FREE GRAPHICS LCD SUPPLEMENT

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY

PRACTICAL ELECTRONICS

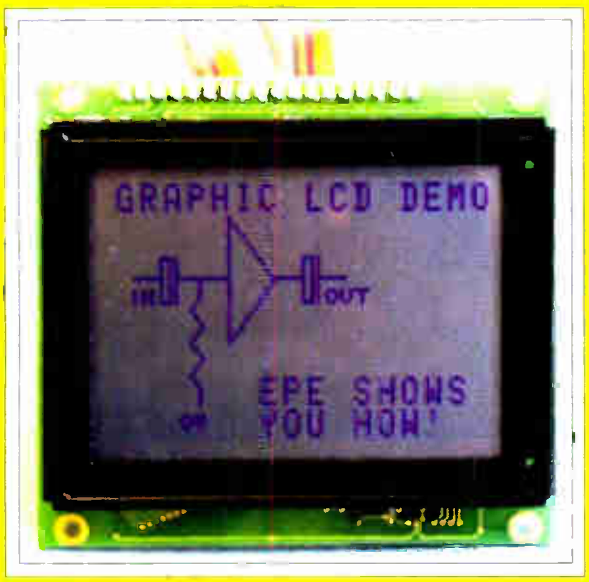
FEBRUARY 2001

INCORPORATING ELECTRONICS TODAY INTERNATIONAL £2.75

ICE ALERT
Watch out for icy roads

Special Supplement

USING GRAPHICS LCD DISPLAYS WITH PICS



PC AUDIO POWER METER
Measures audio amp output power

NOW AVAILABLE TO BUY ON THE WEB
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METRONOME
A Top Tenner £10 project

PLUS

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12v 18Ah SEALED LEAD ACID BATTERIES, new and boxed, unused pack of 4 £39.95 ref CYC7 or £15 each ref CYC6

AUTOMATIC CHARGER For the above batteries charges 2 at once, charge level indicator circuitry, 6 hour charge £10 ref CYC8

A new range of 12v to 240v INVERTERS

IV400S (400 watt) £89

IV800S (800watt)£159

IV1200S (1200 watt) £219

ECG MACHINES?/6v 10AH BATTS/24V 8A TX Ex government ECG machines! Measures 390X320X120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear including video out etc. On the front panel are two DIN sockets for connecting the body sensors to. Sensors not included. Inside 2 x 6v 10AH lead acid batts (not in good condition), pcb's and a 8A? 24v torroidial transformer (mains in) sold as seen, may have one or two broken knobs etc due to poor storage. £15 99 ref VP2

SODIUM LAMP SYSTEMS £75.70 Complete system with 250w or 400watt SON-T Agro bulb, reflector with bulb holder and remote ballast and starter(uncased) all you need is wire. 250W system ref SLS1, 400W system SLS2.

PC SUPPORT HANDBOOK The ultimate technical guide to building and maintaining PC's. Over 460 A4 pages packed with technical data and diagrams just £10 ref PCBK. If you want 4 copies for £33 ref PCBK2. Also available is a CD packed with diagnostic programmes to use with the book £6 ref PCBK1

D SIZE NICADS Tagged, 1200mA, 1.2v pack of 4 for £6 ref CYC9 or as a pack of 24 for £22 ref CYC10

D SIZE SEALED LEAD ACID BATTERIES 2v 2.5ah rechargeable sealed lead acid battery made by Cyclon 60x45mm (standard D size) supplied as a pack of 12 or 20 giving you options for battery configerations eg 12v at 5ah, 24v at 2.5ah, 6v at 10ah. These batteries are particularly useful in that you can arrange them in your project to optimise space etc (eg boat ballast etc) Pack of 12 £10 ref CYC4, pack of 20 £16 ref CYC5

HYDROPONICS DO YOU GROW YOUR OWN? We have a full colour hydroponics catalogue available containing nutrients, pumps, fittings, enviromental control light fittings, plants, test equipment etc Ring for your free copy.

PC COMBINED UPS AND PSU The unit has a total power of 292 watts, standard mother board connectors and 12 peripheral power leads for drives etc. Inside is 3 12v 7.2aH sealed lead acid batteries. Backup time is 8 mins at full load or 30 mins at half load Made in the UK by Magnum, 110 or 240vac input, +5v at 35A -5v at 5A, +12v at 9A, -12v at .5A outputs. 170x260x220mm. new and boxed £29.95 Ref PCUPS2

ALTERNATIVE ENERGY CD, PACKED WITH HUNDREDS OF ALTERNATIVE ENERGY RELATED ARTICLES, PLANS AND INFORMATION ETC £14.50 REF CD56

AERIAL PHOTOGRAPHY KIT This rocket comes with a built in camera! it flies up to 500 feet (150 m) turns over, and takes an aerial photograph of the ground below. The rocket then returns with its film via its paracute. Takes 110 film. Supplied complete with everything including a launch pad and 3 motors (no film) £29.98 ref astro

PROJECT BOXES Another bargain for you are these smart ABS project boxes, smart two piece screw together case measuring approx 6"x5"x2" complete with panel mounted LED. Inside you will find loads of free bits, tape heads, motors, chips resistors, transistors etc Pack of 20 £19.95 ref MD2

TELEPHONES Just in this week is a huge delivery of telephones, all brand new and boxed. Two piece construction - illuminated keypad, tone or pulse (switchable) recall, redial and pause, high/low and off ringer switch and quality construction. Off white colour and is supplied with a standard international lead (same as US or modems) if you wish to have a BT lead supplied to convert the phones these are £1.55 each ref BTLX **Phones £4.99 each ref PH210 off £30 ref SS2**

3HP MAINS MOTORS Single phase 240v, brand new, 2 pole 340x180mm, 2850 rpm, builtin automatice reset overload protector, keyed shaft (40x16mm) Made by Leeson £99 each ref LEE1

BUILD YOU OWN WINDFARM FROM SCRAP New publication gives step by step guide to building wind generators and propellors. Armed with this publication and a good local scrap yard could make you self sufficent in electricity! £12 ref LOT81

CHIEFTAN TANK DOUBLE LASERS 9 WATT+3 WATT+LASER OPTICS Could be adapted for laser listener, long range comms etc Double beam units designed to fit in the barrel of a tank, each unit has 2 semi conductor lasers and motor drive units for alignement. 7 mile range, no circuit diagrams due to MOD, new price £50 000? us? £199. Each unit has two gallium Arsenide injection lasers, 1 x 9 watt, 1 x 3 watt, 900nm wavelength, 28vdc, 600hz pulse freq. The units also contain a receiver to detect reflected signals from targets. £99 Ref LOT4

MAGNETIC CREDIT CARD READERS AND ENCODING MANUAL £9.95 Cased with flyleads, designed to read standard credit cards! complete with control electronics PCB and manual covering everything you could want to know about whats hidden in that magnetic strip on your card! just £9.95 ref BAR31

SOLAR POWER LAB SPECIAL 2 x 6"x6" 6v 130mA cells, 4 LED's, wire, buzzer, switch + relay or motor **£7.99** REF SA27

SOLAR NICAD CHARGERS 4 x AA size £9.99 ref 6P476, 2 x C size £9.99 ref 6P477

BRAND NEW MILITARY ISSUE DOSE METERS Current NATO issue Standard emergency services unit Used by most of the worlds Military personel New and boxed Normal retail price £400, BULLS bargain price just £99The PDRM 82 M is a portable, lightweight, water resistant gamma radiation survey meter to measure radiological dose rate in the range 0.1to 300 centigrays per hour in air. The Geiger Muller (G.M.) tube detecting unit is energy and polar response corrected. The radiation level is displayed on a Liquid Crystal Display. The microcomputer corrects for the non-linearity of the G.M. tube response. The instrument is powered by three international C size batteries giving typically 400 hours operation in normal conditions. The dose rate meter PDRM 82M designed and selected for the United Kingdom Government, has been fully evaluated to satisfy a wide range of environmental conditions and is nuclear hard. The construction enables the instrument to be easily decontaminated. The instrument is designed for radiation surveys for post incident monitoring. Used in a mobile role, either carried by troops or in military vehicles for rapid deployment enabling radiation hot spots to be quickly located. Range 0 - 300 cGy/h in 0.1 cGy/h increments. Over-range to 1500 cGy/h - indicates flashing 300. Accuracy f20% of true dose rate +0.1 cGy/h, 0 - 100 cGy/h. f30% of true dose rate, 100 - 300 cGy/h. Energy Response 0.3 MeV to 3 MeV - within f20% (Ra 226) 80 KeV to 300 KeV - within f40% (Ra 226) Detector Energy compensated Halogen quenched Geiger Muller Tube Controls Combined battery access and ON/ OFF switch. Batteries 3 International standard C cells. Weight 560grms Operating Temperature Range -30degC to +60degC. Indications High contrast 4 digit LCD. Battery low indication Dose rate Rising/Falling £99 ref PDRM

Hydrogen fuel cells Our new Hydrogen fuel cells are 1v at up tp 1A output, Hydrogen input, easily driven from a small electrolosis assembly or from a hydrogen source, our demo model uses a solar panel with the output leads in a glass of salt water to produce the hydrogen! Each cell is designed to be completely taken apart, put back together and expanded to what ever capacity you like. (up to 10watts and 12v per assembly. Cells cost £49 ref HFC11

PHILIPS VP406 LASER DISC PLAYERS, SCART OUTPUT, JUST PUT YOUR VIDEO DISK IN AND PRESS PLAY, STANDARD AUDIO AND VIDEO OUTPUTS, £14.95 REF VP406

SMOKE ALARMS Mains powered, made by the famous Gent company, easy fit next to light fittings, power point. Pack of 5 £15 ref SS23, pack of 12 £24 ref SS24

4AH D SIZE NICADS pack of 4 £10 ref 4AHPK

SENDER KIT Contains all components to build a A/V transmitter complete with case £35 ref VSXX2

10 WATT SOLAR PANEL Amorphous silicon panel fitted in a anodized aluminium frame. Panel measures 3' by 1' with screw terminals for easy connection. **3' x 1' solar panel £55 ref MAG45**

12V SOLAR POWERED WATER PUMP Perfect for many 12v DC uses, from solar fountains to hydroponics! Small and compact yet powerful works direct from our 10 watt solar panel in bright sun. Max hd 17 ft Max flow = 8 Lpm, 1.5A Ref AC8 £18.99

SOLAR ENERGY BANK KIT 50x 6"x12" 6v solar panels(amorphous)+50 diodes £99 ref EF112

PINHOLE CAMERA MODULE WITH AUDIO! Superb board camera with on board sound! extra small just 28mm square (including microphone) ideal for covert surveillance. Can be hidden inside anything , even a matchbox! Complete with 15 metre cable, psu and tv/vcr connnectors. £49.95 ref CC6J

SOLAR MOTORS Tiny motors which run quite happily on voltages from3-12vdc. Works on our 6v amorphous 6" panels and you can run them from the sun! 32mm dia 20mm thick. £1.50 each

WALKIE TALKIES 1 MILE RANGE £37/PAIR REF MAG30

LIQUID CRYSTAL DISPLAY Bargain prices, 40 character 1 line 154x16mm £6.00 ref SMC4011A

YOUR HOME COULD BE SELF SUFFICENT IN ELECTRICITY Comprehensive plans with loads of info on designing systems, panels, control electronics etc £7 ref PV1

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead and cigar plug. 12v 2w. **£12.99** REF AUG10P3

SOLAR POWER LAB SPECIAL 2 x 6"x6" 6v 130mA cells, 4 LED's, wire, buzzer, switch + relay or motor. **£7.99** REF SA27

SOLAR NICAD CHARGERS 4 x AA size £9.99 ref 6P476, 2 x C size £9.99 ref 6P477

MINATURE TOGGLE SWITCHES These top quality Japanese panel mount toggle switches measure 35x13x12mm, are 2 pole changeover and will switch 1A at 250vac, or 3 A at 125vac. Complete with mounting washers and nuts. Supplied as a box of 100 switches for £29.95 ref SWT35 or a bag of 15 for £4.99 ref SWT34

VOICE CHANGERS Hold one of these units over your phone mouth piece an you can adjust your voice using the controls on the unit! Battery operated £15 ref CC3

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250 PORTLAND ROAD, HOVE, SUSSEX. BN3 5QT. (ESTABLISHED 50 YEARS).

