value for resistor R5 to suit (refer to "potential dividers" covered in last month's Double Door-Buzzer project for guidance).
- If you would like the Thermostat to trigger on *rising* temperature (e.g. for a Freezer Alarm), swap the positions of the thermistor and resistor R5.

Choose a high value for the thermistor (e.g. 100 kilohms at 25°C) to conserve power. What is the thermistor's rated value at 0°C? What value is required for resistor R5? Refer to last month's issue for help.

Note that if the potential at IC1 pin 1 needs to rise to about *two-thirds* of the supply voltage to trigger IC1a, it will need to fall to about *one-third* to reset it. How will you reset the gate when the thermostat triggers? Can you do it without a mechanical switch?



TOUCH-SWITCH DOOR-LIGHT

A light touch is all you need to show you the way

THE CIRCUIT diagram for the Touch-Switch Door-Light shown in Fig.3 has several possible applications – among them being to light an entrance upon entering, to illuminate a switchboard during a power failure, or to help you find a keyhole on approaching a door at night.

Once the door-light is triggered, by the touch switch S1, it shines for roughly half a minute at a time. It could be used more than 10 times in the darkness before the regulator's capacitor C1 is exhausted.

The door-light employs a 5mm extreme brightness white l.e.d. (D4) with a narrow viewing angle, which provides a good light in a confined space. The l.e.d. D4 is pulsed by the oscillator IC1c, so as to conserve power. No ballast resistor is required, since the effective current flow is limited by the regulator (the white l.e.d. being rated at 3·6V – any other l.e.d. type would need a suitable ballast resistor.).

Capacitor C3 is charged through resistor R6. When the touch-switch S1 is touched, IC1a conducts, and C3 is discharged through diode D3. The output (pin 4) of IC1b then goes high, so that the oscillator (IC1c) is activated, to pulse l.e.d. D4 via IC1d.

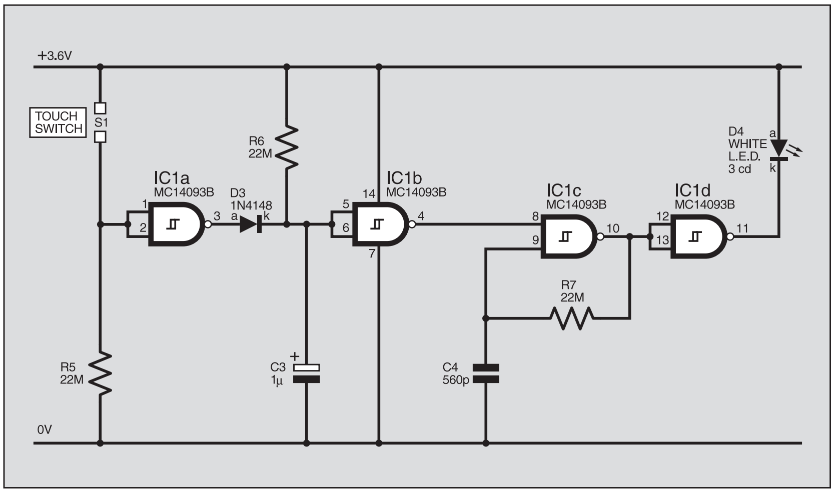


Fig.3. Circuit diagram for the Touch-Switch Door-Light. Note the component references follow on from the power supply published in the July '01 issue.

When C3 has again charged to two-thirds of the supply voltage, the l.e.d. extinguishes. Diode D3 prevents C3 from being re-charged through IC1a. The on-time of the Door-Light may be lengthened by increasing the value of capacitor C3, and vice versa.

TOUCH SWITCH

It was decided to use touch-switches throughout this series, since the symbolism of the "perpetual" might be compromised if any mechanical switches were included.

A touch-switch was constructed by the author from the pieces of a broken ultrasonic transducer, the cavity between the "switch" contacts being filled with quick-set putty. It should be constructed in such a way that a finger is sure to close the gap across the two contacts.

Ready-made touch contacts are available from some component suppliers and which could be used instead.

It would be worth noting that touch-switches can pick up static. A recommended simple means of protecting all the circuits in this series against static would be to wire a one megohm resistor in series with each touch-switch. This would be desirable especially if there is an expanse of carpeting near the touch-switch.

If you would prefer a mechanical switch, remember that all touch-switches in this "Uniboard" series may be replaced with pushbutton switches (push-to-make, release-to-break), the accompanying 22 megohms (22M) resistor R5 being exchanged for one of 100 kilohms (100k) value.

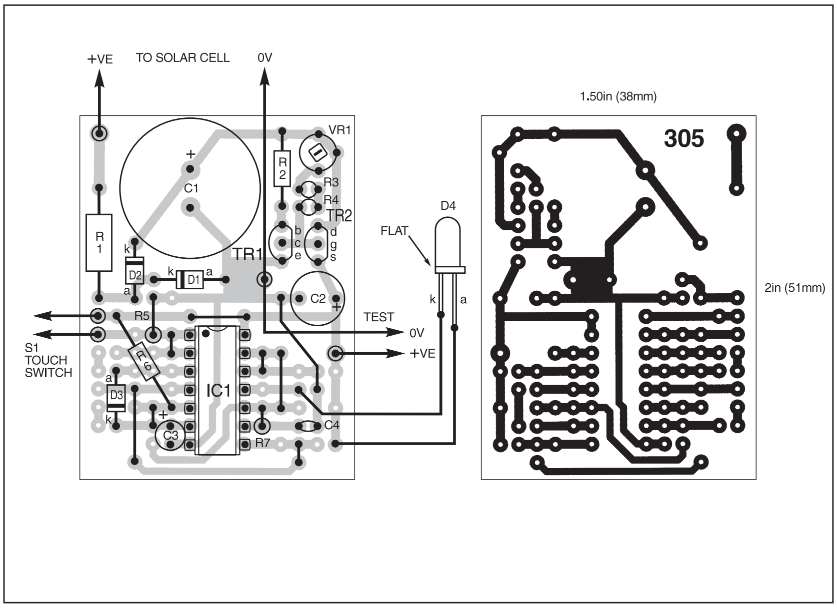


Fig.4. Uniboard component layout and full-size foil master for the Touch-Switch Door-Light. Includes power supply from July '01 issue.

COMPONENTS

TOUCH-SWITCH DOOR-LIGHT

See SHOP TALK page

Resistors
R5, R6, R7 22M (3 off)
All 0·25W 5% metal film

Capacitor
C3 1µ min. radial elec. 10V
C4 560p min. ceramic plate

Semiconductors
D3 1N4148 signal diode
D4 5mm 20° extreme brightness white l.e.d.
IC1 MC14093BCP quad 2-input NAND Schmitt trigger

Miscellaneous
S1 touch-switch – see text

Printed circuit board (Uniboard) available from the *EPE PCB Service*, code 305; multistrand connecting wire; link wires; solder pins; solder etc.

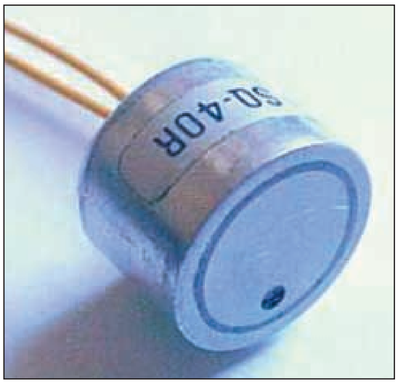
Note: Component designations run on from the Solar-Powered Power Supply and Voltage Regulator *described in the July '01 issue.*

Approx. Cost Guidance Only **£7**

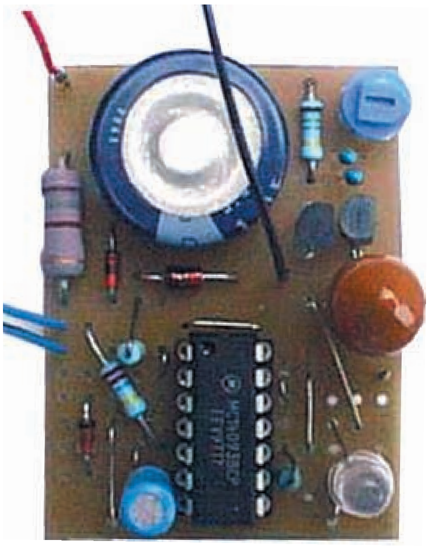
CONSTRUCTION

The Touch-Switch Door-Light is built up on the Uniboard p.c.b., which may or may not already hold the regulator and d.i.l. socket (see July issue, Fig.2) – as shown in the topside component layout details of Fig.4. This board (*minus components*) is available from the *EPE PCB Service,* code 305.

Follow the same procedures as previously described, soldering the components to the board in sequence, and finally inserting IC1, observing anti-static precautions. The white light l.e.d. D4 is also static sensitive, so observe anti-static precautions – careful handling could prevent an expensive mistake.



The author's "touch-switch" was made from a broken ultrasonic transducer.



Completed "touch-light" circuit board.

Once C1 has been fully charged by the solar cell, adjust the regulator's preset VR1 until 3·6V is measured across capacitor C2 – while the l.e.d. is *shining*.

Current consumption should be virtually nil on standby, and rises to about 1·4mA when l.e.d. D4 is shining.

The Touch-Switch Door-Light could, if you wish, be detached from the solar cell and used as a make-shift torch (a jack plug and socket could make the connection) – which could be the closest thing yet to the proverbial sun-powered torch! *(If you're really serious, then why not build the* White L.E.D. Super Torch *elsewhere in this issue – Ed.)*

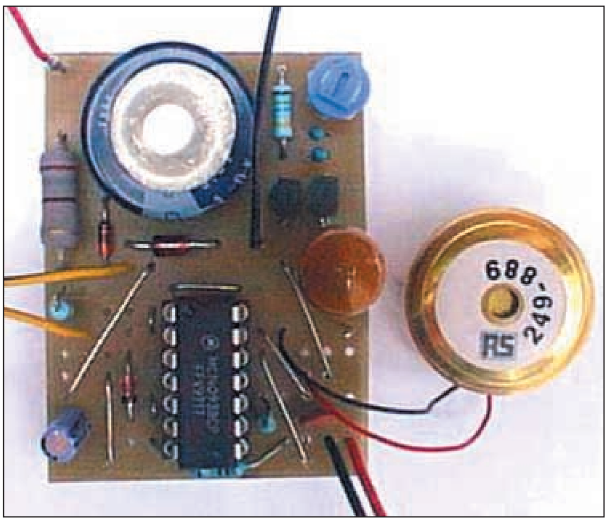
DON'T BE RAINED OFF

SUGGESTION 5 – TIMER

You might wish to build a simple Timer. Use the circuit of the Touch-Switch Door-Light. Note that this Timer sounds *while* timing, and falls silent at the end of the timing period. It would thus best be suited to shorter timing periods, where the activity being timed will not slip one's mind.

A value of about 10µF for capacitor C3 will provide a timing period of about four minutes. The Timer produces an unobtrusive tone rather than the higher tone used in alarm circuits in the series.

- Substitute a piezoelectric disc for the l.e.d. D4
- Substitute a 270pF capacitor for C4.



SOLAR-POWERED RAIN ALARM

Why not let the sun keep guard over your washing or give you an "early morning" call!

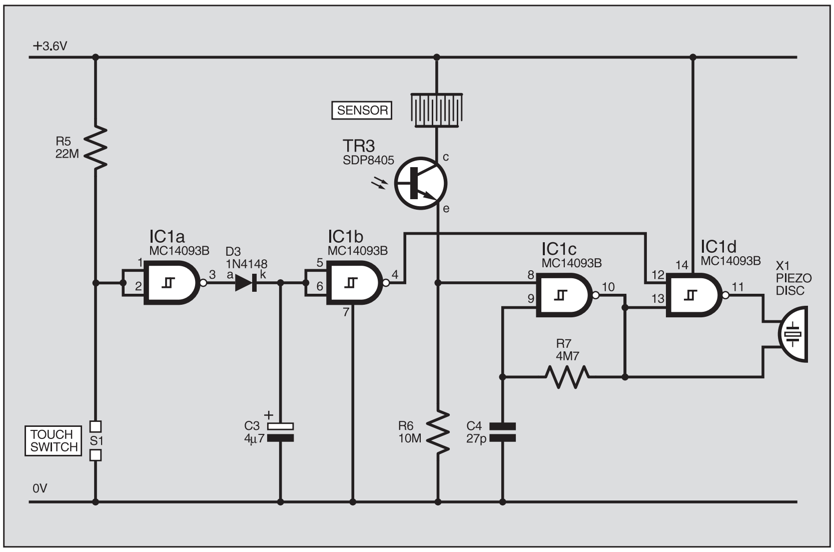


Fig.5. Circuit diagram of the Solar-Powered Rain Alarm. The component annotations run on from the power supply (July '01).