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FAX 01273 323077

Sales@bull-electrical.com

30 WATTS OF SOLAR POWER for just £69, 4 panels each one 3'x1' and producing 8w, 13v. PACK OF FOUR £69 ref SOLX

200 WATT INVERTERS plugs straight into your car cigarette lighter socket and is fitted with a 13A socket so you can run your mains operated devices from your car battery. £49.95 ref SS66

THE TRUTH MACHINE Tells if someone is lying by micro tremors in their voice, battery operated, works in general conversation and on the 'phone and TV as well! £42.49 ref TD3

INFRA RED FILM 6" square piece of flexible infra red film that will only allow IR light through. Perfect for converting ordinary torches, lights, headlights etc to infra red output only using standard light bulbs. Easily cut to shape. 6" square £15 ref IRF2

33 KILO LIFT MAGNET Neodynium 32mm diameter with a fixing bolt on the back for easy mounting. Each magnet will lift 33 kilos. 4 magnets bolted to a plate will lift an incredible 132 kilos! £15 ref MAG33 Pack of 4 just £39 reg MAG33AA

HYDROGEN FUEL CELL PLANS Loads of information on hydrogen storage and production. Practical plans to build a Hydrogen fuel cell (good workshop facilities required) £8 set ref FCP1

STIRLING ENGINE PLANS Interesting information pack covering all aspects of Stirling engines, pictures of home made engines made from an aerosol can running on a candle! £12 ref STIR2

ENERGY SAVER PLUGS Saves up to 15% electricity when used with fridges, motors up to 2A, light bulbs, soldering irons etc. £9 ea ref LOT71, 10 pack £69 ref LOT72

12V OPERATED SMOKE BOMBS Type 3 is a 12v trigger and 3 smoke cannisters, each cannister will fill a room in a very short space of time! £14.99 ref SB3. Type 2 is 20 smaller cannisters (suitable for mock equipment fires etc) and 1 trigger module for £29 ref SB2 Type 1 is a 12v trigger and 20 large cannisters £49 ref SB1

HI POWER ZENON VARIABLE STROBES Useful 12v PCB fitted with hi power strobe tube and control electronics and speed control potentiometer. Perfect for interesting projects etc 70x55mm 12vdc operation. £6 ea ref FLS1, pack of 10 £49 ref FLS2

NEW LASER POINTERS 4.5mw, 75 metre range, hand held unit runs on two AA batteries (supplied) 670nm. £29 ref DEC49J

HOW TO PRODUCE 35 BOTTLES OF WHISKY FROM A SACK OF POTATOES Comprehensive 270 page book covers all aspects of spirit production from everyday materials. Includes construction details of simple stills. £12 ref MS3

NEW HIGH POWER MINI BUG With a range of up to 800 metres and a 3 days use from a PP3 this is our top selling bug! less than 1" square and a 10m voice pickup range. £28 Ref LOT102

IR LAMP KIT Suitable for cctv cameras, enables the camera to be used in total darkness! £6 ref EF138

INFRA RED POWERBEAM Handheld battery powered lamp, 4 inch reflector gives out powerful pure infrared light! perfect for CCTV use, nightsights etc. £29 ref PB1

SUPER WIDEBAND RADAR DETECTOR Detects both radar and laser. X K and KA bands, speed cameras and all known speed detection systems. 360 degree coverage, front&r earwaveguides, 1.1"x2.7"x4.6" fits on visor or dash £149

LOPTX Made by Samsung for colour TV £3 each ref SS52

LAPTOP LCD SCREENS 240x175mm. £12 ref SS51

WANT TO MAKE SOME MONEY? STUCK FOR AN IDEA? We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is the certificate enabling you to reproduce (and sell) the manuals as much as you like! £14 ref EP74

ELECTRONIC SPEED CONTROLLER KIT For the above motor is £19 ref MAG17. Save £5 if you buy them both together, 1 motor plus speed controller rrp is £41, offer price £36 ref MOT5A

INFRA RED REMOTE CONTROLS made for TV's but may have other uses pack of 100 £39 ref IREM

RCB UNITS Inline IEC lead with fitted RC breaker. Installed in seconds. Pack of 3 £9.98 ref LOT5A

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YOUR HOME COULD BE SELF SUFFICENT IN ELECTRICITY Comprehensive plans with loads of info on designing systems, panels, control electronics etc £7 ref PV1

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead and cigar plug. 12v 2w. **£12.99** REF AUG10P3

STEPPER MOTORS Brand new stepper motors, 4mm fixing holes with 47.14mm fixing centres, 20mm shaft, 6.35mm diameter, 5v/phase, 0.7A/phase, 1.8 deg step (200 step) Body 56x36mm £14.99 ea ref STEP6, pack of 4 for £49.95. PIC based variable speedcontroller kit £15 ref STEP7

ISSN 0262 3617
PROJECTS . . . THEORY . . . NEWS . . .
COMMENTS . . . POPULAR FEATURES . . .

VOL. 30. No. 2 FEBRUARY 2001
Cover illustration by Jonathan Robertson

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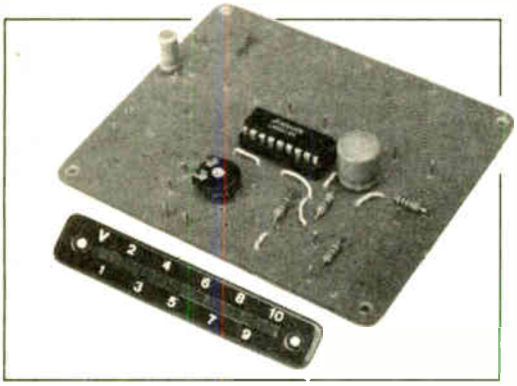
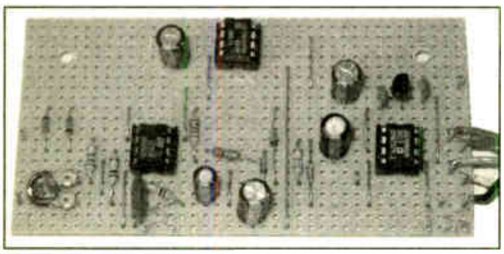
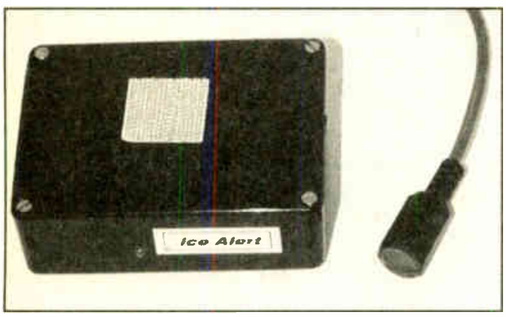
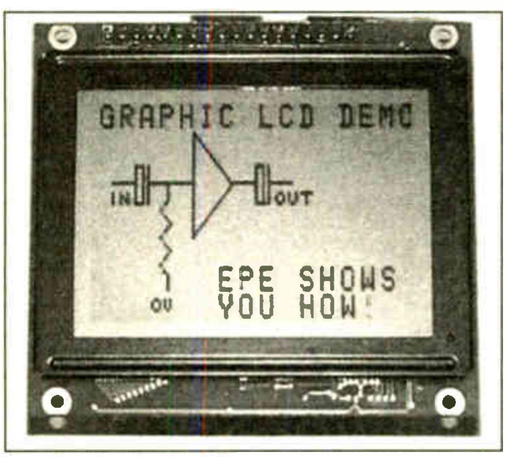








Projects and Circuits

Series and Features

Regulars and Services

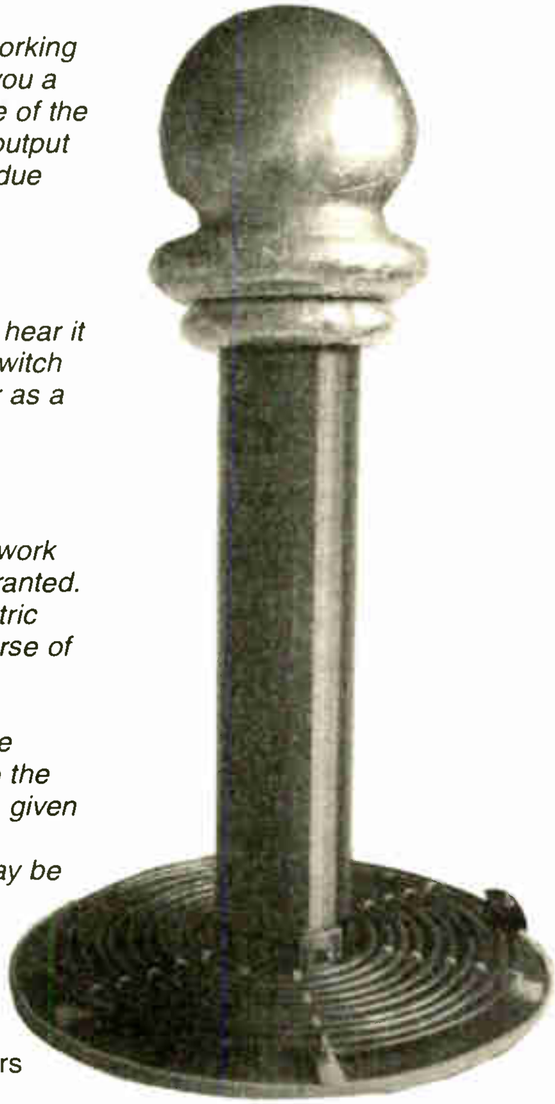
Free 16-Page Supplement

Our March 2001 issue will be published on Thursday, 8 February 2001. See page 83 for details

NEXT MONTH

DIY LIGHTNING

Short of divine intervention, most of us are never going to get to control nature's most spectacular effect. However, thanks to the genius of a 144-year-old physicist, you can.
The purpose of this article is to allow you, the reader, to build a working Tesla coil (see photo) with an arc output of at least 50cm, giving you a general idea as to why and how it works and a few ideas for some of the fun effects that can be demonstrated with it. But, be warned, the output from this project is easily capable of killing you if not treated with due respect.