THE FIRST electronic project which the author ever constructed was a *Rain Alarm*, published in *Everyday Electronics* (June 1973). As simple as it was, he was very chuffed with the result!

The Rain Alarm in this Uniboard series is significantly different to that old rain alarm in at least one respect – there would have been no obvious way then to power such an alarm around the clock without batteries.

CIRCUIT DETAILS

The full circuit diagram for the Solar-Powered Rain Alarm is shown in Fig.5 and involves the most complicated logic of the series (as far as we can call it "complicated")! This is because the user would probably want to switch it *off* again when it is triggered by falling rain. How is this to be achieved without a mechanical switch?

It was decided that, when the alarm sounded, the touch of a finger would put it to sleep again for an hour or so. By that time, the sensor can have been rubbed down with a towel and given time to dry.

Note that oscillator IC1c continues to oscillate "in the background" *while* the sensor is wet. Therefore if the sensor does not dry within an hour or two, the regulator's "power" capacitor C1 may be exhausted until the sun again strikes the solar panel.

AUTO SNOOZE

The "off switch" action works as follows. When the touch-switch S1 is touched, IC1a is triggered and its output (pin 3) goes *high*. This charges capacitor C3, via diode D3, which causes gate IC1b's output, pin 4, to go *low*, switching off the buffer (IC1d) of oscillator IC1c.

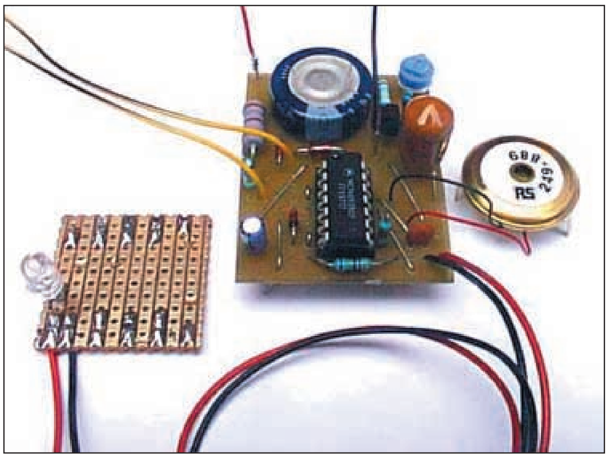
Diode D3 is included to prevent discharge of capacitor C3 once it has been charged. Once charged, C3 discharges through various leakage currents in the circuit. The value of C3 may be increased to increase the timing period, and vice versa.

The rain alarm also incorporates a phototransistor TR3, so that the circuit will switch off at night (washing is more often than not taken off the line by nightfall, and you would probably not want to be woken up in the early hours)! In this case, the phototransistor is wired in series with the sensor, being mounted on the sensor stripboard as shown in Fig.7. If triggering is unreliable, experiment with the value of resistor R6 – a higher value for greater sensitivity to light (and rain), and vice versa.

The oscillator IC1c is activated when a build-up of rain droplets spread (short circuit) across two copper sensor strips.

CONSTRUCTION

The rain alarm is built up on the Uniboard p.c.b., as shown in the topside component layout details of Fig.6. This board (*minus components*) is available from the *EPE PCB Service*, code 305. Once again, the *Solar-Powered Power Supply and Voltage Regulator* components are included in this diagram.



Completed Solar-Powered Rain Alarm with the warning sounder and small rain sensor attached.

SUGGESTION 6 – LIQUID-LEVEL ALARM

Use the circuit of the Rain Alarm. For an alarm that senses a *rising* liquid level, just one modification is required.

● Substitute *two probes* for the stripboard sensor. These trigger the alarm when they are bridged simultaneously by water.

● If you would like the Liquid-Level Alarm to be triggered by *falling* liquid level (e.g. an empty-tank alarm), swap the positions of the probes and resistor R6.

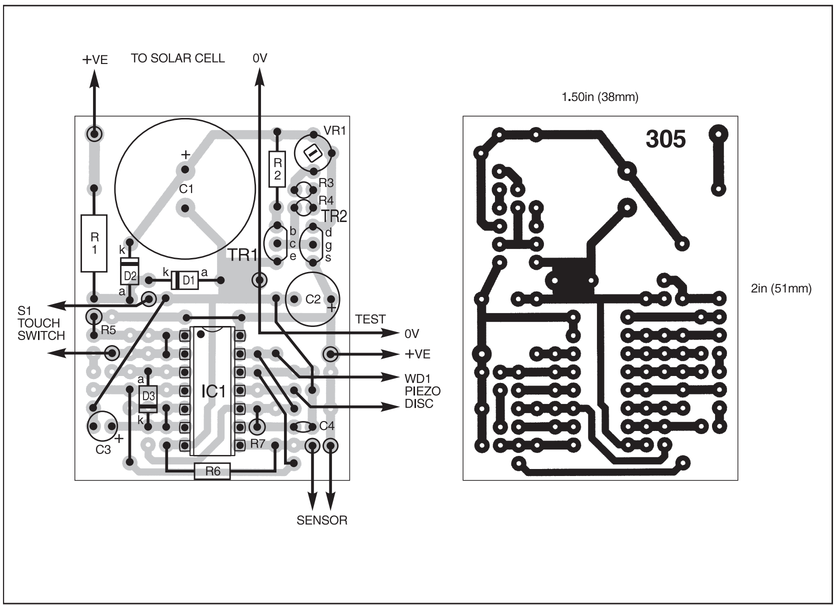


Fig.6. Uniboard component layout and full-size foil master for the Solar-Powered Rain Alarm. Includes the power supply from Part One (July '01).

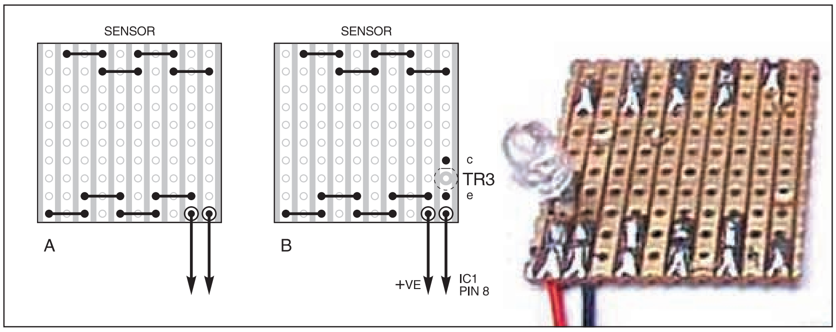


Fig.7. Rain alarm sensor topside (a) without and (b) with a phototransistor, mounted on the track side. (Right) Stripboard rain sensor with phototransistor soldered directly to the copper tracks.

Follow the same procedures as previously described, soldering the components to the board in sequence, finally inserting IC1, taking anti-static precautions. Take special care with the construction of this project, since a number of diagonal link wires are used.

The Sensor is made from a small piece of stripboard, as shown in the topside layout details of Fig.7. Alternate copper strips are wired together, so that each adjacent strip forms a bridge to its neighbour when droplets of rain fall into the gaps. The sensor is attached to the circuit by means of a length of twin-flex wire, so that the p.c.b. itself may be kept in a dry place.

Phototransistor TR3 is mounted on the sensor stripboard (Fig.7b) on the same side as the copper tracks, with a break being cut in the copper track between the collector (c) and emitter (e) leads. It should be placed where it will not be affected by any night-time light source such as a street lamp.

SETTING UP

The sensor should be sited where it will be struck by any falling rain or drizzle.

COMPONENTS

SOLAR-POWERED RAIN ALARM

Resistors

R5	22M metal film	See **SHOP TALK** page
R6	10M carbon film	
R7	4M7 carbon film	

All 0·25W 5%

Capacitor

C3	4µ7 sub-min. radial elect. 10V
C4	27p min. ceramic plate

Semiconductors

D3	1N4148 signal diode
TR3	SDP8405 *npn* phototransistor (optional)
IC1	MC14093BCP quad 2-input NAND Schmitt trigger

Miscellaneous

WD1	low profile wire-ended piezo sounder
S1	touch-switch – see text

Printed circuit board (Uniboard) available from the *EPE PCB Service*, code 305; piece of 0·1in. matrix stripboard, 10 strips x 10 holes, for sensor; multistrand connecting wire; link wires; solder pins; solder etc.

Note: Component designatons run on from the Solar-Powered Power Supply and Voltage Regulator *described last month (July '01)*

Approx. Cost Guidance Only £5

This project needs a supply of 3·6V, so the regulator's voltage should be adjusted to give this voltage – while the circuit is *sounding*.

Current consumption is virtually nil on standby, and about 500µA when the circuit is sounding. A moist finger on the sensor board will cause the Rain Alarm to sound.

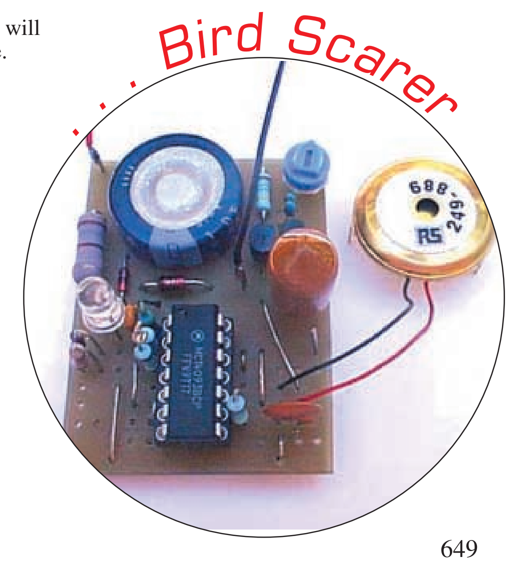
SUGGESTION 7 – WAKE-UP ALARM

Another variation on the Rain Alarm would be a Wake-up Alarm, to wake you at dawn (but no guarantees that this will get you to work on time)! An *npn* phototransistor is used to trigger the alarm at dawn.

The touch-switch S1 now serves as a "snooze" button. The value of C3 may be increased to give a longer snooze (even to switch it off all day), and vice versa.

- Substitute an *npn* phototransistor for the stripboard Sensor (if you have built a sensor with a phototransistor mounted on it, you may simply short the tracks of the sensor). Wire the phototransistor's emitter (e) to IC1 pin 8 (and R6), and collector (c) to the +3·6V rail.
- Change the value of resistor R6 to 2M2.

Next month we conclude this short "solar-powered" series with a *Gate Sentinel*, a *Register* and a *Bird Scarer* project. Plus a suggestion for a *Break Contact Alarm*.



SHOP TALK
with David Barrington

Water Monitor

Two of the components called up for the *Water Monitor* project are RS components and any local *bona fide* stockist, including many of our advertisers, will be able to obtain them for readers. The 12V d.c. water solenoid valve used in the prototype was ordered from their mail order outlet, **Electromail** (☎ ***01536 204555*** or ***http://rswww.com***), code 342-023. They also supplied the water flow sensor module, code 257-133.

There should not be any problems finding a suitable 2-line 16-character per line alphanumeric l.c.d. module as connection details are included for two possible formats. The one used in the author's model came from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***). You should specify that you wish to purchase one with a pin connector attached.