DOORBELL EXTENDER

This "through the mains" unit will extend your doorbell so you can hear it in the garage or workshop. It will also act as a control system to switch on or off a remote appliance from the comfort of your armchair, or as a safety button for the bed-ridden etc.

BODY DETECTOR

Capacitance is an extraordinary phenomenon, in that it is able to work through empty space. This is a quality that is normally taken for granted. The accumulation of charge on a metal plate gives rise to an electric field, which will affect another plate in direct proportion to the inverse of its distance. Capacitance, also, is one of a vast range of physical phenomena that may be translated into electrical oscillations.
The Body Detector featured in this article relies on the fact that the human body itself possesses a fairly large order of capacitance to the ground, and that if such a body approaches the positive plate of a given capacitor, its value will rise.
Due to its high sensitivity and good stability, the Body Detector may be attached to a wide variety of metal objects – in the process sensitising the entire object concerned.
Although in theory the Body Detector is dependent on the electric field which surrounds the human body, in effect it acts as though an invisible field were created around the object concerned – similar to the "invisible" defence shields seen in the latest Star Wars *movie.*

PLUS ALL THE REGULAR FEATURES

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PROJECT KITS

Our electronic kits are supplied complete with all components, high quality PCBs (NOT cheap Tripad strip board!) and detailed assembly/operating instructions

● **2 x 25W CAR BOOSTER AMPLIFIER** Connects to the output of an existing car stereo cassette player, CD player or radio. Heatsinks provided. PCB 76x75mm. **1046KT. £27.95**

● **3-CHANNEL WIRELESS LIGHT MODULATOR** No electrical connection with amplifier. Light modulation achieved via a sensitive electret microphone. Separate sensitivity control per channel. Power handing 400W/channel. PCB 54x112mm. Mains powered. Box provided. **6014KT £27.95**

● **12 RUNNING LIGHT EFFECT** Exciting 12 LED light effect ideal for parties, discos, shop-windows & eye-catching signs. PCB design allows replacement of LEDs with 220V bulbs by inserting 3 TRIACs. Adjustable rotation speed & direction. PCB 54x112mm. **1026KT £17.95; BOX (for mains operation) 2026BX £10.00**

● **DISCO STROBE LIGHT** Probably the most exciting of all light effects. Very bright strobe tube. Adjustable strobe frequency 1-60Hz. Mains powered. PCB 60x68mm. Box provided. **6037KT £31.95**

● **ANIMAL SOUNDS** Cat, dog, chicken & cow. Ideal for kids farmyard toys & schools. **SG10M £6.95**

● **3 1/2 DIGIT LED PANEL METER** Use for basic voltage/current displays or customise to measure temperature, light, weight, movement, sound levels, etc. with appropriate sensors (not supplied). Various input circuit designs provided. **3061KT £13.95**

● **IR REMOTE TOGGLE SWITCH** Use any TV/VCR remote control unit to switch onboard 12V/1A relay on/off. **3058KT £10.95**

SPEED CONTROLLER for any common DC motor up to 100V/5A. Pulse width modulation gives maximum torque at all speeds. 5-15VDC. Box provided. **3067KT £12.95**

● **3 x 8 CHANNEL IR RELAY BOARD** Control eight 12V/1A relays by Infra Red (IR) remote control over a 20m range in sunlight. 6 relays turn on only, the other 2 toggle on/off. 3 operation ranges determined by jumpers. Transmitter case & all components provided. Receiver PCB 76x89mm. **3072KT £52.95**

PRODUCT FEATURE

4 WATT FM TRANSMITTER

Small but powerful 4 Watt 88-108MHz FM transmitter with an audio preamplifier stage and 3 RF stages. Accepts a wide variety of input sources – the electret microphone supplied, a tape player or for more professional results, a separate audio mixer (like our 3-Input Mono Mixer kit *1052*). Can be used with an open dipole or ground plane antenna. Supply: 12-15V DC/0·5A. PCB: 45 x 145mm.

ORDERING INFO: Kit **1028KT £24.95.**
OPTIONAL EXTRAS: 3-Input Mono Mixer Kit 1052KT **£17.95.** AS1028 **£39.95.**

● **SOUND EFFECTS GENERATOR** Easy to build. Create an almost infinite variety of interesting/unusual sound effects from birds chirping to sirens. 9VDC. PCB 54x85mm. **1045KT £9.95**

● **ROBOT VOICE EFFECT** Make your voice sound similar to a robot or Darlek. Great fun for discos, school plays, theatre productions, radio stations & playing jokes on your friends when answering the phone! PCB 42x71mm. **1131KT £9.95**

● **AUDIO TO LIGHT MODULATOR** Controls intensity of one or more lights in response to an audio input. Safe, modern opto-coupler design. Mains voltage experience required. **3012KT £8.95**

● **MUSIC BOX** Activated by light. Plays 8 Christmas songs and 5 other tunes. **3104KT £7.95**

● **20 SECOND VOICE RECORDER** Uses non-volatile memory - no battery backup needed. Record/replay messages over & over. Playback as required to greet customers etc. Volume control & built-in mic. 6VDC. PCB 50x73mm. **3131KT £12.95**

● **TRAIN SOUNDS** 4 selectable sounds : whistle blowing, level crossing bell, 'clickety-clack' & 4 in sequence. **SG01M £6.95**

X FACTOR PUBLICATIONS

THE EXPERTS IN RARE & UNUSUAL INFORMATION!

Full details of all X-FACTOR PUBLICATIONS can be found in our catalogue. N.B. Minimum order charge for reports and plans is £5.00 PLUS normal P&P.

● **SUPER-EAR LISTENING DEVICE** Complete plans to build your own parabolic dish microphone. Listen to distant voices and sounds through open windows and even walls! Made from readily available parts. **R002 £3.50**

● **TELEPHONE BUG PLANS** Build you own micro-beetle telephone bug. Suitable for any phone. Transmits over 250 metres - more with good receiver. Made from easy to obtain, cheap components. **R006 £2.50**

● **LOCKS** - How they work and how to pick them. This fact filled report will teach you more about locks and the art of lock picking than many books we have seen at 4 times the price. Packed with information and illustrations. **R008 £3.50**

● **RADIO & TV JOKER PLANS** We show you how to build three different circuits for disrupting TV picture and sound plus FM radio! May upset your neighbours & the authorities!! DISCRETION REQUIRED. **R017 £3.50**

● **INFINITY TRANSMITTER PLANS** Complete plans for building the famous Infinity Transmitter. Once installed on the target phone, device acts like a room bug. Just call the target phone & activate the unit to hear all room sounds. Great for home/office security! **R019 £3.50**

● **THE ETHER BOX CALL INTERCEPTOR PLANS** Grabs telephone calls out of thin air! No need to wire-in a phone bug. Simply place this device near the phone lines to hear the conversations taking place! **R025 £3.00**

● **CASH CREATOR BUSINESS REPORTS** Need ideas for making some cash? Well this could be just what you need! You get 40 reports (approx. 800 pages) on floppy disk that give you information on setting up different businesses. You also get valuable reproduction and duplication rights so that you can sell the manuals as you like. **R030 £7.50**

● **PC CONTROLLED RELAY BOARD** Convert any 286 upward PC into a dedicated automatic controller to independently turn on/off up to eight lights, motors & other devices around the home, office, laboratory or factory using 8 240VAC/12A onboard relays. DOS utilities, sample test program, full-featured Windows utility & all components (except cable) provided. 12VDC. PCB 70x200mm. **3074KT £31.95**

● **2 CHANNEL UHF RELAY SWITCH** Contains the same transmitter/receiver pair as 30A15 below plus the components and PCB to control two 240VAC/10A relays (also supplied). Ultra bright LEDs used to indicate relay status. **3082KT £27.95**

● **TRANSMITTER RECEIVER PAIR** 2-button keyfob style 300-375MHz Tx with 30m range. Receiver encoder module with matched decoder IC. Components must be built into a circuit like kit 3082 above. **30A15 £14.95**

● **PC DATA ACQUISITION/CONTROL UNIT** Use your PC to monitor physical variables (e.g. pressure, temperature, light, weight, switch state, movement, relays, etc.), process the information & use results to control physical devices like motors, sirens, relays, servo & stepper motors. Inputs: 16 digital & 11 analogue. Outputs: 8 digital & 1 analogue. Plastic case with printed front/rear panels, software utilities, programming examples & all components (except sensors & cable) provided. 12VDC. **3093KT £99.95**

● **PIC 16C71 FOUR SERVO MOTOR DRIVER** Simultaneously control up to 4 servo motors. Software & all components (except servos/control pots) supplied. 5VDC. PCB 50x70mm. **3102KT £15.95**

● **PC SERIAL PORT ISOLATED I/O BOARD** Provides eight 240VAC/10A relay outputs & 4 optically isolated inputs. Designed for use in various control & sensing applications e.g. load switching, external switch input sensing, contact closure & external voltage sensing. Controlled via serial port & a terminal emulator program (built into Windows). Can be used with ANY computer/operating system. Plastic case with printed front/rear panels & all components (except cable) provided. **3108KT £54.95**

● **UNIPOLAR STEPPER MOTOR DRIVER** for any 5/6/8 lead motor. Fast/slow & single step rates. Direction control & on/off switch. Wave, 2-phase & half-wave step modes. 4 LED indicators. PCB 50x65mm. **3109KT £14.95**

● **PC CONTROLLED STEPPER MOTOR DRIVER** Control two unipolar stepper motors (3A max. each) via PC printer port. Wave, 2-phase & half-wave step modes. Software accepts 4 digital inputs from external switches & will single step motors. PCB fits in D-shell case provided. **3113KT £17.95**

● **12-BIT PC DATA ACQUISITION/CONTROL UNIT** Similar to kit 3093 above but uses a 12 bit Analogue-to-Digital Converter (ADC) with internal analogue multiplexor. Reads 8 single ended channels or 4 differential inputs or a mixture of both. Analogue inputs read 0-4V. Four TTL/CMOS compatible digital input/outputs. ADC conversion time <10uS. Software (C, QB & Win), extended D shell case & all components (except sensors & cable) provided. **3118KT £52.95**

SURVEILLANCE

High performance surveillance bugs. Room transmitters supplied with sensitive electret microphone & battery holder/clip. All transmitters can be received on an ordinary VHF/FM radio between 88-108MHz. Available in Kit Form (KT) or Assembled & Tested (AS).

ROOM SURVEILLANCE

● ***MTX*** **- MINIATURE 3V TRANSMITTER** Easy to build & guaranteed to transmit 300m @ 3V. Long battery life. 3-5V operation. Only 45x18mm. ● **3007KT £6.95 AS3007 £11.95**

MRTX **- MINIATURE 9V TRANSMITTER** Our best selling bug. Super sensitive, high power - 500m range @ 9V (over 1km with 18V supply and better aerial). 45x19mm. **3018KT £7.95 AS3018 £12.95**

HPTX **- HIGH POWER TRANSMITTER** High performance, 2 stage transmitter gives greater stability & higher quality reception. 1000m range 6-12V DC operation. Size 70x15mm. **3032KT £9.95 AS3032 £18.95**

● ***MMTX*** **- MICRO-MINIATURE 9V TRANSMITTER** The ultimate bug for its size, performance and price. Just 15x25mm. 500m range @ 9V. Good stability 6-18V operation. **3051KT £8.95 AS3051 £14.95**

● ***VTX*** **- VOICE ACTIVATED TRANSMITTER** Operates only when sounds detected. Low standby current. Variable trigger sensitivity. 500m range. Peaking circuit supplied for maximum RF output. On/off switch. 6V operation. Only 63x38mm. **3028KT £12.95 AS3028 £21.95**

HARD-WIRED BUG/TWO STATION INTERCOM Each station has its own amplifier, speaker and mic. Can be set up as either a hard-wired bug or two-station intercom. 10m x 2-core cable supplied. 9V operation. **3021KT £15.95 (kit form only)**

● ***TRVS*** **- TAPE RECORDER VOX SWITCH** Used to automatically operate a tape recorder (not supplied) via its REMOTE socket when sounds are detected. All conversations recorded. Adjustable sensitivity & turn-off delay. 115x19mm. **3013KT £9.95 AS3013 £21.95**

TELEPHONE SURVEILLANCE

● ***MTTX*** **- MINIATURE TELEPHONE TRANSMITTER** Attaches anywhere to phone line. Transmits only when phone is used! Tune-in your radio and hear both parties. 300m range. Uses line as aerial & power source. 20x45mm. **3016KT £8.95 AS3016 £14.95**

● ***TRI*** **- TELEPHONE RECORDING INTERFACE** Automatically record all conversations. Connects between phone line & tape recorder (not supplied). Operates recorders with 1.5-12V battery systems. Powered from line. 50x33mm. **3033KT £9.95 AS3033 £18.95**

● ***TPA*** **- TELEPHONE PICK-UP AMPLIFIER/WIRELESS PHONE BUG** Place pick-up coil on the phone line or near phone earpiece and hear both sides of the conversation. **3055KT £11.95 AS3055 £20.95**

● **1 WATT FM TRANSMITTER** Easy to construct. Delivers a crisp, clear signal. Two-stage circuit. Kit includes microphone and requires a simple open dipole aerial. 8-30VDC. PCB 42x45mm. **1009KT £14.95**

● **4 WATT FM TRANSMITTER** Comprises three RF stages and an audio preamplifier stage. Piezoelectric microphone supplied or you can use a separate preamplifier circuit. Antenna can be an open dipole or Ground Plane. Ideal project for those who wish to get started in the fascinating world of FM broadcasting and want a good basic circuit to experiment with. 12-18VDC. PCB 44x146mm. **1028KT. £24.95 AS1028 £39.95**

● **15 WATT FM TRANSMITTER (PRE-ASSEMBLED & TESTED)** Four transistor based stages with Philips BLY 88 in final stage. 15 Watts RF power on the air. 88-108MHz. Accepts open dipole, Ground Plane, 5/8, J, or YAGI configuration antennas. 12-18VDC. PCB 70x220mm. SWS meter needed for alignment. **1021KT £74.95**

● **SIMILAR TO ABOVE BUT 25W Output. 1031KT £84.95**

● **LIQUID LEVEL SENSOR/RAIN ALARM** Will indicate fluid levels or simply the presence of fluid. Relay output to control a pump to add/remove water when it reaches a certain level. **1080KT £6.95**

● **STEREO VU METER** shows peak music power using 2 rows of 10 LED's (mixed green & red) moving bar display. 0-30db. **3089KT £11.95**

● **AM RADIO KIT 1** Tuned Radio Frequency front-end, single chip AM radio IC & 2 stages of audio amplification. All components inc. speaker provided. PCB 32x102mm. **3063KT £10.95**

● **DRILL SPEED CONTROLLER** Adjust the speed of your electric drill according to the job at hand. Suitable for 240V AC mains powered drills up to 700W power. PCB: 48mm x 65mm. Box provided. **6074KT £18.95**

● **3 INPUT MONO MIXER** Independent level control for each input and separate bass/treble controls. Input sensitivity: 240mV. 18V DC. PCB: 60mm x 185mm. **1052KT £17.95**

● **NEGATIVE/POSITIVE ION GENERATOR** Standard Cockcroft-Walton multiplier circuit. Mains voltage experience required. **3057KT £10.95**

● **LED DICE** Classic intro to electronics & circuit analysis. 7 LED's simulate dice roll, slow down & land on a number at random. 555 IC circuit. **3003KT £9.95**

● **STAIRWAY TO HEAVEN** Tests hand-eye co-ordination. Press switch when green segment of LED lights to climb the stairway - miss & start again! Good intro to several basic circuits. **3005KT £9.95**

● **ROULETTE LED** 'Ball' spins round the wheel, slows down & drops into a slot. 10 LED's. Good intro to CMOS decade counters & Op-Amps. **3006KT £10.95**

● **9V XENON TUBE FLASHER** Transformer circuit steps up 9V battery to flash a 25mm Xenon tube. Adjustable flash rate (0-25-2 Sec's). **3022KT £11.95**

● **LED FLASHER 1** 5 ultra bright red LED's flash in 7 selectable patterns. **3037MKT £5.95**

● **LED FLASHER 2** Similar to above but flash in sequence or randomly. Ideal for model railways. **3052MKT £5.95**

● **INTRODUCTION TO PIC PROGRAMMING.** Learn programming from scratch. Programming hardware, a P16F84 chip and a two-part, practical, hands-on tutorial series are provided. **3081KT £22.95**

● **SERIAL PIC PROGRAMMER** for all 8/18/28/40 pin DIP serial programmed PICs. Shareware software supplied limited to programming 256 bytes (registration costs £14.95). **3096KT £13.95**

● **'PICALL' SERIAL & PARALLEL PIC PROGRAMMER** for all 8/18/28/40 pin DIP parallel AND serial PICs. Includes fully functional & registered software (DOS, W3.1, W95/8). **3117KT £59.95**

● **ATMEL 89Cx051 PROGRAMMER** Simple-to-use yet powerful programmer for the Atmel 89C1051, 89C2051 & 89C4051 uC's. Programmer does NOT require special software other than a terminal emulator program (built into Windows). Can be used with ANY computer/operating system. **3121KT £24.95**

● **3V/1-5V TO 9V BATTERY CONVERTER** Replace expensive 9V batteries with economic 1.5V batteries. IC based circuit steps up 1 or 2 'AA' batteries to give 9V/18mA. **3035KT £5.95**

● **STABILISED POWER SUPPLY 3-30V/2.5A** Ideal for hobbyist & professional laboratory. Very reliable & versatile design at an extremely reasonable price. Short circuit protection. Variable DC voltages (3-30V). Rated output 2.5 Amps. Large heatsink supplied. You just supply a 24VAC/3A transformer. PCB 55x112mm. Mains operation. **1007KT £18.95.**

● **STABILISED POWER SUPPLY 2-30V/5A** As kit 1007 above but rated at 5Amp. Requires a 24VAC/5A transformer. **1096KT £32.95.**

● **MOTORBIKE ALARM** Uses a reliable vibration sensor (adjustable sensitivity) to detect movement of the bike to trigger the alarm & switch the output relay to which a siren, bikes horn, indicators or other warning device can be attached. Auto-reset. 6-12VDC. PCB 57x64mm. **1011KT £12.95** Box **2011BX £7.00**

● **CAR ALARM SYSTEM** Protect your car from theft. Features vibration sensor, courtesy/boot light voltage drop sensor and bonnet/boot earth switch sensor. Entry/exit delays, auto-reset and adjustable alarm duration. 6-12V DC. PCB: 47mm x 55mm. **1019KT £12.95** Box **2019BX £8.00**

● **PIEZO SCREAMER** 110dB of ear piercing noise. Fits in box with 2 x 35mm piezo elements built into their own resonant cavity. Use as an alarm siren or just for fun! 6-9VDC. **3015KT £10.95**

● **COMBINATION LOCK** Versatile electronic lock comprising main circuit & separate keypad for remote opening of lock. Relay supplied. **3029KT £10.95**

● **ULTRASONIC MOVEMENT DETECTOR** Crystal locked detector frequency for stability & reliability. PCB 75x40mm houses all components. 4-7m range. Adjustable sensitivity. Output will drive external relay/circuits. 9VDC. **3049KT £13.95**

PIR DETECTOR MODULE 3-lead assembled unit just 25x35mm as used in commercial burglar alarm systems. **3076KT £8.95**

● **INFRARED SECURITY BEAM** When the invisible IR beam is broken a relay is tripped that can be used to sound a bell or alarm. 25 metre range. Mains rated relays provided. 12VDC operation. **3130KT £12.95**

● **SQUARE WAVE OSCILLATOR** Generates square waves at 6 preset frequencies in factors of 10 from 1Hz-100KHz. Visual output indicator. 5-18VDC. Box provided. **3111KT £8.95**

● **PC DRIVEN POCKET SAMPLER/DATA LOGGER** Analogue voltage sampler records voltages up to 2V or 20V over periods from milli-seconds to months. Can also be used as a simple digital scope to examine audio & other signals up to about 5KHz. Software & D-shell case provided. **3112KT £18.95**

● **20 MHz FUNCTION GENERATOR** Square, triangular and sine waveform up to 20MHz over 3 ranges using 'coarse' and 'fine' frequency adjustment controls. Adjustable output from 0-2V p-p. A TTL output is also provided for connection to a frequency meter. Uses MAX038 IC. Plastic case with printed front/rear panels & all components provided. 7-12VAC. **3101KT £69.95**

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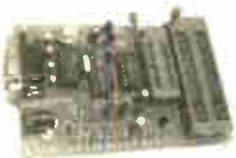
ABC Mini 'Hotchip' Board

Currently learning about microcontrollers? Need to do something more than flash a LED or sound a buzzer? The ABC Mini 'Hotchip' Board is based on Atmel's AVR 8535 RISC technology and will interest both the beginner and expert alike. Beginners will find that they can write and test a simple program, using the BASIC programming language, within an hour or two of connecting it up. Experts will like the power and flexibility of the Atmel microcontroller, as well as the ease with which the little Hot Chip board can be "designed-in" to a project. The ABC Mini Board 'Starter Pack' includes just about everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled microcontroller PC board with both parallel and serial cables for connection to your PC. Windows software included on CD-ROM features an Assembler, BASIC compiler and an in-system programmer. The pre-assembled boards only are also available separately.