For those readers unable to program their own PICs, a ready-programmed PIC16F84 microcontroller can be obtained from **Magenta** (see above) for the inclusive price of £5.90 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (*EPE* Disk 4) from the *EPE* Editorial Office for the sum of £3 each (UK), to cover admin costs (for overseas see page 673). It is also available *Free* from the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/WaterMonitor**.

The printed circuit board is obtainable from the *EPE PCB Service*, code 317 (see page 673).

L.E.D. Super Torches

One or two problems could arise when "shopping" for parts for the *L.E.D. Super Torches*, particularly the red and white l.e.d.s and the ferrite r.f. choke.

The 8mm ultrabright red l.e.d. used in the *Red* L.E.D. Torch came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code UK24B. The rest of the semiconductors for the "red" version should be readily available. Watch out for the BC184***L*** transistor, other versions have a different pinout line-up. You must specify a "log" type for the Brilliance control VR1.

Both the 5mm extreme brightness (400-mcd) white l.e.d. (code NR73Q) and the MAX761 5V to 12V d.c.-to-d.c. step-up switching regulator (code NR61R) came from the above mentioned company. The MAX761 is also listed by **Electromail** (☎ ***01536 204555*** or ***http://rswww.com***), code 299-553. They also supplied the 47μH 1·2A ferrite bobbin r.f. choke, code 228-450.

The printed circuit boards for the torches are available from the *EPE PCB Service*, codes 313 (Main Red), 314 (Display Red) and 315 (White L.E.D.). The case used by the author for both torches is not the cheapest, but it does have a separate battery compartment and was obtained from Electromail, code 583-195.

Perpetual Projects 3 – Loop Burglar Alarm, Touch-Switch Door-Light and Solar-Powered Rain Alarm

As pointed out in the first instalment (July '01) of this short "solar-powered" series, the Motorola MC14093BCP quad 2-input NAND Schmitt trigger i.c. should be used in all these projects. It was obtained from **Electromail** (☎ ***01536 204555***) or ***http://rswww.com***) code 640-765. In fact, most of the "special" items came from this source.

The 5mm extreme brightness (3cd, 20° viewing) white l.e.d. used in the *Touch-Switch Door-Light* carries the code 310-6690 and the optional SDP8405 phototransistor for the Solar-Powered Rain Alarm is coded 122-267.

The low-profile piezo sounder also came from them, code 249-889, as did the solar cell, code 194-098. you could try using one of the standard disc type piezoelectric sounders.

All three of these projects, plus the additional suggestions, can be built on the special Uniboard p.c.b., which is available from the *EPE PCB Service*, code 305 (see page 673).

Synchronous Clock Driver

The main cause of concern regarding parts for the *Synchronous Clock Driver* is likely to be finding mains transformers which will fit on the circuit board. Once again, these are RS component types and local *bona-fide* stockists should be able to help.

All of the following were ordered through **Electromail** (☎ ***01536 204555***), their mail order operation: p.c.b. mounting mains transformers, 0V-9V 6VA twin secondaries (code 805-669) and 0V-15V 6VA twin secondaries (code 805-681); 100μH 2·6A toroidal inductor (306-8605); class X2 275V a.c. suppression capacitor (124-5591) and the 5p to 65p trimmer capacitor (125-660).

The original supplier of the IRF540 *n*-channel MOSFET has now stopped stocking it. However, we have found the above company has two listings (codes 655-486 and 244-9536) and also that **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***) carry two entries (354-375 and 260-204) for it.

A pre-programmed PIC16F84 microcontroller can be purchased from the author for the sum of £6 (add £1 for overseas). Orders (mail only) should be sent to **Andy Flind, 22 Holway Hill, Taunton, Somerset, TA1 2HB**. Payments should be made out to *A. Flind*. For those who wish to program their own PICs, the software is available from the Editorial offices on a 3·5in. PC-compatible disk (*EPE* Disk 4), see *PCB Service* page 637. It is also available *Free* via the *EPE* web site: **ftp://epemag.wimborne.co.uk/pub/PICS/synclock**.

Finally, the printed circuit board is available from the *EPE PCB Service*, code 316 (see page 637).

PLEASE TAKE NOTE

Compact Shortwave Loop Aerial *(August '01)*

Some readers have reported problems in obtaining the varicap diode for the loop aerial. Peter Thomas of JAB has confirmed that he is holding good stocks of the KV1235 and KV1236. The prices are £3.80 for the KV1235 and £2.25 for the KV1236. Postage is £2.00 for orders under £5.00 and £1.20 for orders between £5 and £20. Orders should be placed by fax (☎ ***0121 681 1329***) or E-mail (**Peter@JAB.Demon.co.uk**). Mail orders should be sent to: **JAB Electronic Components (☎ 0121 682 7045), PO Box 5774, Birmingham, B44 8PJ**.

Cricklewood Electronics (see their ad on page 659) have offered the BB112 single varicap diode as an alternative. This should be OK but has not been tried in the model.

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JULY '00

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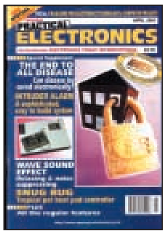

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M09/01

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

THE TOPIC of this month's article could be described as "loose ends". Beginners at electronic project construction are often fazed when they find the construction diagrams for a project have one or more tags, pins or leads unconnected. Surely the project cannot possibly work with one or more of the components only partially connected?

Spare Capacity

The simple answer to this is that most projects can and do work even though some of the components have these "loose ends". There are two main reasons for some of the tags, etc. not connecting to anything. One is the use of standard encapsulations for some types of component, and integrated circuits (i.c.s) are the most common example of this.

Integrated circuits are available in standard case sizes and styles having from six to 40 or more pins. All the normal types of encapsulation have an even number of pins, but some devices require an odd number of pins. If an operational amplifier (op.amp) only requires seven pins, it will therefore be housed in an 8-pin type with one terminal having no internal connection.

In the past it was quite common for some integrated circuits, but op.amps in particular, to be produced in various eight and fourteen pin versions. Why the 14-pin versions were produced is not too clear, but it meant that these devices had about six or seven pins that did not have internal connections.

This practice has now largely ended, but there are still a few integrated circuits that have far more pins than are actually needed. The number that have one unused pin is much more substantial.

Pinouts

If you look at pinout diagrams for some integrated circuits you will probably find some of the pins marked "n.c.". These are the ones that are unused, and "n.c." simply stands for no connection. Fig.1 shows the pinout diagram for the 741C op.amp and the many pin compatible types. Pin 8 is marked "n.c.", and is therefore unused.

Occasionally there may be a pin that is designated "IC" (internal connection), "Test", or something of this type. This indicates that there is an internal connection to the pin, but that no external connection is made in normal use. It is provided for use in the manufacturer's final testing procedure.

It is usually quite easy to eliminate unused integrated circuit pins as a source of problems. Checking the circuit diagram should show that the pin or pins in question do not connect to anything. Either the pins in question will be included on the circuit diagram but there will be no "wires" connected to them, or the pins will simply not be shown at all.

In the unlikely event that there is a definite discrepancy between the circuit diagram and other diagrams in the book or article, the publisher of the material should be able to provide corrections. If there is a strong possibility of an error in a construction diagram, do not simply press on and hope for the best. There is a risk that components could be damaged if you do, and there could be safety issues as well.

Part-time Components

The second cause of unused connections is components that are not fully utilized. This is quite common with integrated circuits that contain two or more elements, such as logic devices that contain several gate circuits or amplifier packages that contain several op.amps.

If a design requires (say) two CMOS 2-input NOR gates, a quad 2-input NOR gate has to be used because a twin version is not manufactured.

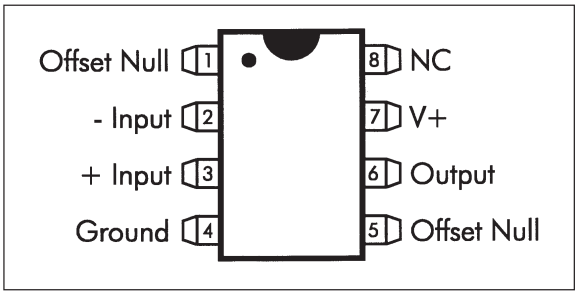


Fig.1. The 741C op.amp pinout details. There is no internal connection to pin 8, and pin 1 and pin 5 are little used in practice.

Depending on the device in question, unused sections may simply be ignored, or unused inputs could be connected to one or other of the supply rails.

However, with most MOS input devices there can be problems if unused inputs are left unconnected. They are vulnerable to damage from static charges and can be operated by stray signals, producing an unnecessary increase in current consumption.

Connecting the inputs to one or other of the supply rails avoids these problems. This still leaves any unused outputs unconnected though. Again, checking the circuit diagram should show whether or not there are any missing connections on the layout diagrams, or simply some unused pins.

Integrated circuits often have one or two pins that are not utilized because they provide functions that are unnecessary in most applications. Returning to the 741C op.amp (Fig.1), pin 1 and pin 5 provide an offset null facility. This enables better accuracy to be obtained in precision d.c. applications. Although originally designed for applications of this type, op.amps now have a wide range of uses. Consequently, in the vast majority of applications any offset null pins are left unused.

Transformers

The transformer is another type of component that is often only partially utilized. Whether a project requires a radio frequency (r.f.), audio frequency (a.f.) or mains transformer, designs for the home constructor do not usually have the luxury of a custom component. Instead the designer usually has to do the best he or she can with an "off the shelf" component.

Rationalisation by manufacturers and retailers means that only a limited range of transformers is readily available these days. It is often necessary for the designer to settle for a component that is less than ideal. Where there are three or four connection points on a winding, only two might actually be used. In some cases a complete winding is left unused.

Where an audio or mains transformer with flying leads has one or two spare leads, do not simply leave the leads flapping around inside the case. It is best to cut the leads quite short and then insulate the ends with p.v.c. sleeving or insulation tape. This ensures that there can be no accidental connections to other parts of the circuit. It is a good idea to tape the leads to the case, or chassis rather than just leaving them dangling.

Rotary Switches

Switches represent another type of component where the designer has to make the best of what is available to the home constructor. This is not usually a problem where the more simple switches are required, but there can sometimes be one or two tags left unconnected.

There can be and often are many unused tags where multi-way rotary switches are involved. I must have used multiway rotary switches hundreds of times over the years, but you could probably count on the fingers of one hand the number of times that all the tags were used. The multiway rotary switches used in most designs for the home constructor are supplied in four types, which are 3-way 4-pole, 4-way 3-pole, 6-way 2-pole, and 12-way 1-pole.

Modern switches of this type invariably have an adjustable end-stop (Fig.2). If a design required (say) a 5-way 2-pole switch, it is actually a 6-way 2-pole switch that would be used, with the end-stop set for 5-way operation.

Fig.2. Multiway rotary switches have an end-stop that fits over the mounting bush.

Where a 3-way 2-pole switch is required, the designer would probably opt for a 3-way 4-pole type with two poles left unused. Alternatively, a 6-way 2-pole type set for 3-way operation could be used. Either way, something like half the tags would be left unused.

The pole tags of rotary switches are usually labelled A, B, etc., and the other tags are numbered from 1 to 12. In the case of a 6-way 2-pole switch for example, tag A is used with tags 1 to 6, and tag B is used with tags 7 to 12. This makes it much easier to get these switches connected correctly.

Relays

It is perhaps worth mentioning relays. A relay is a two-way switch that is operated via an electromagnet. For maximum versatility relays often have two or four sets of changeover contacts.

Many practical applications require a basic on/off action. A changeover switch can be used as an on/off type by using the pole tag and one of the other two. This often results in two tags being used and four or 10 tags being left unused.

Connectors

The connectors used with computer projects often have a number of unused pins. This is partially due to the use of standard connectors that do not always have the exact number of terminals required, and the compromises this requires. Also, a computer interface may have twenty input and output lines, but many practical applications require something like two inputs and three outputs.

It is not uncommon for about half a dozen connections to be made to a 25-way connector. The other pins are either totally unused or are not required in that particular application.

There are also plenty of examples where all but one or two pins are left unused, and it is these that tend to get inexperienced constructors worried. With only one or two pins unused it looks as if something has been overlooked, but it is likely that everything is actually present and correct.

"Spare" pins are less common when dealing with audio connectors, although you may occasionally encounter DIN plugs and sockets that have some unused terminals. This stems from the use of 5-way connectors that act as stereo inputs and outputs. Two pins are left unused where only an input or an output is required.

Jack Connectors

Jack sockets are the more common cause of problems. Mono jack sockets are 2-way connectors, but the 2·5mm and 3·5mm types often have three tags, and many standard types sport four tags! The reason for the extra tag or tags is that the socket incorporates a switch.

Jack connectors are used in a variety of audio applications, but one of their most common uses is with headphones and earphones. The switch contacts are normally closed, but open when a plug is inserted into the socket. The switch is used to automatically switch off the internal loudspeaker when the earphone or headphones are in use. These days most applications do not require any built-in switch, and one or two tags are often left unused.

The correct method of connection for switched versions of standard (6·35mm) and 3·5mm sockets is shown in Fig.3. Switched 2·5mm jack sockets are the same as the 3·5mm type incidentally, but scaled down slightly. There is an extra tag on the standard jack socket because it has two sets of switch contacts. The loudspeaker is totally disconnected when the plug is inserted.

A 3·5mm jack socket has only one built-in switch, and one lead to the loudspeaker is not switched. Of course, disconnecting one lead is sufficient to mute the loudspeaker. If the switching action is not required, the two leads to the loudspeaker are omitted.

Not all jack sockets have the integral switch contacts, so make sure you ob-tain a socket of the correct type where a design does require automatic switching. The switched sockets shown in Fig.3 are the most common types, but there are some variations. Some 3·5mm sockets are a sort of miniature version of the standard type for example.

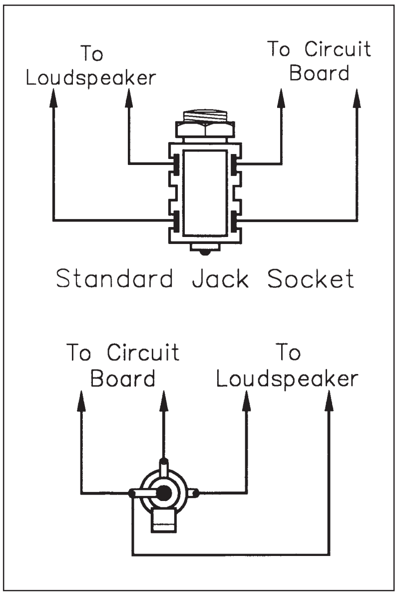
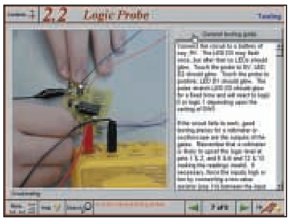


Fig.3. Using jack sockets to provide automatic muting of a loudspeaker.

Retailers' catalogues sometimes provide diagrams that show the functions of the tags on the more exotic jack sockets. Failing that, the most basic of continuity testers plus some simple checks will soon show which tags connect to the plug, and the connections between tags when the plug is removed.

ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS



Logic Probe testing

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

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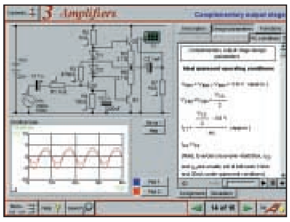
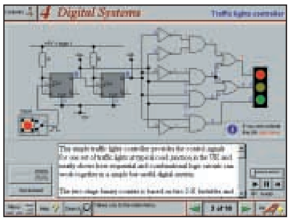


Complimentary output stage

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

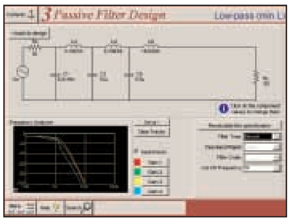
DIGITAL ELECTRONICS



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.

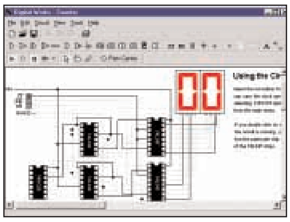
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability.

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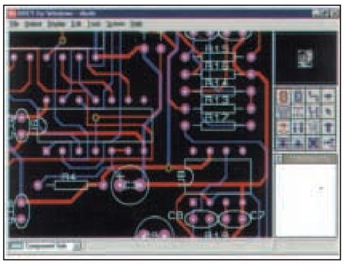
- Powerful tool for designing and learning

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: **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 even a **fully functional autorouter**.

"C" FOR PICMICRO MICROCONTROLLERS

C for PICmicro Microcontrollers is designed for students and professionals who need to learn how to use C to program embedded microcontrollers. This product contains a complete course in C that makes use of a virtual C PICmicro which allows students to see code execution step-by-step. Tutorials, exercises and practical projects are included to allow students to test their C programming capabilities. Also includes a complete Integrated Development Environment, a full C compiler, Arizona Microchip's MPLAB assembler, and software that will program a PIC16F84 via the parallel printer port on your PC. (Can be used with the *PICtutor* hardware – see opposite.)
Although the course focuses on the use of the PICmicro series of microcontrollers, this product will provide a relevant background in C programming for any microcontroller.

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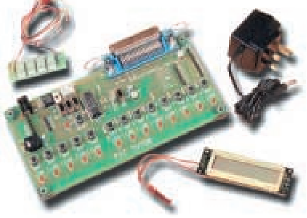

Deluxe PICtutor Hardware

This highly acclaimed CD-ROM, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject.
Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

HARDWARE
Whilst the CD-ROM can be used on its own, the physical demonstration provided by the **PICtutor Development Kit**, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work.
Two levels of PICtutor hardware are available – Standard and Deluxe. The **Standard** unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials. The **Deluxe** Development Kit is supplied with a plug-top power supply (the **Export** Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC. All hardware is supplied **fully built and tested** and includes a PIC16F84.

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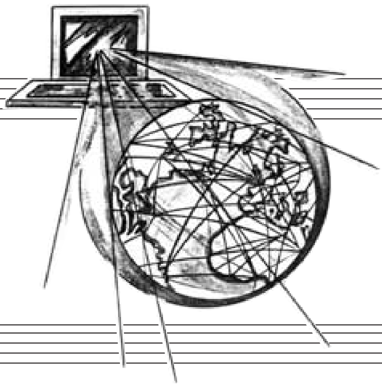


Windows Shopping

In my ten years' experience of internet usage, including five years or so of shopping over the internet, I have purchased many items from the USA at prices considerably cheaper than any available in the UK. However, my internet shopping experiences had not been entirely trouble-free: a small order placed with the Exploratorium Online Store in the US resulted in over a dozen inexplicable debits and credits being made on my credit card account; then the goods were delivered twice.

Shipping companies such as DHL and UPS have also gained a new market, as they can pocket a £10 documentation fee merely for collecting a few pounds of import duty from the consignee. The courier UPS in the UK received a major blackmark from the writer, for threatening to sue him for import costs related to an American import which he had already paid, cash on delivery.

After ordering a new PC online last year, Dell Computers UK delivered it three weeks late, missing the year end, which has cost the writer £1,800 ($2,700) in postponed tax allowances. It would also appear that internet orders placed with Dell UK were re-input by human beings: how else would it become a desktop PC (I ordered a mini tower) fitted with a much cheaper graphics card as well? Only an expert would have noticed that the required video card had not been fitted.

Of course problems like these are not limited to internet orders and generally the internet provides an easy, quick and efficient way of buying, as our own transactions with readers buying from the *EPE* online shop at **http://www.epemag.wimborne.co.uk/shopdoor.htm** proves.

Everything I have bought has been transacted in US dollars or Pounds Sterling. In fact, I have to say that the Euro currency, or any other currency (apart from one transaction for $Australian 400), has never featured on the internet landscape although I fear the Euro soon might. Nevertheless it is towards mainland Europe that I now look as regards the future of broadband Internet services.

Satellite Links

For a regular internet user like myself, who has become tired of BT's confusing and constantly changing array of tariffs, who is fed up of squawking modems, who gets nowhere trying to get a cable modem installed (NTL laid a CATV cable in the pavement just yards away years ago, but never switched it on), or for whom DSL will never happen – then help may be at hand towards the end of 2001.

Tiscali International (**www.tiscali.com**) is the Italian ISP and telco that now owns the major UK ISP LineOne (**www.lineone.net**) and France's Liberty Surf. Tiscali's avowed intention is to become one of the top three ISP's in every major European country.

Interestingly, Tiscali is aiming to roll out satellite internet services across Europe and South Africa through their TiscaliSat subsidiary (**http://satellite.tiscali.com**). That's right – install a small satellite dish and you have unlimited usage, always-on bi-directional internet access with no cable worries, no tie-ins to local telephone or cable TV services nor any complicated tariffs – almost anywhere in the country. It may be the ultimate "wireless" internet service for the regular-to-heavy internet user and it will also have a flat-rate monthly fee.

TiscaliSat claims download at speeds up to ten times faster than dial-up services. It is claimed that speeds will often reach 400kbps with targeted peak-time speeds in excess of 150kbps, with current upload speeds ranging between 40kbps and 140kbps. You can register your interest on their web site, and a pan-European service is promised by the end of the year. I am keeping a close watch.

May the farce be with you

My faithful Nokia 8100 mobile phone had served me well for half a decade but it was recently traded in for a new Nokia 6210. Actually, the phone upgrade was prompted by a recent mishap, when a high-sided lorry ripped down all my overhead phone lines, leaving me completely "wire-less" for several days. If only I had satellite....

However, the new phone does have infra red. Although IR communications are tediously slow, at least you can communicate in "black and white" by sending plain text emails from a laptop computer. Or you could try sending mail through a WAP phone, which is a hideously slow and cumbersome process.

Wireless Application Protocol promised much but has failed to live up to anyone's expectations: this is the industry's fault to start with, as the service has been hyped to death, not helped by TV adverts that imply that all manner of information is available instantly on tap – what they don't show of course, is the chronic process of logging in and tapping away on a small keypad in order to access the WAP service at all. Then there's the waiting!

My WAP service was to be enabled after three working days (Wednesday), but a week later it was still inoperative. I was told that in order to enable the service, I had to call BT Cellnet myself to arrange it. I did this several times. On the Saturday, they finally provided me with data and fax numbers that I needed to configure the new phone, adding that I would need to speak to Genie (**www.genie.co.uk**), the mobile internet service, to get the WAP service set up.

A few hours later, BT called back to say that actually, I needed to enter some different fax/data numbers instead – I explained that writing them down could be difficult because I was driving down the motorway at a fair rate of knots at that time. They suggested I call them back – which I did, except the number turned out to be that of Syncordia, a marketing call centre that closes at the weekends.

Back to BT Cellnet. A terse BT call centre worker insisted that their call centre never closes ("well that one was," I exclaimed) and that I should be talking to BT Cellnet's main office anyway. But no, to switch on the WAP service they insisted that I speak to Genie again. Genie charges 50p/minute for these calls but their operator, in turn, knew nothing about setting up a mobile phone for WAP, as they only handle PC desktop services at that call centre.

Back to BT Cellnet yet again!, where BT still refused to have anything to do with WAP phones, least of all enabling it on mine. "Call Genie again," said the BT Cellnet agent "and tell them you want something called the 'con-fig-ur-ation' settings for your WAP phone". Oh, right....

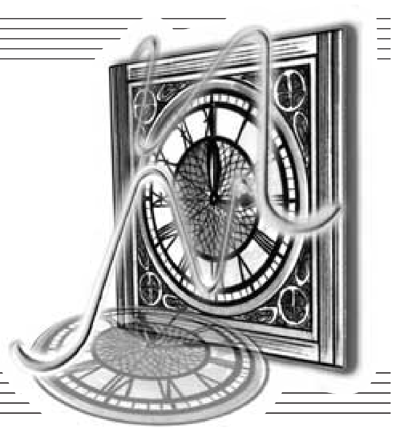
Before giving it up as a bad job, the last resort was to speak to Genie yet again (50p/minute remember); actually, an extremely helpful Genie operator explained that BT Cellnet were supposed to be handling all such WAP configuration queries now, or at least that's what they had been told. Nevertheless he looked up my model of phone and went through all the set-up pages. My phone suddenly bleeped as we spoke: WAP had finally been enabled. The moment of truth had arrived.