ABCMINISP	ABC MINI Starter Pack	**£64.95**
ABCMINIB	ABC MINI Board Only	**£39.95**

ATMEL 89xxxx Programmer



Powerful programmer for Atmel 8051 microcontroller family. All fuse and lock bits are programmable. Connects to serial port. Can be used with ANY computer and operating system. 4 LEDs to indicate programming status. Supports 89C1051, 89C2051, 89C4051, 89C51, 89LV51, 89C52, 89LV52, 89C55, 89LV55, 89S8252, 89LS8252, 89S53, 89LS53 devices. NO special software required – uses any terminal emulator program (built into Windows).
NB: ZIF sockets not included.

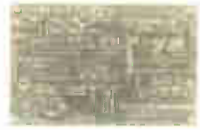
3123KT	ATMEL 89xxx Programmer	**£24.95**
AS3123	Assembled 3023	**£39.95**

Atmel 89C051 and AVR programmers also available.

Educational Robot Kits

This range of nine computerised battery robot kits teaches the basic principles of robotic sensing and locomotion. Each of the kits features pre-assembled PCBs, hardware and mechanical drive systems that can be handled by almost anyone from aged 10 and up. Only basic hand tools are required for assembly. These fascinating robots allow you to experience and learn any one of the following features: sound sensor, remote control, infra-red sensor, wired control and/or programmable memory.
See the full range of these high quality Japanese robot kits on our website or call for details.

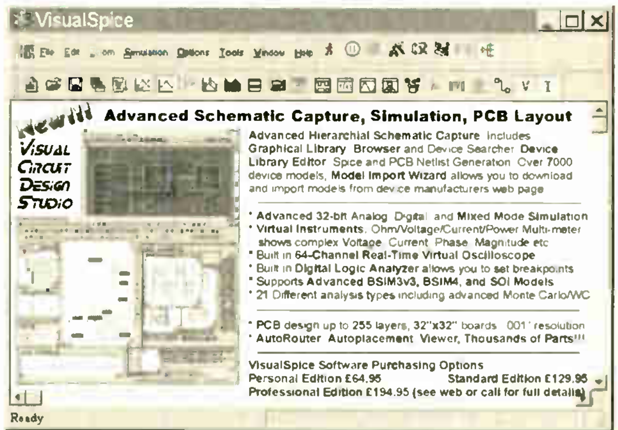
'PICALL' PIC Programmer



Kit will program **ALL** 8, 18, 28 and 40-pin serial AND parallel programmed PIC micro controllers. Connects to the parallel port of a PC. Supplied with fully functional pre-registered PICALL DOS and WINDOWS AVR software packages, all components and high quality DSPTH PCB. Also programs certain ATMEL AVR, serial EPROM and SCENIX SX devices. New PICs can be added to the software as they are released. Software shows you where to place your PIC chip on the board for programming. Now has new-chip auto sensing feature for super-fast bulk programming.

3117KT	'PICALL' PIC Programmer Kit	**£59.95**
AS3117	Assembled 'PICALL' PIC Programmer	**£69.95**
AS3117ZIF	Assembled 'PICALL' PIC Programmer c/w ZIF socket	**£84.95**

Advanced Schematic Capture, Simulation, PCB Layout



Serial Port Isolated I/O Controller

Kit provides eight 12A 240V AC (15A 110V AC) rated relay outputs and four optically isolated inputs. Can be used in a variety of control and sensing applications including load switching, external switch input sensing, contact closure and external voltage sensing. Programmed via a computer serial port, it is compatible with ANY computer and operating system. After programming, PC can be disconnected. Serial cable can be up to 35m long, allowing 'remote' control. User can easily write batch file programs to control the kit using simple text commands. NO special software required – uses any terminal emulator program (built into Windows). All components provided including a plastic case with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo).

3108KT	Serial Port Isolated I/O Controller Kit	**£54.95**
AS3108	Assembled Serial Port Isolated I/O Controller	**£69.95**

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KMX5	MK484 + 2030 MW RADIO	£21.95	KMB46	LM386 AMPLIFIER GENERAL	£6.75
KMX7	MK484 TUNER MW, NO AMP	£7.50	KMB48	COMMON PRE-AMP RADIO	£6.75
KMB2	BASIC CRYSTAL SET AMPLIFIED	£11.50	KMB49	PEST SCARER HIGH PITCH	£14.99
KMB4	WORKSHOP AMPLIFIER	£11.50	KMB50	VARIABLE FREQ. OSCILLATOR	£6.75
KMX11	S. METER	£11.95	KMB51	AUTOMATIC NIGHT LIGHT	£6.75
KMB44	SIMPLE HF MW ATU	£9.25	KMB52	FROST ALARM	£6.99
KMB8	SW TUNER GENERAL	£11.50	KMB53	PRESSURE MAT & ALARM	£16.50
KMC1	BASIC CRYSTAL SET MW	£7.95	KMB54	GUITAR TUNER	£11.50
KMB61	MW SIGNAL BOOSTER	£14.99	KMB55	TOUCH ALARM	£6.99
KMB9	FAKE CAR ALARM FLASHER	£6.30	KMB56	SIMPLE LIGHT METER	£16.50
KMB10	2 L.E.D. FLASHER	£5.95	KMB57	L.E.D. CONTINUITY METER	£5.50
KMB11	LOW VOLTS L.E.D. ALARM 9-12V	£6.30	KMB58	SOUND-OPERATED SWITCH	£7.95
KMB12	LIE DETECTOR WITH METER	£11.50	KMB58A	8 FLASHING L.E.D.s	£8.25
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KMB21	BURGLAR ALARM L.E.D. & SPEAKER	£6.30	KMB68	LIGHT-OPERATED RELAY	£9.25
KMB22	LOOP SECURITY ALARM	£6.30	KMB69	MICROPHONE PRE-AMP	£9.25
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KMB37	IC 555 TESTER – L.E.D.	£6.75	KMX12	AUDIO PROBE	£11.95
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KMK15 MW OR SW THREE VALVE REGEN RADIO USING A DIFFERENT SYSTEM, THIS USES EF91, EF80, EL84, VERY LOUD SPEAKER £39.95

KMK16 FOUR VALVE MW OR SW TOP OF THE RANGE, DESIGNED FOR EASY BUILDING NOVICES, GOOD SELECTIVITY, GOOD SPEAKER VOLUME £55.00

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GREENWELD

UNIT 24, WEST HORNDON INDUSTRIAL PARK
WEST HORNDON, BRENTWOOD, ESSEX CM13 3XD

GREENWELD

TEL: 01277 811042
FAX: 01277 812419

022001

ESR ELECTRONIC COMPONENTS

Station Road, Cullercoats, Tyne & Wear, NE30 4PQ

All Major Credit cards Accepted   SWITCH   SOLO

Prices Exclude Vat @17½%. Add £1.25 (UK) carriage & Vat to all orders. Cheques / Postal orders payable to ESR Electronic Components.

See Next / Last Months Ad. for COMPONENT ACCESSORIES

4000 Series

4000B	£0.18
4001B	£0.20
4002B	£0.17
4006B	£0.40
4007UB	£0.18
4008B	£0.23
4009UB	£0.23
4010B	£0.23
4011B	£0.20
4012B	£0.16
4013B	£0.20
4014B	£0.30
4015B	£0.32
4016B	£0.28
4017B	£0.29
4018B	£0.27
4019B	£0.25
4020B	£0.36
4021B	£0.31
4022B	£0.32
4023B	£0.19
4024B	£0.30
4025B	£0.20
4026B	£0.79
4027B	£0.25
4028B	£0.33
4029B	£0.33
4030B	£0.17
4035B	£0.31
4040B	£0.32
4041B	£0.31
4042B	£0.22
4043B	£0.28
4044B	£0.35
4046B	£0.38
4047B	£0.32
4048B	£0.34
4049B	£0.29
4049UB	£0.24
4050B	£0.28
4051B	£0.32
4052B	£0.32
4053B	£0.29
4054B	£0.56
4055B	£0.34
4060B	£0.29
4063B	£0.29
4066B	£0.23
4067B	£2.20
4068B	£0.16
4069UB	£0.19
4070B	£0.21
4071B	£0.26
4072B	£0.18
4073B	£0.17
4075B	£0.17
4076B	£0.30
4077B	£0.28
4078B	£0.20
4081B	£0.20
4082B	£0.21
4085B	£0.28
4086B	£0.33
4093B	£0.22
4094B	£0.29
4095B	£0.56
4097B	£1.20
4098B	£0.48
4099B	£0.39
4502B	£0.32
4503B	£0.40
4508B	£1.40
4510B	£0.45
4511B	£0.39
4512B	£0.32
4514B	£0.77
4515B	£0.99
4516B	£0.44
4518B	£0.38
4520B	£0.34
4521B	£0.62
4526B	£0.40
4527B	£0.40
4528B	£0.40
4529B	£0.44
4532B	£0.32
4536B	£1.00
4538B	£0.37
4541B	£0.33
4543B	£0.47
4555B	£0.32
4556B	£0.40
4566B	£1.96
4584B	£0.24
4585B	£0.47
4724B	£0.94
40106B	£0.24
40109B	£0.58
40174B	£0.46
40175B	£0.41

74 Series

7407	£0.40

SAMEDAY DESPATCH

No Minimum Order Value

74HC Series

74HC00	£0.20
74HC02	£0.18
74HC03	£0.21
74HC04	£0.21
74HC08	£0.25
74HC10	£0.16
74HC11	£0.20
74HC14	£0.22
74HC20	£0.28
74HC27	£0.16
74HC30	£0.22
74HC32	£0.20
74HC42	£0.36
74HC73	£0.40
74HC74	£0.22
74HC75	£0.42
74HC76	£0.20
74HC85	£0.24
74HC86	£0.22
74HC107	£0.40
74HC123	£0.33
74HC125	£0.26
74HC126	£0.46
74HC132	£0.35
74HC133	£0.34
74HC137	£0.30
74HC138	£0.25
74HC139	£0.31
74HC151	£0.33
74HC153	£0.30
74HC154	£0.85
74HC157	£0.40
74HC158	£0.23
74HC160	£0.64
74HC161	£0.28
74HC162	£0.45
74HC163	£0.26
74HC164	£0.35
74HC165	£0.35
74HC173	£0.38
74HC174	£0.27
74HC175	£0.35
74HC192	£0.72
74HC195	£0.32
74HC240	£0.37
74HC241	£0.37
74HC244	£0.42
74HC245	£0.42
74HC251	£0.30
74HC253	£0.25
74HC257	£0.25
74HC259	£0.57
74HC273	£0.32
74HC299	£0.64
74HC365	£0.34
74HC367	£0.25
74HC368	£0.25
74HC373	£0.35
74HC374	£0.40
74HC390	£0.52
74HC393	£0.38
74HC541	£0.35
74HC563	£0.56
74HC564	£0.48
74HC573	£0.39
74HC574	£0.38
74HC595	£0.39
74HC688	£0.64
74HC4002	£0.31
74HC4017	£0.42
74HC4020	£0.36
74HC4040	£0.36
74HC4049	£0.31
74HC4051	£0.40
74HC4052	£0.43
74HC4053	£0.38
74HC4060	£0.44
74HC4075	£0.27
74HC4078	£0.32
74HC4511	£0.64
74HC4514	£0.84
74HC4538	£0.41
74HC4543	£0.90