A Genial Genie

Only, there was a bug in the system, explained the genial man from Genie – the password setup doesn't work properly, so I would have to enter that manually, and then re-enter it to confirm. It was at that point that I had my first taste of typing text into a WAP phone, and I can tell you that the convoluted process almost put me off using a WAP phone for good.

Nevertheless, I did manage to login, create a new account and send one tiny E-mail, a few words that took a good four or five minutes to prepare and send. Somehow I don't think that 100 free minutes a month will go very far: I think I'll stick to my laptop and infra red. Or wait for satellite. You can check out WAP set-up issues for your model of phone at the Genie web site.

You can E-mail me at **alan@epemag.co.uk** but not by WAP, please!



SYNCHRONOUS CLOCK DRIVER

ANDY FLIND

By popular request – a dual-frequency, 50Hz/60Hz converter for mains operated synchronous clocks.

THIS project took shape following a request for advice from UK reader Chris Betts with a rather attractive American synchronous clock, which naturally enough he wanted to see in operation.

Many readers will know that these clocks rely upon accurate frequency of the a.c. mains supply for their timekeeping, and that the supply across the pond is 60Hz, whereas ours here in Britain is 50Hz. This means that even if the voltage were to be transformed down to the US standard of 115 volts, the clock would still lose ten minutes per hour in the UK. The fact that this would be a very accurate ten minutes is not really much compensation!

A reply of a fairly general nature was given in *Readout* (April '01), to the effect that the solution would be to construct a sinewave source of suitable frequency and power and transform it up to the required voltage. Whilst basically correct, this is not very helpful to someone with insufficient experience to design such a circuit.

MEETING TIME

As a fellow clock enthusiast, the present author asked to be put in touch with the reader and a meeting, complete with the clock, was duly arranged. The possibility of a constructional feature for *EPE* wasn't overlooked of course.

The clock was purchased through an internet auction so there must be others like it which need a suitable driver. Some of our British synchronous clocks are becoming collectible nowadays too, and it is likely that some of these will have found their way to America.

A circuit designed to supply 60Hz here could easily be modified to provide 50Hz over there, where *EPE* is well known through the internet. A further application for a 50Hz circuit can be found in the operation of public clocks from an uninterruptible battery-backed supply.

Most modern public clocks are simply convex dials that can be fixed to an external surface, with space behind the centre for a robust synchronous movement which operates the hands. If the mains supply fails for a few minutes it's often necessary to call the expert with a ladder!

Because of this, it is possible to purchase commercially produced "synchronisers" which work by monitoring the total mains failure time. When this exceeds around thirty seconds the device stops the clock for exactly eleven hours, fifty nine minutes and thirty seconds before starting it again!

This is hardly an ideal solution, especially when it is known that the price of such equipment is typically several hundred pounds.

MYSTERY CLOCK

The clock in this project is a Jefferson "mystery" clock, so called because it is not immediately obvious how it works. As can be seen in the photograph, it has a gold lacquered base to house the motor and a gold metal outer dial surround with the numerals. This holds a circular glass panel, to the centre of which the hands are attached.

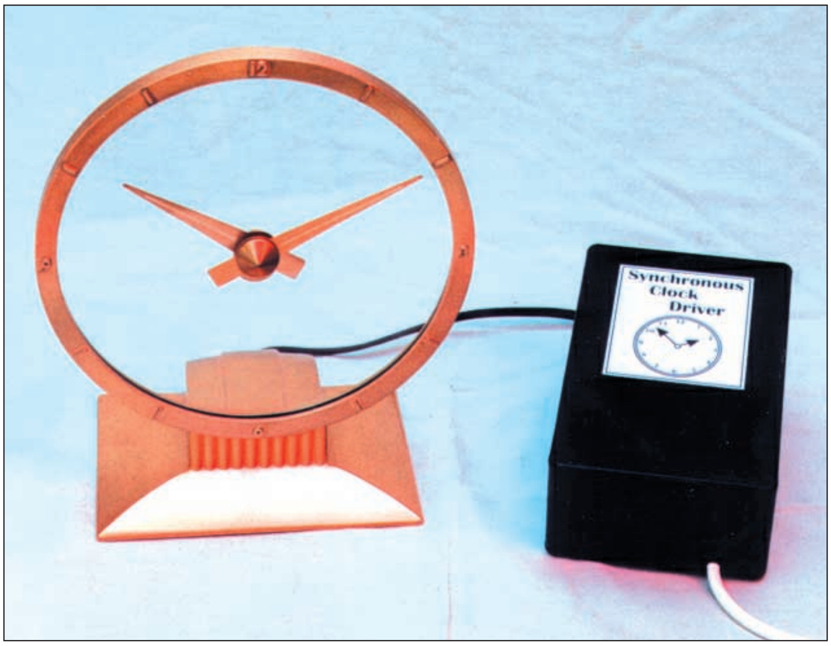
There is no apparent mechanical connection to the hands, so the "mystery" is how power from the motor is transmitted to them. Readers can ponder this question for the present (answer at the end of the article!) It's certainly a good looking clock so it's owner's desire to see it working is easy to understand.

PIC THE FREQUENCY

Moving to the design, a PIC microcontroller was chosen as the basis for the design since it already has a robust crystal oscillator circuit and can be programmed to divide this by almost any factor of one's choice.

Considering this for a moment, it should be apparent that to generate an output of a given frequency, the PIC must perform the minimum action of switching an output on for half a cycle, then off for half a cycle, so the period of half a cycle of the desired output must be exactly divisible by an integer number of periods of the PIC instruction cycle, remembering of course that the PIC divides it's crystal frequency by four to get the instruction cycle frequency.

Clear as mud? Well, try dividing the crystal frequency by eight times the desired output frequency. If there's a fraction in the answer that frequency isn't available. This explains the choice of a 3·6864MHz crystal for this project, as these are readily available and their



frequency can be divided easily to obtain 60Hz.

Experiments began with the synthesis of a fairly good sinewave with the PIC and driving the output transformer – a mains type used "backwards" – with a power amplifier i.c. intended for in-car audio power-boosting applications.

This worked but the use of linear power circuitry resulted in rather wasteful heat generation, mostly from the power amplifier stage. It also led to a fairly complex circuit so a large case with external heatsinking would have been required.

WAVEFORM UNIMPORTANT

When the clock was tested however, it was found that so long as the frequency was correct and sufficient voltage was available, the waveform was unimportant. This led rapidly to a circuit using switching outputs, which is much simpler, generates practically no heat and is consequently physically smaller and far more efficient. The principle of this is shown in Fig.1.

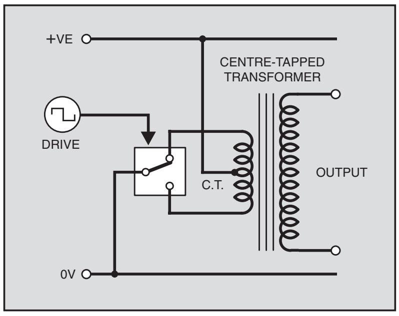


Fig.1. Switch-mode voltage conversion.

A centre-tapped transformer has the tap connected to the positive supply. The two ends of the winding are connected alternately to ground at the required output frequency by a switch, effectively creating an a.c. drive. In practice, power MOSFET devices replace the switch and are driven with pulses from the PIC.

Most synchronous clocks can operate from much less than their rated voltage. In the present case, the 115V clock motor started reliably from 70V, so 100V was considered perfectly adequate. Lower voltage means lower power consumption and less heat generation within the clock motor, which should reduce drying out of the lubricants and therefore less wear and tear.

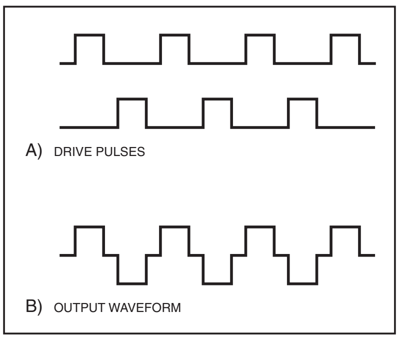


Fig.2. Combining two pulses to create a variable output waveform.

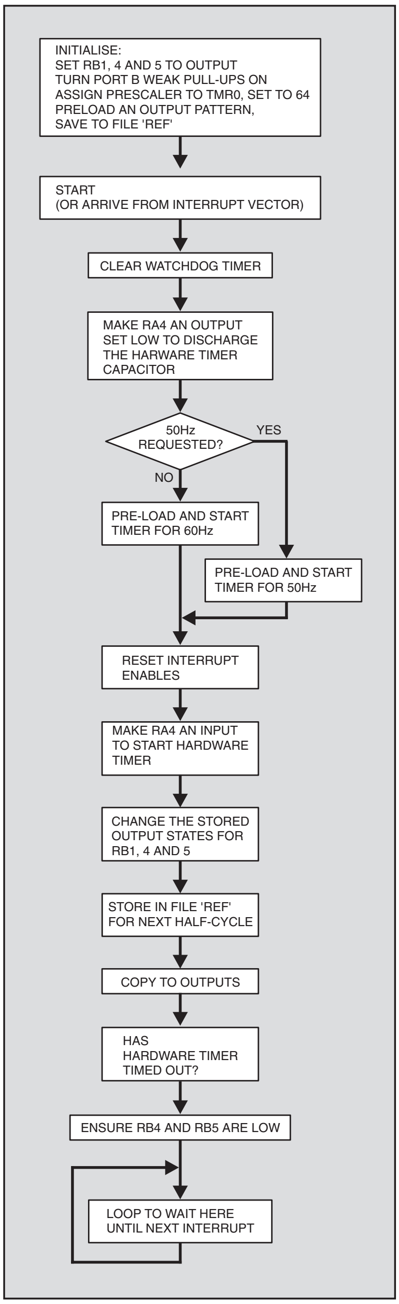


Fig.3. Flow chart for the PIC-based control program.

The output voltage of the switching circuit may be easily controlled by adjusting the width of the output pulses to the MOSFETs, keeping each of them "on" for only part of a half cycle, as shown in Fig.2. This can be made user-adjustable with a preset control.

FLOWCHART

The operation of the PIC software is shown in the flowchart of Fig.3. This has been arranged to provide either 50Hz or 60Hz, the former being obtainable by shorting a couple of adjacent points on the printed circuit board (p.c.b.).

The interrupt facility of the internal timer is primarily used to control frequency, though readers examining the software will find a couple of small timing loops and "NOPs" used to fine-tune to the exact number of cycles required.

The usual initialisation is carried out, setting RB1, RB4 and RB5 as outputs, turning on the internal Port B pull-up resistors (for the pins used as inputs) and assigning a prescaler set to a factor of 64 to the timer.

A register named **REF** is used to hold the current states of the three outputs and is pre-loaded at this stage. Program flow then reaches the point to which it will return following each interrupt. The watchdog timer is enabled in this design, so first this is cleared *(nice to see WDT being used in a project! Ed).*

HARDWARE TIMING

Next we come to the hardware timer used to control the output pulse width. This consists of a small-value capacitor connected to RA4, with a preset resistance to charge it from the positive supply. RA4 is made an output and set low to discharge the capacitor, then it is made an input and monitors the capacitor voltage until it deems this to be high for a period adjustable with the preset.

As an input, RA4 has Schmitt characteristics so it is particularly suitable for this task. With RA4 having been put into the discharge state, RB3 is checked to see if it is low to decide whether the program is going to proceed with timing for 60Hz or branch to that for 50Hz.

In each case some fine tuning delays are executed and then the timer, TMR0, is preloaded with the necessary factor for the appropriate interrupt time. The interrupt enable bits are then reset, and RA4 is changed back to an input since by now the capacitor should be sufficiently discharged. The Timer Interrupts panel later details how precise software timing is achieved.

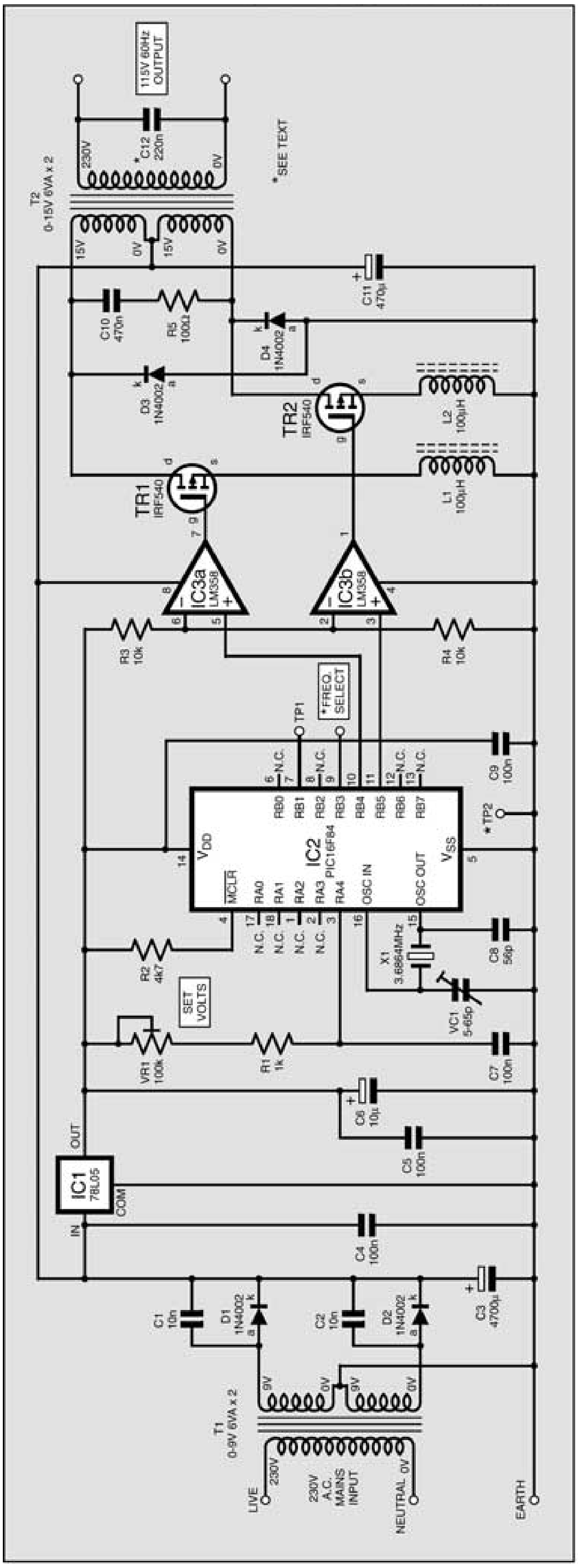
The XOR instruction is used to change the state of the three output bits in register **REF**, the new values are stored and applied to the outputs. Then the program waits for the hardware timer to complete, ensures both the MOSFET drives are off, and waits in a loop for the next interrupt before repeating these actions. If the hardware timer never times out it won't matter since the output drives will be switched by the next run through this procedure anyway, giving full alternate half cycles of drive.

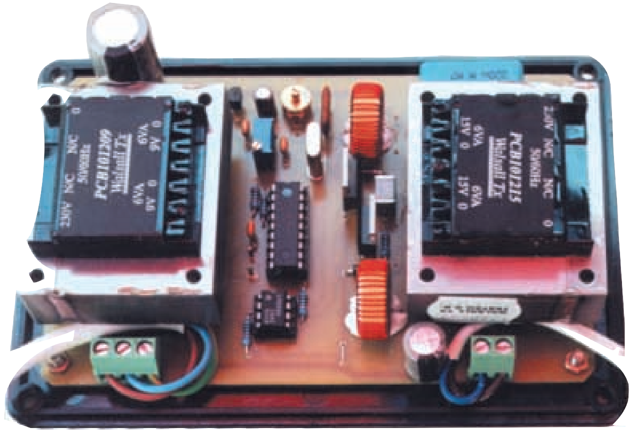
CIRCUIT DIAGRAM

Moving to the full circuit of Fig.4, the current required by this circuit can be up to three or four hundred milliamps so the supply section has to be capable of this, although in most cases the supply current will be closer to 250mA. Transformer T1 is therefore a dual 6VA type, with two 0-9V secondaries capable of over 500mA.

This is slightly "over the top", but more copper and iron in the transformers was found to improve efficiency, especially on the output side. The type used is compact, p.c.b. mounting and inexpensive, so is well suited to this design.

The classic two-diode full-wave rectifier circuit is used, with diodes D1 and D2 and reservoir capacitor C3 developing around 12V d.c. A lot of care went into minimising radio frequency (r.f.) emission from this circuit. It is likely to be operated continuously so interference caused by it could be particularly troublesome.





COMPONENTS

Approx. Cost Guidance Only £32 excluding case.

See **SHOP TALK** page

Resistors

R1	1k
R2	4k7
R3, R4	10k (2 off)
R5	100Ω

All 0·6W 1% metal film.

Potentiometers

VR1	100k multiturn cermet preset, vertical

Capacitors

C1, C2	10n ceramic, resin-dipped (2 off)
C3	4700µ radial elect. 25V
C4, C5, C7, C9	100n ceramic, resin-dipped (4 off)
C6	10µ radial elect. 25V
C8	56p silver-mica
C10	470n polyester, 100V
C11	470µ radial elect. 25V
C12	220n X2 suppression type, 275V a.c.
VC1	5p-65p trimmer

Semiconductors

D1 to D4	1N4002 rectifier diode (4 off)
TR1, TR2	IRF540 *n*-channel MOSFET (2 off)
IC1	78L05 +5V 100mA voltage regulator
IC2	PIC16F84 microcontroller, preprogrammed (see text)
IC3	LM358 dual op.amp

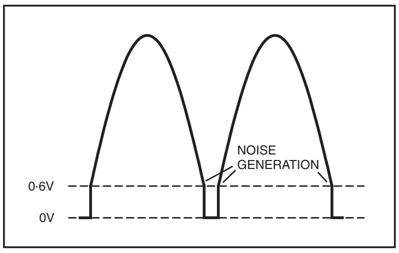
Miscellaneous

L1, L2	100µH 2·6A toroidal inductor (2 off)
T1	mains transformer, p.c.b. mounting, with dual 9V, 6VA per winding, secondaries
T2	mains transformer, p.c.b. mounting, with dual 15V, 6VA per winding, secondaries (see text)
X1	3·6864MHz crystal (see text)

Printed circuit board, available from the *EPE PCB Service*, code 316; plastic size case, 150mm × 100mm × 60mm; 8-pin d.i.l. socket; 18-pin d.i.l. socket; p.c.b. mounting terminal block 2-way, 5·08mm pitch; p.c.b. mounting terminal block 3-way, 5·08mm pitch; mains connectors and cable to suit; connecting wire; solder etc.

Fig.4 (left). Complete circuit diagram for the Synchronous Clock Driver.

Fig.5 (right). Noise generation across a rectifier diode.



Eventually the "noises" were suppressed to the point where a loud buzz still detectable by a radio at close range proved to be coming from this rectifier stage. The reason for this is that silicon diodes have a small forward voltage drop, of typically about 0·6V, leading to kinks in the output around the zero-crossing points, as shown in exaggerated form in Fig.5.

Small capacitors are sometimes used to suppress this noise so the feature was included in this circuit with C1 and C2, which cured the problem completely.

A standard 78L05 +5V 100mA regulator, IC1, is used to provide power for the PIC, IC2.

The 3·6864MHz crystal, X1, has a 5-65pF trimmer on the input side, VC1, for fine adjustments to the output frequency. The other capacitor associated with this part of the circuit, C8, is a 56pF type. These values are relatively high compared to the 30pF stated in the manufacturer's (C-MAC) data, but were found by experiment to be correct for this application.

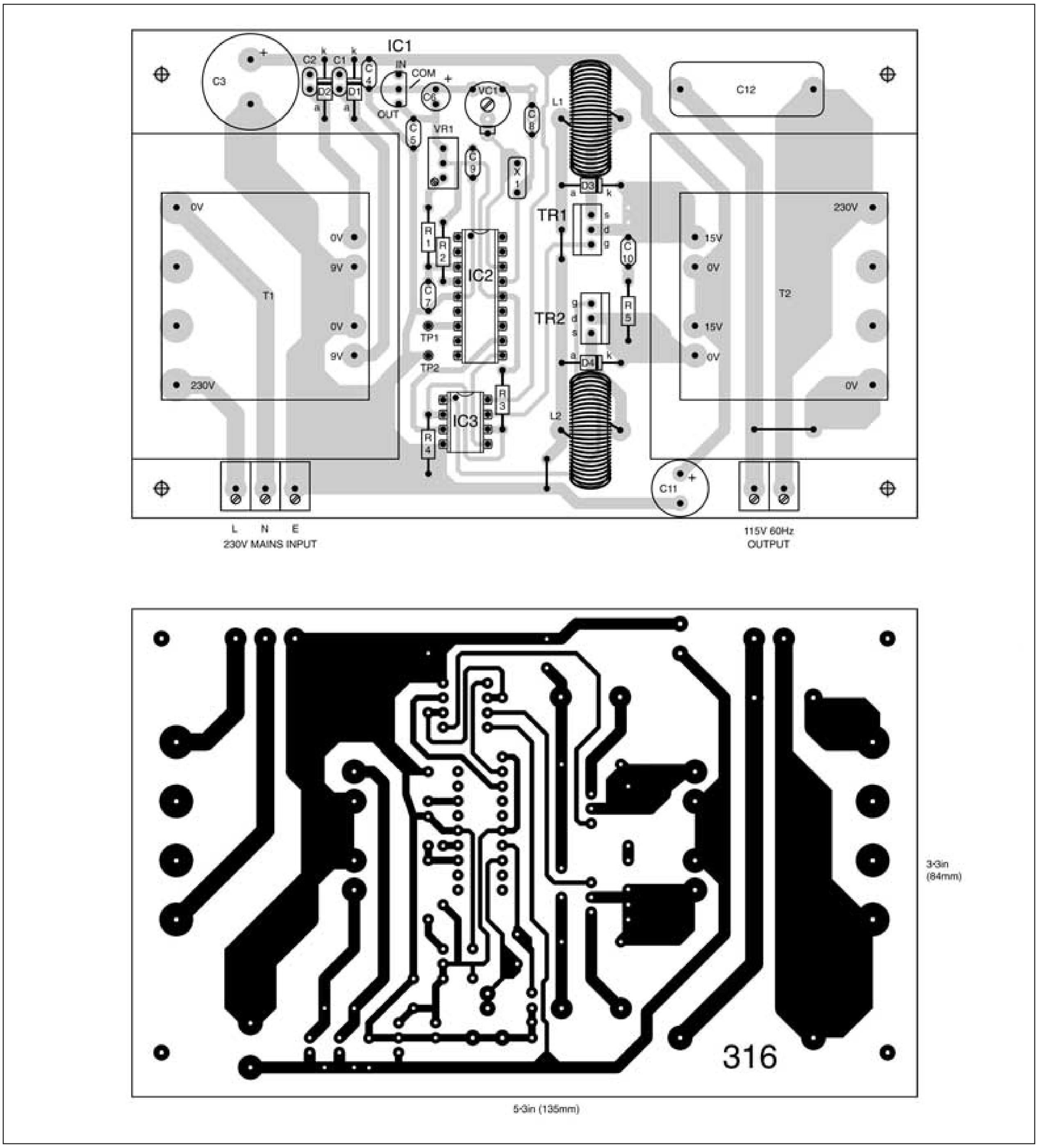


Fig.6. Printed circuit board component layout and full size copper foil master track pattern for the Synchronous Clock Driver.

If a different type is used some adjustment of the values of these capacitors may be needed.

The adjustable hardware timer referred to above is implemented with capacitor C7 plus resistor R1 and preset potentiometer VR1 connected to RA4, pin 3 of IC2.