74LS Series

74LS00	£0.23
74LS01	£0.14
74LS02	£0.26
74LS03	£0.29
74LS04	£0.21
74LS05	£0.14
74LS08	£0.23
74LS09	£0.15
74LS10	£0.14
74LS11	£0.17
74LS12	£0.28
74LS13	£0.29
74LS14	£0.25
74LS15	£0.24
74LS20	£0.25
74LS21	£0.14
74LS26	£0.14
74LS27	£0.25
74LS30	£0.20
74LS32	£0.21
74LS37	£0.14
74LS38	£0.18
74LS40	£0.14
74LS42	£0.42
74LS47	£0.48
74LS51	£0.24
74LS73	£0.40
74LS74	£0.32
74LS75	£0.30
74LS76	£0.40
74LS83	£0.38
74LS85	£0.48
74LS86	£0.25
74LS90	£0.40
74LS92	£0.45
74LS93	£0.42
74LS107	£0.30
74LS109	£0.21
74LS112	£0.24
74LS113	£0.23
74LS114	£0.36
74LS122	£0.31
74LS123	£0.31
74LS125	£0.28
74LS126	£0.25
74LS132	£0.26
74LS133	£0.36
74LS136	£0.23
74LS138	£0.33
74LS139	£0.24
74LS145	£0.56
74LS148	£0.64
74LS151	£0.25
74LS153	£0.38
74LS154	£0.70
74LS156	£0.36
74LS157	£0.22
74LS158	£0.21
74LS160	£0.48
74LS161	£0.32
74LS162	£0.44
74LS163	£0.32
74LS164	£0.24
74LS165	£0.48
74LS173	£0.24
74LS174	£0.24
74LS175	£0.24
74LS190	£0.60
74LS191	£0.24
74LS192	£0.60
74LS193	£0.48
74LS195	£0.24
74LS196	£0.24
74LS221	£0.41
74LS240	£0.32
74LS241	£0.32
74LS243	£0.30
74LS244	£0.32
74LS245	£0.36
74LS247	£0.32
74LS251	£0.24
74LS257	£0.24
74LS258	£0.24
74LS259	£0.45
74LS266	£0.14
74LS273	£0.32
74LS279	£0.24
74LS365	£0.21
74LS367	£0.21
74LS368	£0.21
74LS373	£0.33
74LS374	£0.34
74LS378	£0.62
74LS390	£0.24
74LS393	£0.33
74LS395	£0.26

Linear ICs

AD524AD	£23.04
AD548JN	£2.48
AD590JH	£5.28
AD592AN	£4.48
AD595AQ	£13.92
AD620AN	£9.88
AD625JN	£16.20
AD633JN	£7.54
AD648JN	£3.57
AD654JN	£7.18
AD708JN	£5.69
AD711JN	£1.46
AD712JN	£2.48
AD736JN	£8.75
AD797AN	£8.69
AD811N	£6.24
AD812AN	£6.32
AD817AN	£3.12
AD820AN	£3.41
AD822AN	£5.20
AD829JN	£6.41
AD830AN	£5.44
AD847JN	£5.95
AD9696KN	£7.73
ADEL2020A	£5.06
ADM222AHE	£3.55
ADM232AA	£3.55
ADM485JN	£2.97
ADM690AN	£5.13
ADM691AN	£6.48
ADM695AN	£6.48
ADM699AN	£3.58
CA741CE	£0.24
CA747CE	£0.39
CA3046	£0.42
CA3059	£1.33
CA3080E	£0.60
CA3130E	£0.87
CA3140E	£0.52
CA3189E	£1.26
CA3240E	£1.00
DG211CJ	£1.55
DG411DJ	£2.00
ICL7106CPL	£2.80
ICL7107CPL	£2.00
ICL7109CLP	£8.99
ICL7611DCP	£0.75
ICL7621	£0.96
ICL7660SCP	£0.75
ICL8038	£3.84
ICM7555	£0.38
ICM7556	£0.84
L165	£2.56
L272M	£1.21
L293E	£3.84
L297	£6.72
L298N	£6.67
L6219	£4.48
LF347N	£0.46
LF351N	£0.45
LF353N	£0.40
LF356	£0.84
LM301AN	£0.40
LM308N	£0.58
LM311N8	£0.25
LM318	£1.05
LM319N14	£0.90
LM324	£0.26
LM335Z	£0.97
LM339N	£0.25
LM348N	£0.31
LM358N	£0.23
LM380N	£0.86
LM381N	£2.64
LM386	£0.45
LM392N	£0.79
LM393N	£0.21
LM748CN8	£0.37
LM1881	£3.92
LM2917N8	£3.10
LM3900N	£0.72
LM3914	£2.16
LM3915	£2.10
LM13600	£1.10
LMC660CN	£1.44
LMC6032IN	£1.55
LP311N	£0.74
LP324N	£0.72
LP339N	£0.75
LT1013CN8	£4.64
MAX202CPE	£2.97
MAX208CN	£6.99
MAX220CPE	£5.06
MAX222CPE	£5.06
MAX232CPE	£1.82
MAX483CP	£3.13
MAX485CP	£2.08
MAX631ACP	£4.99
MAX635ACP	£4.99
MAX1232CP	£2.80
MC1458N	£0.27
MC1488	£0.40
MC1489	£0.40
MC3302	£0.56
MC3340P	£1.60
MC4558P	£0.33
MV601DP	£2.97
NE521N	£6.39
NE555N	£0.21
NE556N	£0.29
NE565N	£1.94
NE566N	£0.90
NE567N	£0.39
NE571N	£2.72
NE592	£0.62
NE5532N	£0.48
NE5534N	£0.64
NE5539N	£4.35
OP07CN	£0.90
OP27CN	£2.48
OP77GP	£2.18
OP90GP	£3.11
OP97FP	£2.24
OP113GP	£3.44
OP176GP	£2.09
OP177GP	£1.89
OP200GP	£5.60
OP213FP	£5.20
OP275GP	£2.57
OP282GP	£2.27
OP283GP	£5.20
OP290GP	£5.40
OP297GP	£4.64
OP400GP	£11.81
OP495GP	£8.69
RC4136	£1.00
SG3524N	£0.96
SG3543	£6.88
SSM2017P	£3.12
SSM2141P	£3.63
SSM2142P	£6.16
SSM2143P	£3.78
TBA120S	£0.90
TBA800	£0.75
TBA810S	£0.64
TBA820M	£0.38
TDA1170S	£4.80
TDA2004	£2.88
TDA2030	£1.18
TDA2050V	£2.84
TDA2611A	£1.88
TDA2822A	£0.86
TDA2653A	£2.99
TED3718DP	£5.03
TEA5115	£3.11
TL061CP	£0.37
TL062CP	£0.60
TL064CN	£0.72
TL071CP	£0.38
TL072CN	£0.33
TL074CN	£0.48
TL081	£0.29
TL082CN	£0.35
TL084CN	£0.42
TL494CN	£0.70
TL7705ACP	£0.82
TLC271	£0.63
TLC272	£0.90
TS555CN	£0.34
TMP01FP	£5.60
ULN2003	£0.40
ULN2004A	£0.44
ULN2803	£0.60
ULN2804A	£1.64
XR2206	£3.84

EPROM's

2716	£5.22
2732	£5.51
2764-200	£3.99
27C64-250	£2.88
27128-200	£3.99
27C128-15	£3.02
27256-200	£3.99
27C256-20	£3.68
27C512-150	£2.64
27C1001-15	£3.12
27C2001-15	£4.50
27C4001-120	£5.73

RAM

GM76C88	£3.60
HM62128-7	£9.14
HT6116-10	£0.88
U6264ADC7	£1.42
KM62256-7	£3.20
41256-10	£3.52

A/D Converters Data Acquisition

AD420AN	£25.38
AD557JN	£8.75
AD7528JN	£11.42
AD7545AKN	£14.04
AD7828KN	£20.33
DAC0800	£2.72
ICL7109CPL	£7.75
TLC549IP	£2.75
ZN448E	£7.34

µControllers

AT89C2051	£6.43
12C508A-04P	£0.82
12C509A-04P	£0.85
16C54A04P	£3.07
16C54JW	£12.48
16C56-04P	£2.05
16F84-04P	£3.17
16F84-10P	£5.44

PHONE FOR OTHER DEVICES & QUANTITY DISCOUNTS

Voltage Regulators

7805	£0.31
7806	£0.32
7808	£0.35
7812	£0.29
7815	£0.30
78L05	£0.20
78L06	£0.32
78L08	£0.25
78L12	£0.25
78L15	£0.26
78L24	£0.39
78S05	£0.73
78S12	£0.70
78S15	£0.98
7905	£0.32
7912	£0.29
7915	£0.38
7924	£0.38
79L05	£0.23
79L12	£0.23
79L15	£0.28
79L24	£0.30
ADM666AN	£3.44
L200CV	£1.50
L296	£6.30
L387A	£2.72
LM2940CT5	£0.96
LM317LZ	£0.30
LM317T	£0.43
LM317K	£2.48
LM323K	£2.40
LM334Z	£1.35
LM337T	£0.67
LM338K	£5.52
LM338T	£1.48
LM723	£0.29
LP2950CZ	£2.70
REF01CP	£3.44
REF02CP	£4.66
REF12Z	£1.28
REF195GP	£4.72
REF25Z	£1.24
REF50Z	£1.20
TL431CP	£0.20
ZR423	£0.82
ZN458B	£1.41