The "frequency select" pin was chosen as RB3, pin 9, simply because in the physical layout it is adjacent to a 0V track to which it may conveniently be connected if 50Hz is required.

SQUARE WAVE CONVERSION

RB1, pin 7, provides a square wave output to test point TP1 for use with a frequency meter, if one is available, for use during setting up.

RB4 and RB5, pins 10 and 11, are the outputs to drive the two power MOSFETs TR1 and TR2, though they do so through the two op.amps of IC3, an LM358 dual type. Power MOSFETs often require rather more than five volts to ensure full turn-on, so these two devices, used simply as comparators, provide drive voltage close to the main positive supply instead of the five volts available from IC2.

The two chokes, L1 and L2, reduce the rate of rise of current as TR1 and TR2 switch on, which results in a large drop in interference radiated by the circuit. The "snubber" network of R5 and C10 also contributes to interference control.

Transformer T2 is a 2 × 0-15V 6VA type, connected as a centre-tapped winding and used "backwards". This was found to give comfortably in excess of 115 volts if required. For 230V output a 9V-0-9V transformer may be suitable, more about this later.

Finally, capacitor C12 "rounds" the corners of the output waveform just a little, which was found to be necessary to prevent a slight "buzzing" from the clock motor. Its value of 220nF is a compromise since it increases current consumption slightly. As little as was necessary to prevent the buzz was applied. Due to the high a.c. voltage at this point this capacitor *must* be a mains suppression type.

SAFETY WARNING

Before commencing description of construction and testing it must be pointed out that this circuit involves hazardous voltages at both input and output. Constructors should therefore be experienced enough to avoid harmful contact with these by taking appropriate precautions whilst testing and setting up the circuit. If in doubt consult a suitably experienced person.

The "live" bits are confined to small areas of track around the two transformers and the terminal blocks which should be covered with insulation material. When properly connected to the supply all the low-voltage circuitry will be earthed and safe to handle or connect with test equipment.

CONSTRUCTION

Printed circuit board layout details are shown in Fig.6. This board is available from the *EPE PCB Service*, code 316.

Construction can commence with the fitting of the three links and the two pins for testing, followed by the resistors, diodes and small capacitors. Next two d.i.l. (dual-in-line) sockets, essential for *IC2* and recommended for *IC3*, should be fitted, followed by VR1, VC1 and the remaining passive components, except capacitors C3, C11 and C12 for the moment.

The 5V regulator IC1, crystal X1, two chokes L1 and L2 and transformers T1 and T2 can be fitted next. The chokes used in the prototype were toroidal types with no support save for their leads. This seemed insufficient so each was provided with a blob of silicone sealant, the sort of stuff used around the edges of baths and showers, to help hold it in place. The leads were pulled through and bent over to hold them in place for soldering. This worked well and is recommended to constructors of this design.

BENCH TESTING

It is best to test this circuit in stages with a bench power supply, ideally with a current limit, since this is always preferable to simply turning on a transformer capable of supplying over half an ampere and hoping for the best!

Hopefully, such a supply will be available, which should be set for 12V and connected with 0V to the Earth connection and +12V to a lead temporarily connected to the cathode (k) side of diodes D1 and D2. The current drawn at this stage should be about 4mA. The presence of the regulated 5V supply can be checked at pin 14 of the socket for the PIC, IC2.

Variable capacitor VC1 should now be set to about half-travel and a programmed PIC inserted into the socket. The average d.c. voltage at test point TP1 should be about 2·5V, indicating that the 60Hz squarewave output is present. This can be checked with a 'scope or frequency meter if available.

Following this, preset VR1 should be wound completely clockwise and the average d.c. voltage at pins 3 and 5 of IC3's socket checked. With VR1 fully clockwise they should be receiving square wave cycles of 60Hz, so will measure about 2·5V, as with TP1.

Turning VR1 in an anti-clockwise direction, should have the effect of lowering the measured voltages as the pulse widths are narrowed. Leave them set for about 1V average.

TIMER INTERRUPTS

If a 3·6864MHz crystal is employed, the frequency of the PIC's internal clock will be $3{\cdot}6864 \times 10^6 / 4$ or 921600Hz. The period therefore is 1/921600secs.

A square wave output state is changed twice per cycle when generating a frequency, therefore if interrupts are used these must be at 100Hz for a 50Hz output and 120Hz for a 60Hz output. These, therefore, correspond to 921600/100 = 9216 and 921600/120 = 7680 clock cycles respectively.

For 50Hz, the interrupt period must be 9216 PIC instruction cycles.

For 60Hz, the interrupt period must be 7680 PIC instruction cycles.

Since TMR0 is "pre-loaded" each time, and there are other functions involved such as coming out of the interrupt vector, there will be overheads to allow for and in most cases it will prove impossible to obtain the exact period required from TMR0. Consequently there will be a short timing loop and perhaps also some "NOPs" for fine tuning of each frequency.

In the program, taking 50Hz, the instruction cycle count is as follows:

The GOTO from interrupt vector to start of program	2
Clear the watchdog timer	1
Start the output pulse timer capacitor discharging	4
Test RB3 to see if 50Hz requested	1
GOTO the 50Hz TMR0 routine	2
Load a fine-tuning loop (single) with value of 15	2
Execute the loop	46
NOPs	2
Pre-load TMR0	2
Time for TMR0 to begin running	2
Total overhead so far:	64

The TMR0 prescaler is set for 64

TMR0 is pre-loaded with 113 and counts up, so the total clock cycles taken before interrupt occurs will be $(256 - 113) \times 64 = 9152$

The total number of instruction cycles taken is therefore 9152 + 64 = 9216

The equivalent for 60Hz is as follows:

The GOTO from interrupt vector to start of program	2	
Clear the watchdog timer	1	
Start the output pulse timer capacitor discharging	4	
Test RB3 to see if 50Hz requested	2	(it isn't, so this becomes a 2-cycle instruction)
Load a fine tuning loop (single) with value of 16	2	
Execute the loop	49	
NOPs	0	(None used in this routine)
Pre-load TMR0	2	
Time for TMR0 to begin running	2	
Total overhead so far:	64	(same as above, but this is a coincidence!)

The TMR0 prescaler is set for 64

TMR0 is pre-loaded with 137 and counts up, so the total clock cycles taken before interrupt occurs will be $(256 - 137) \times 64 = 7616$

The total number of instruction cycles taken is therefore 7616 + 64 = 7680

The interrupts, loaded with these factors and used with the appropriate crystal, will enable the precise generation of 50Hz and 60Hz output frequencies by the PIC program, while leaving the program free to perform other functions such as updating the output states and timing the output drive pulses for most of its operating time.

OUTPUT TESTING

Next op.amp IC3 can be fitted, taking the supply current to around 6mA. The outputs from IC3, pins 3 and 5, should measure around 2V average; if so, they are operating correctly.

The two power MOSFETs TR1 and TR2 and the two large electrolytics C3 and C11 should be fitted now, observing correct orientation.

An a.c. voltmeter with a range of 200V or more should be connected to the output and the circuit powered again, still from a bench supply if possible. With VR1 left set as above, the prototype's output voltage measured about 78V, though the measured value may depend on how individual meters interpret the output waveform.

The supply current, as yet with no output load, measured about 30mA. Fitting capacitor C12 raised the measured output to about 95V and the supply current to around 50mA. Finally, the clock can be connected and the output voltage set to its final value.

As mentioned earlier, the clock used with the prototype started reliably at about 70V so the circuit was set to provide 100V. The voltage of this project is quite heavily dependent on the load so the final voltage must be adjusted with it connected. The Jefferson clock had a coil resistance of about 4kΩ and was rated at 2·5W. With the voltage adjusted to a measured 100V a.c., the supply drain was about 270mA.

With the circuit connected to the mains, and obviously taking necessary precautions to prevent shock, the output voltage was re-checked and adjusted as necessary. A frequency meter was connected to TP1 to set the output to exactly 60Hz.

ENCLOSING TIME

The size of case shown in the components list fits almost perfectly, just a tiny bevel being needed at the corners of the p.c.b. for clearance. Four 3mm nylon screws were used to secure the board, using 4mm nuts as spacers. Other enclosures could be used, of course, according to the preference of the constructor. *If a metal case is used it must be earthed.*

The 9V transformer runs slightly warm – transformers seem to be designed to run warm nowadays. Otherwise there is no heat dissipation from the circuit at all so no heatsinking or ventilation holes are required.

CUSTOMISING

Almost finally, here are some details of modifications and customising:

If it is required to operate a 50Hz 230V clock, pin 9 (bottom left) of IC2 should be connected to the earth point to the left of it, notated as TP2. This is easily done on the copper track side of the board. The software will recognise this connection and switch to 50Hz operation.

The input and output transformer voltage ratios may also need changing for 230V output and/or 115V input operation.

Incidentally, if the crystal trimmer has been adjusted to the correct value for one frequency it will automatically be correct at the other so it is possible to use a switch here.

During design work, testing was carried out with two 50Hz clock motors, both of which had coil resistances of about 4kΩ. One was a large, old movement of the type which has to be manually started with a "flicking" mechanism. This was actually removed from a tower clock by a clockmaker who became tired of call-outs to restart it every time the mains failed!

The other came from a cooker timer and appeared to be of the shaded-pole type rather than the more familiar "toothed wheel" construction commonly found in clock motors.

These two very different motors both ran happily with this circuit and required much less than 200V to operate. A 9V-0-9V transformer for T2 just about managed 200V output. A 6V-0-6V could easily exceed 230V but was less efficient, suggesting that in most cases a 9V type would be the better choice.

Where the specified type of transformer is not available, other types of suitable rating can be used, using wires to connect them to the p.c.b. if necessary.

BATTERY POWER

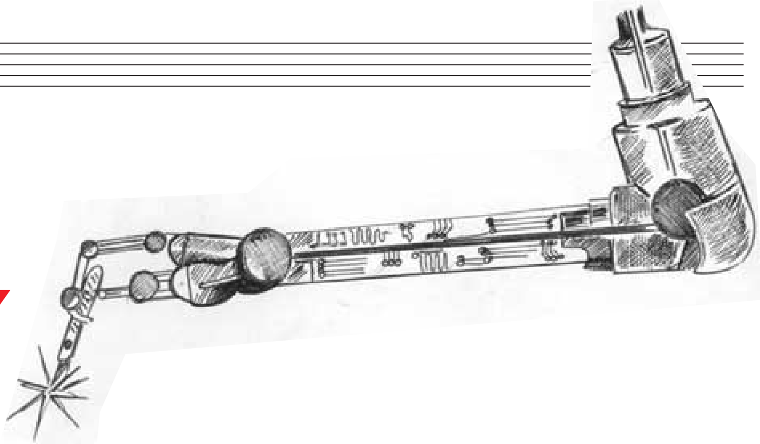
If a battery-backed supply is to be used, diodes D1, D2 and capacitors C1 and C2 should be omitted, along with transformer T1. A supply of about 12V capable of around 500mA can then be connected across C3. This can be backed by batteries of suitable type, the small sealed lead acid types common nowadays would be ideal. The float-charge voltage of these is around 13·8V, which will be OK for use with this circuit.

One final modification that some constructors may like to consider is replacement of variable capacitor VC1 with a smaller value in parallel with a fixed capacitor to make it less critical to adjust. On an early prototype a 1-10pf was used together with a 47pF ceramic, though a 15pF or 22pF might be better.

Although a silver mica type was used for capacitor C8, a ceramic should be OK as the effect of temperature will probably have little effect with the crystal as the primary timekeeper.

REVOLVING TIME

And now the answer you've been eagerly awaiting . . . how does the clock work? The glass rotates! The minute hand is attached by a friction mechanism to allow time setting, and the hour hand is operated from it with an ingenious counterbalance and some gears. The overall effect is very pleasing to look at, and the way it works is not at all obvious to those who haven't met such clocks before. □



CIRCUIT SURGERY

ALAN WINSTANLEY
and IAN BELL

Our monthly feature of readers' queries examines the use of differing types of decoupling capacitors and investigates the operating temperatures of electronic components

Curious Decoupling

"As a beginner at electronics I am repeatedly baffled by the following: many times, usually on power supply circuits, I see two or more capacitors in parallel used for "decoupling" the supply line. One is usually big (say 100µF), and one smaller (100nF). What is the reason for using two capacitors?

All I know about capacitors in parallel is that their total capacitance is the sum of their individual capacitances. I assume that this is not the reason for their use . . . namely to obtain a capacitance of 100·1µF!

*Also if capacitive reactance is inversely proportional to frequency, then a large capacitor should be able to bypass the low frequencies and the high frequencies alike so why need the smaller capacitor? Also, how are the values for a suitable decoupling capacitor arrived at? Thanks in anticipation." **Gerard Galvin*** by E-mail.

Welcome to the real world! Your argument would be completely correct if the capacitors and power supply wires and tracks we used were *ideal*, but of course they are not. In particular, real capacitors have *inductance* due to the way they are made – as a spiral of material – which means that their impedance does not continue to fall off as frequency rises, in fact it may well *increase* again.

Larger value capacitors tend to have a larger inductance and hence poorer performance at high frequencies. Smaller value capacitors are made from materials that have better performance at high frequencies. Thus, *two* capacitors are often used in order to cover the full range of frequencies we have to deal with.

So why are decoupling capacitors used at all? The answer is to try to keep the power supply voltage as steady and as "clean" as possible. Many analogue circuits have poor **power supply rejection**, that is, if you vary the power supply voltage this variation will show up (as noise) in the signal at the circuit's output.

Digital circuits have a finite **noise margin**, which indicates how much you can shift a good logic output voltage by before the next gate will not longer recognise it as a valid logic state. If you vary the power supply voltage then gate output voltages and input thresholds shift. If this shift exceeds the noise margin you may get a logic error.

We get variations in power supply voltage as a circuit operates because the power supply circuitry and the wiring between it is not ideal – it has a finite rather than zero impedance. As the current taken by the circuit (or various parts of it) changes, the voltage dropped across the supply's internal impedance and the power supply wires (p.c.b. tracks etc) varies. It is not just the positive rail voltage that can vary, the ground voltage (ideally zero) may vary too.

Crosstalk

One of the problems this causes is **crosstalk**. Imagine an analogue circuit board processing multiple channels (e.g. amplifying several audio signals). As the signal in one channel varies, so will the current taken by that amplifier from the power supply; this will cause a variation of the power supply voltage in sympathy with the signal.

Thus, the other channels will have a power supply with voltage variations that follow the signal in the first channel! This will cause a variation in their output voltage that follows the signal in the first channel, so the signal from the first channel has "crossed" to the other via the power supply. Hopefully this signal will be very small compared to the proper signals for those channels.

However, crosstalk can also occur in digital circuits. As a gate (or set of gates and flip-flops) switches over, current is taken from the supply causing a voltage change on supply or ground rail (or both). If this voltage shift is large enough to overcome the noise margin of a gate elsewhere in the circuit (on the same supply line), then the logic state in the second sub-circuit may become erroneous. Thus the switching of one block of logic has caused another part of the circuit to react when it should not have done so.

A power supply voltage should be d.c. The unwanted effects we have just discussed are effectively a.c. signals superimposed on the supply's d.c. voltage. If we "short out" the supply for a.c. signals we should be able to reduce the magnitude of these troublesome signals. That's why we use capacitors across the supply. They have infinite impedance at d.c., but low impedance at a.c.

What values should be used? First you need to know what the largest voltage change you can tolerate is likely to be. For digital circuits the main problem is caused by *changes* in current demand from the power supply going through the supply line inductance.

So to calculate the capacitor value, find the worse case step change in current you are likely to have. Then, the maximum voltage change divided by the maximum current change gives you the maximum supply line impedance. You also need to know the supply line resistance and series inductance (not necessarily very easy . . .).

From this and maximum impedance value you can use the usual impedance formula to find the frequency at which the supply impedance exceeds your required maximum. Then find the capacitance value that equals the maximum impedance value at this frequency to give the minimum capacitance you need. This calculation is straightforward but finding the values to go in it may not be!

We Value Decoupling

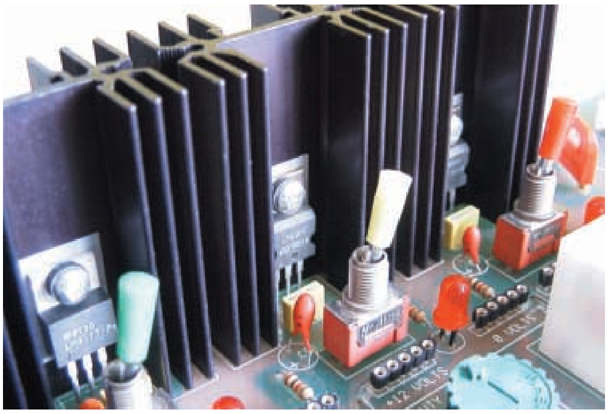
For a reasonably sized digital circuit this may be a value in the region of tens or hundreds of microfarads. Such capacitors, as mentioned above, have inductance and will not provide supply decoupling at higher frequencies (check the effective series resistance and inductance of the capacitor you are using if you can).

The large capacitor is suitable for the board, but we also need smaller capacitors near to individual i.c.s to take care of the higher frequencies. The small capacitors have to be kept very close to the i.c.s they are decoupling, in order to keep the supply impedance between them and the i.c.s as small as possible. That's why you often see ceramic capacitors close to the chips on large logic boards (see photograph below).

Supply decoupling is particularly demanding for high-speed logic. This is because of the very fast step changes in current demanded from the supply as logic lines switch. Often many lines switch at once.

From the defining equation for inductance $V=(dI/dt)L$ we see that the voltage is determined by the rate of change of current (dI/dt). Fast logic switching edges therefore result in large supply voltage changes due to supply line inductance. The faster the edges then the higher the frequencies which have to be handled by the decoupling and the larger the voltage drops become. For example, for a logic rise time of four nanoseconds (the waveform edge takes this time to go from 10% to 90% of its final value) frequencies of 250MHz will have to be dealt with by the decoupling.

Decoupling capacitors positioned close to the logic chips on a microprocessor circuit board. Polyester types are used here



Heatsinks help to maintain the temperature of devices within their operating limits. Also note the decoupling capacitors close by – tantalum and polyester types are both used near these regulators

Going Critical

In the electronics industry, decoupling and supply line characteristics are of critical importance in the design of state-of-the-art logic boards. Digital circuits are now so fast that hundreds of megahertz to gigahertz frequencies have to be considered.

Another problem associated with digital switching is the generation of radio frequency interference. Poorly deigned p.c.b.s can result in the loops being formed via the decoupling capacitors and i.c. supplies acting like little radio transmitters. Just designing the power supply tracks on modern high speed digital boards can be a major feat of radio frequency engineering!

However, in modest hobby projects, you will often see just an electrolytic – say 220µF to 470µF – strapped across the supply, which helps to remove ripple in battery supply rails. This becomes more important as the battery begins to age. Elsewhere you may see a 100nF polyester capacitor in parallel, to catch high frequency noise.

Even with the simplest of circuits (let's say a 556 twin oscillator, operating from a single supply), placing decoupling capacitors near to the chip's supply pins can cure strange interaction amongst the oscillators, which will stabilise their operation. This is a classic case of a circuit that should work correctly "on paper" but it's only with a bit more experience that you learn some of the tricks needed to coax them into operation in reality. *I.M.B.*

Some Like it Hot

Reader ***D. Lee*** from the Wirral writes about hot components: *"How hot should a component be when it is working normally? I have an alarm control panel and the transformer can be described as belching heat, measured at a constant 30ºC. The 12V regulator heatsink was also very hot with some discolouring of nearby plastics.*

The panel is in good working order, but the heat generated is astronomical. It is the same for a battery fast charger. Even the video recorder on standby seems to give off lots of heat from heatsinks."

Power is dissipated by the action of electronic circuitry, which in turn leads to increased temperature of the components and their immediate surroundings. That heat has to go somewhere: the purpose of heatsinks is to remove excess heat energy from components to keep their temperature within bounds, so when you feel heat coming off a heatsink, it is only doing its intended job!

The real question is, how hot should a *component* be when working? This depends on the component of course, but it is possible to calculate thermal requirements for components and temperature data is often included in datasheets (especially those of semiconductors) and catalogues.

A component's maximum working temperature will be set either by degradation of the materials used to construct the component, or by onset of unacceptable changes in operating characteristics. In operation, components dissipate power, that is they produce a "continuous stream" of thermal energy.

If the thermal energy stays more or less where it is (i.e. in the component) the temperature of the component will continue to rise. However if the energy flows away from the component, a point will be reached where the energy leaving it equals the energy produced by the component, and it is this "balance" which determines the working temperature.

Thermal Resistance

The flow of heat away from a component depends on the difference in temperature between it and its surroundings as well as the properties of the materials in which it is embedded (e.g. whether they are thermal insulators or thermal conductors). Materials can be described by their *thermal resistance*, which indicates the ease with which heat flows through them. If we assume that the component's surroundings can absorb all the heat from it without changing temperature then we can calculate the difference between the surrounding temperature (known as ambient temperature) and the component.

From the point where the heat is generated in the component to the surroundings there may be a number of "layers", such as the component's packaging and a heatsink. We need to know the thermal resistance to heat flow between each of these layers (e.g. component to package, package to heatsink, heatsink to surroundings) in order to calculate the temperature of the component. Manufacturers of power semiconductors publish thermal resistance data for their products, as do heatsink manufactures, so we can obtain these figures.

Power Dissipation

We also need the power dissipation in watts in the component, which the circuit designer should of course know. Then the temperature above ambient is found by multiplying the series thermal resistance (i.e. the sum of thermal resistances) by the power dissipated.

The fact that power dissipation causes a rise in temperature relative to ambient temperature, means that ambient temperature is an important consideration in the thermal design of electronics. This can be affected by ventilation in the system. Some systems, such as personal computers, need fans to keep the ambient temperature inside the case reasonably low.

For power transistors, the key issue is the junction temperature, which may typically have a maximum value of 100ºC to 200ºC. Specific temperature and thermal resistance figures are often published for power devices where it is assumed that heatsinks will be used and thermal calculations will be made by designers. For other components it is typical to be given maximum power ratings and ambient temperatures.

Next month we'll show you how to calculate heatsink ratings for a typical semiconductor application. *I.M.B.*

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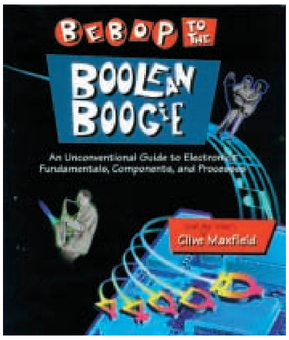

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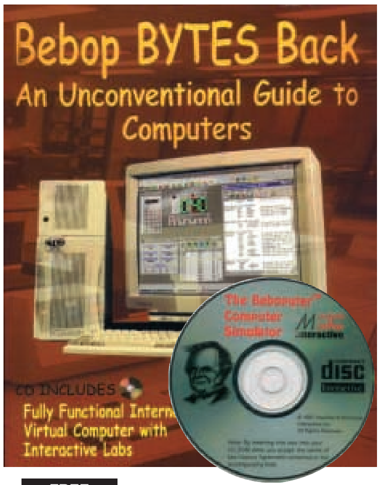

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WANTED: SL561 AUDIO PRE-AMP CHIP. Probably Plessey. Adrian, 6 Aidan Grove, Ellington, NE61 5HJ.

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Access the FTP site by typing the above into your web browser, or by setting up an FTP session using appropriate FTP software, then go into quoted sub-directories:
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You can also enter the FTP site via the link at the top of the main page of our home site at: **http://www.epemag.wimborne.co.uk**
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Ensure you set your FTP software to ASCII transfer when fetching text files, or they may be unreadable.

Note that any file which ends in **.zip** needs unzipping before use. Unzip utilities can be downloaded from:
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