Diodes

1N914	£0.06
1N916	£0.05
1N4001	£0.04
1N4002	£0.04
1N4003	£0.04
1N4004	£0.04
1N4005	£0.04
1N4006	£0.04
1N4007	£0.05
1N4148	£0.03
1N4149	£0.07
1N5400	£0.09
1N5401	£0.08
1N5402	£0.08
1N5404	£0.09
1N5406	£0.10
1N5407	£0.10
1N5408	£0.11
6A05	£0.27
6A1	£0.27
6A2	£0.27
6A4	£0.28
6A6	£0.29
6A8	£0.30
6A10	£0.35
BA157	£0.10
BA158	£0.08
BA159	£0.14
BAT41	£0.12
BAT42	£0.10
BAT46	£0.20
BAT49	£0.36
BAT85	£0.12
BAV21	£0.07
BAW62	£0.07
BAX13	£0.05
BAX16	£0.05
BY126	£0.13
BY127	£0.18
BY133	£0.10
OA47	£0.48
OA90	£0.24
OA91	£0.26
OA200	£0.56
OA202	£0.30
UF4001	£0.08
UF4002	£0.09
UF4003	£0.09
UF4004	£0.09
UF4005	£0.10
UF4006	£0.10
UF4007	£0.10
Zeners 2.7 to 33V 500mW	£0.06
1.3W	£0.10

Bridge Rectifiers

1.5A 50V	£0.19
1.5A 200V	£0.20
1.5A 400V	£0.22
1.5A 600V	£0.22
1.5A 800V	£0.27
1.5A 1kV	£0.24
3A 200V	£0.36
3A 400V	£0.40
3A 600V	£0.33
6A 200V	£0.70
6A 800V	£0.59
10A 400V	£1.39
25A 200V	£1.54
25A 600V	£1.81

Thyristors

C106D	£0.30
PO102AA	£0.30
TIC116D	£0.66
TIC126D	£0.77

Triacs

BT136-500	£0.60
BT136-600	£0.50
BT137-500	£0.65
BT137-600	£0.58
BT139-500	£1.00
BT139-600	£1.20
BTA08-600B	£0.84
BTA08-600BW	£0.89
BTA08-600C	£0.89
BTA08-600SW	£0.99
BTA12-600BW	£1.07
BTA16-600CW	£1.50
BTA16-600B	£1.28
BTA26-600B	£2.78
TIC206D	£0.55
TIC206M	£0.80
TIC226D	£0.76
TIC226M	£1.02
TIC246D	£1.00
TIC246M	£1.00
TIC236D	£1.12
ZO105DA	£0.53

Diac

DB3, 32V	£0.16

Transistors

2N1711	£0.26
2N1893	£0.29
2N2218A	£0.28
2N2219A	£0.24
2N2222A	£0.19
2N2646	£1.06
2N2904A	£0.25
2N2905A	£0.25
2N2907A	£0.19
2N3053	£0.27
2N3054	£0.85
2N3055	£0.62
2N3439	£0.62
2N3440	£0.50
2N3702	£0.09
2N3703	£0.10
2N3704	£0.11
2N3705	£0.08
2N3706	£0.10
2N3771	£1.44
2N3772	£1.51
2N3773	£1.70
2N3819	£0.33
2N3820	£0.66
2N3904	£0.09
2N3905	£0.08
2N3906	£0.10
2N4036	£0.34
2N5245	£0.80
2N5296	£0.57
2N5401	£0.12
2N5551	£0.11
2N6491	£1.58
2SB548	£0.30
AC126	£0.74
AC127	£0.50
AC187	£0.68
AC188	£0.97
ACY17	£3.84
AD149	£1.29
AD161	£0.92
AD162	£0.92
BC107	£0.16
BC107B	£0.14
BC108	£0.14
BC108B	£0.14
BC108C	£0.16
BC109	£0.17
BC109C	£0.17
BC114	£0.19
BC115	£0.41
BC118	£0.41
BC132	£0.36
BC134	£0.36
BC135	£0.36
BC140	£0.25
BC141	£0.27
BC142	£0.34
BC143	£0.38
BC154	£0.36
BC157	£0.12
BC159	£0.17
BC160	£0.28
BC170B	£0.16
BC171B	£0.16
BC172B	£0.13
BC177	£0.23
BC178	£0.18
BC179	£0.18
BC182	£0.10
BC182L	£0.09
BC183L	£0.08
BC184	£0.10
BC184L	£0.10
BC204C	£0.72
BC206B	£0.72
BC208	£0.72
BC209A	£0.72
BC212	£0.08
BC212L	£0.08
BC213B	£0.10
BC213LC	£0.11
BC214	£0.08
BC214L	£0.11
BC225	£0.15
BC237B	£0.09
BC238B	£0.11
BC239C	£0.10
BC250A	£0.15
BC252	£0.13
BC261B	£0.30
BC262B	£0.24
BC267B	£0.30
BC307	£0.10
BC308	£0.10
BC319C	£0.13
BC327	£0.08
BC328	£0.12
BC337	£0.10
BC337-25	£0.10
BC338	£0.12
BC348B	£0.14
BC357	£0.25
BC393	£0.73
BC441	£0.40
BC461	£0.46
BC463	£0.29
BC478	£0.32
BC479	£0.32
BC516	£0.21
BC517	£0.17
BC528	£0.20
BC537	£0.20
BC546B	£0.08
BC546C	£0.08
BC547A	£0.09
BC547B	£0.09
BC547C	£0.09
BC548C	£0.08
BC549B	£0.11
BC549C	£0.10
BC550C	£0.09
BC556A	£0.08
BC557A	£0.09
BC557B	£0.09
BC557C	£0.08
BC558B	£0.09
BC559B	£0.11
BC560A	£0.09
BC560B	£0.09
BC637	£0.19
BC638	£0.21
BC639	£0.11
BC640	£0.13
BCY70	£0.22
BCY71	£0.22
BCY72	£0.20
BD124P	£6.86
BD131	£0.52
BD135	£0.21
BD136	£0.21
BD137	£0.23
BD138	£0.24
BD139	£0.25
BD140	£0.25
BD150C	£0.82
BD165	£0.42
BD201	£0.40
BD202	£0.70
BD232	£0.50
BD237	£0.32
BD238	£0.44
BD240C	£0.37
BD245C	£1.18
BD246C	£1.18
BD283	£0.61
BD284	£0.61
BD400	£0.79
BD437	£0.38
BD442	£0.37
BD534	£0.47
BD535	£0.50
BD581	£0.62
BD597	£0.92
BD646	£0.52
BD648	£0.52
BD650	£0.53
BDX32	£1.78
BDX33C	£0.56
BDX34C	£0.50
BDX53C	£0.47
BDX54C	£0.50
BF180	£0.31
BF182	£0.31
BF185	£0.58
BF194	£0.31
BF194B	£0.19
BF195	£0.14
BF244	£0.35
BF244B	£0.35
BF244C	£0.35
BF257	£0.33
BF259	£0.33
BF337	£0.40
BF423	£0.13
BF451	£0.19
BF459	£0.33
BF469	£0.36
BFX29	£0.29
BFX84	£0.31
BFX85	£0.32
BFY50	£0.30
BFY51	£0.22
BFY52	£0.28
BS107	£0.21
BS170	£0.20
BU208A	£1.24
BU326A	£1.40
BU500	£1.54
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BU508D	£0.98
BU806	£1.06
BUT11A	£0.57
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IRF540	£0.82
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MJ3001	£1.80
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MPSA13	£0.13
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ZTX753	£0.36
ZTX789A	£0.41
ZTX790A	£0.41
ZTX851	£0.50
ZTX853	£0.50
ZTX951	£0.54
ZTX1048A	£0.48
ZTX1051A	£0.48
ZTX1053A	£0.48

Electrolytic Radial / Electrolytic Axial

	Electrolytic Radial					Electrolytic Axial						
µF	16v	25v	40v	63v	100v	16v	25v	40v	63v	100v	250v	450v
0.47	---	---	---	£0.05	---	---	---	---	---	---	---	---
1.0	---	---	---	£0.05	£0.05	---	---	---	£0.13	---	---	£0.22
2.2	---	---	---	£0.05	---	---	---	---	£0.13	---	---	£0.30
4.7	---	---	£0.05	£0.05	£0.06	---	---	---	£0.13	---	---	£0.41
10	£0.05	£0.05	£0.05	£0.05	£0.09	£0.12	---	£0.12	£0.13	£0.17	£0.40	£0.67
22	£0.05	£0.05	£0.05	£0.07	£0.11	£0.12	£0.13	£0.14	£0.15	£0.21	£0.52	£1.06
33	£0.05	---	£0.05	---	---	---	---	---	---	---	---	---
47	£0.05	£0.05	£0.08	£0.11	£0.19	£0.13	£0.13	£0.15	£0.19	£0.32	£0.57	---
100	£0.07	£0.08	£0.10	£0.13	£0.26	£0.14	£0.16	£0.19	£0.26	£0.44	---	---
220	£0.09	£0.09	£0.13	£0.28	---	£0.19	£0.20	£0.25	£0.39	£0.48	---	---
330	£0.09	---	£0.19	---	---	---	---	---	---	---	---	---
470	£0.13	£0.17	£0.24	£0.33	---	£0.24	£0.28	£0.41	£0.53	---	---	---
1000	£0.21	£0.33	£0.34	£0.84	---	£0.33	£0.43	£0.59	£1.08	---	---	---
2200	£0.32	£0.55	£0.70	---	---	£0.53	£0.69	£1.18	£1.55	---	---	---
3300	---	£0.94	---	---	---	---	---	---	---	---	---	---
4700	£0.67	£1.05	---	---	---	£0.86	£1.11	---	---	---	---	---

Resistors - Please State Value Required

per 100 of one value only

1/8W Carban Film 5%	E12 Series	10Ω-1M0	£0.02 Each, £0.80 per 100
¼W Carban Film 5%	E12 Series	1Ω-10M	£0.02 Each, £0.60 per 100
¼W Metal Film 1%	E24 Series	10Ω-1M	£0.04 Each, £1.72 per 100
½W Carban Film 5%	E12 Series	1Ω-10M	£0.02 Each, £0.95 per 100
2.5W Wirewaund 5%	E12 Series	0Ω1-220Ω	£0.23 Each

1W, 2W & 5W also in stock - selected values only, contact sales dept. for details.

Preset Resistors - Please State Value Required

Enclosed, 10mm Square Harz / Vert.	100Ω - 1M0 0.15W	£0.15 Each
Skeleton, 10mm Dia. Harizontal.	100Ω - 1M0 0.1W	£0.11 Each
Sub-min, 6mm Dia, Harizontal	E3 200Ω-1M0 0.1W	£0.13 Each
Multiturn, 10mm Square, Tap Adjust.	E3 100Ω-1M0 0.5W	£0.89 Each
Multiturn, 19mm Long, End Adjust.	E3 50Ω-1M0 0.5W	£0.60 Each

Potentiometers - Please State Value Required

Single Gang ¼" Shaft, 25mm Dia.	470Ω-2M2 Linear	£0.56 Each
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Dual Gang ¼" Shaft, 20mm Dia.	10k-1M0 Logarithmic	£1.54 Each
Switched ¼" Shaft, 20mm Dia.	1k0-2M2 Linear	£1.92 Each
Switched ¼" Shaft, 20mm Dia.	4k7-2M2 Logarithmic	£1.92 Each
PCB Mount, Splined Shaft, 16mm Dia.	470Ω-1M0 Linear	£0.48 Each
PCB Mount, Splined Shaft, 16mm Dia.	470Ω,4k7,100k,1M0 Log	£0.48 Each
Dual PCB, Splined Shaft, 16mm Dia.	10k,50k100k,500k Lin	£0.84 Each
Dual PCB, Splined Shaft, 16mm Dia.	10k,50k,100k,500k Log	£0.84 Each

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EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 30 No. 2 FEBRUARY 2001

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SOMETHING SOGGY

I asked Marilyn what I should write my Editorial about this month; as she was gazing out of the window at the level of the River Allen just a few feet from my office, her reply was "Something soggy". Despite the flood protection wall (built through Wimborne at great expense a few years ago), our small office garden was awash because the water table was so high and the river just a foot or so from the top of the wall and our office floor level. At least at the time it had stopped raining – probably only for a day or so – and the water level was receding.

What has all this got to do with technology? Well, nothing really, and that is the point. Whilst we can monitor the water levels and the weather with all means of high tech gubbins, we can't do anything about changing it. We have satellites and the Internet, we have mind-boggling electro-mechanical data storage (see the Millipede *News* item last month), we can generate massive amounts of power by all sorts of means, but we still fail to protect ourselves and our homes from the effects of the elements. Our world is far more powerful than we are, and it will no doubt remain so.

COMMERCIAL

Of course, we live in a commercial world where profit rules – if someone could make money from flood protection, like they can from communications, then we would soon see more barriers, pumps and pipes to protect vulnerable areas. Sadly, at present this is not the case, but maybe insurance companies and their regularly flooded customers could make schemes viable in the future. With, of course, electronics to monitor and control the systems.

There are few bounds to what we can achieve – as electronics developments continue to prove – if it is financially worthwhile. We are, however, still limited to what we can achieve when the elements decide to be nasty. However, next month we intend to show you how to generate your own lightning – see page 83.

Mike Kenward

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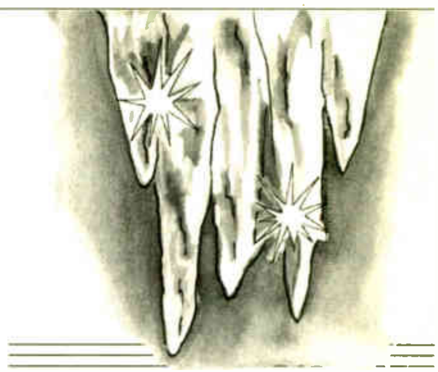
ICE ALERT



TERRY de VAUX-BALBIRNIE

Red alert for a frost warning!

THIS project gives an indication of the outside temperature by the changing appearance of a three-colour light-emitting diode (l.e.d.). Above a certain threshold (nominally 6°C), it will be off. As the temperature falls, it will progressively appear Green (below 6°C), Yellow (below 4°C) and Red (below 2°C). These operating points could be changed over a small range to suit the application.

The Ice Alert will be found particularly useful by car drivers. However, readers will find many other applications for it. For example, gardeners could use it to monitor the temperature inside a greenhouse or at the ground surface from a point inside the house.

EARLY WARNING

In many situations, the actual temperature of the surroundings does not need to be known. It is sufficient to be aware of it falling towards freezing point (0°C). When driving a car, steps may then be taken to reduce speed and be alert to the possibility of icy patches developing on the road.

When used in a car, the Ice Alert must not be relied on by the driver or used as a substitute for normal vigilance. It is designed simply to provide additional information which may assist safe driving.

Experienced motorists know that there may be isolated frosty patches even when the general temperature is several degrees above freezing point. Since the sensor takes a few minutes to respond, isolated regions having a lower temperature may not be "seen".

APPEARANCE

The circuit is built in a small plastic box. On the front panel a 3mm tri-colour l.e.d. shows through a small hole (see photograph). A temperature sensor is connected through a length of twin wire to a piece of screw terminal block on the circuit board.

Depending on the application, the sensor will need to be protected against mechanical damage and weatherproofed. For automotive use, it will be attached to a suitable place underneath the car.

When installed in a car, the inter-connecting lead will be fairly short. However, for other purposes it might be considerably longer. The system was used successfully with a lead 10m (33ft. approx.) in length. It could probably be made longer than this but the constructor would need to make the necessary tests.

THERMAL CHECK

It may be possible to set up the circuit without calibration using common sense methods but this is not advised. For best results you will need to use a good quality laboratory-type thermometer capable of reading over the range 0°C to 10°C with an accuracy of 0·5°C.

Beware of inexpensive digital thermometers whose good resolution (say, 0·1°C) may deceive the user into thinking that they must be accurate. The author's was "out" by almost 1·5°C.

Calibration does not take long and it may be possible to borrow a suitable thermometer from a local school or college for an hour or two. Note that a photographic thermometer is not suitable because its scale often starts at 15°C.

POWERING UP

When used in the car, the circuit receives current through the ignition switch so, while left unattended, no current is drawn. With the ignition on, the current required by the prototype unit is between 7mA (with no colour showing) and 40mA with *yellow*. Such a low value imposes very little load on the charging system.

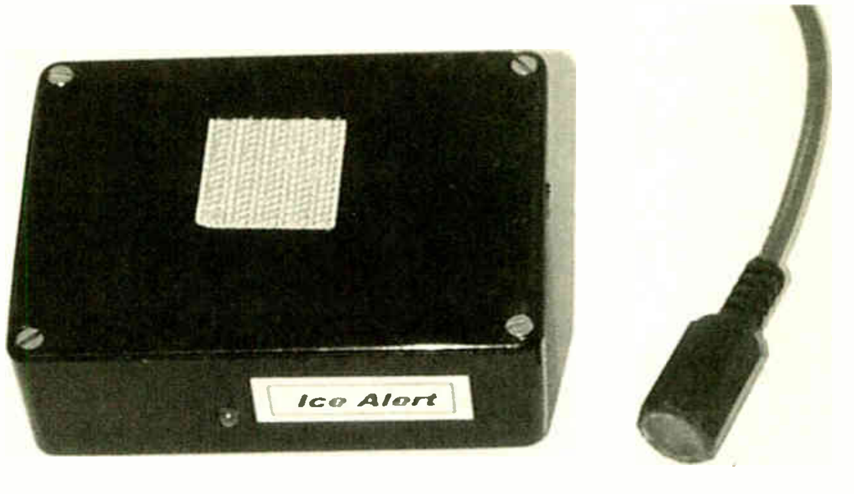
If the circuit is to be used for other than car purposes, it may be operated from a 9V battery (for example, the PP3 type) which can be accommodated inside the unit. When using such a supply, it will be necessary to include a pushbutton switch to power-up the circuit only when required. The current drawn will be less than that stated above for a 12V supply but, even so, *continuous* operation will soon drain the battery.

CIRCUIT DESCRIPTION

The complete circuit diagram for the Ice Alert is shown in Fig.1. The temperature sensor consists of miniature bead thermistor, R1. This relatively simple, small and inexpensive device proved to have several advantages over temperature sensing i.c.s.

Note that the thermistor should be of the specified type if the circuit is to work without modification. Other types of thermistor could be used but the user may need to experiment with component values. More will be said about this later.

Ignore capacitor C1 for the moment. The thermistor R1 is connected in series with fixed resistor R2. This forms a potential divider connected across Zener diode D1. The Zener diode operates in conjunction with resistor R4 to provide a fixed 5·1V (nominal) supply.



Completed Ice Alert. The small square of Velcro enables it to be easily installed below a vehicle dashboard.

As the battery voltage rises or falls, the voltage appearing across resistor R4 will be the difference between that of the supply and the Zener breakdown voltage. Of course, the supply will need to exceed 5·1V for this to happen.

RISING VOLTAGE

As the temperature falls, the resistance of thermistor R1 increases and so does the voltage across it. At the operating temperatures (6°C, 4°C and 2°C), the voltages will be some 2·8V, 3·95V and 3·1V respectively. Note that these figures are approximate and are given only for the purpose of illustration.

By sensing the voltage across the thermistor, the tri-colour l.e.d., D2, may be made to operate at the correct temperatures. From now on, 6°C is referred to as the "upper fixed point", 4°C the "intermediate fixed point" and 2°C the "lower fixed point".

In operation, only a few microamps flow through thermistor R1. Its power dissipation is therefore only a matter of microwatts and this results in very low self-heating. Its ability to measure temperature is therefore hardly affected by the heating effect of the current.

Capacitor C1 is connected in parallel with the thermistor. If the sensor connecting lead is fairly long, it tends to pick up "hum" from a.c. power fields and this could cause the l.e.d.s to flicker near the operating points. The capacitor bypasses the a.c. while having no effect on the standing d.c. voltage. This allows the l.e.d.s to switch more smoothly.

SMALL CHANGE

Integrated circuit IC1 is a quad operational amplifier (op.amp). This means that it contains four identical units contained in a single 14-pin package. Only three of the sections (IC1a, IC1b and IC1c) are actually used. The unused op.amp is "grounded" on the circuit board.

The inverting input of IC1a (pin 2), the non-inverting input of IC1b (pin 5) and the non-inverting input of IC1c (pin 12) are connected together and these, in turn, are connected to the top end of thermistor R1.

When the temperature of the thermistor is high, the voltage between these inputs and the 0V line will be low. When the temperature is low, the voltage here will be relatively high.

The remaining op.amp inputs (IC1a non-inverting input pin 3, IC1b inverting input pin 6 and IC1c inverting input pin 13) are connected to the sliding contacts of preset potentiometers VR2, VR1 and VR3 respectively. These provide adjustments to the operating points. The specified devices are multiturn trimmers which makes for very easy, accurate and convenient adjustment at the setting-up stage.

The ends of VR1 and VR2 tracks are connected in parallel and share fixed resistors R5 and R6 to form potential divider arrangements. The whole network is connected across D1, the 5·1V Zener stabilised supply. The fixed resistors limit the range of voltage available at the sliding contacts between some 2·5V and 3·6V.

With the specified thermistor this corresponds to a change from –5°C to +12°C approximately. This easily covers the range of temperatures over which the device is likely to be used.

Preset potentiometer VR3 works in a similar way to VR1 and VR2 but it has its own pair of resistors R3 and R7 to form a potential divider. The range of voltage available is 2·2V to 3·3V and this corresponds to a change from –1°C to +18°C approximately.

Stabilising the voltage applied to the potential dividers gives a precision effect and helps to maintain operating accuracy.

INPUT CONDITIONS

Look at IC1c first. Preset VR3 will be adjusted so that when the temperature sensed by the thermistor is 6°C (the upper fixed point) or less, the non-inverting input (pin 12) voltage will exceed the inverting one (pin 13).

Under these conditions, the output at pin 14 will be high and current will flow through current-limiting resistor R10 into the base (b) of transistor TR1. This turns it on and the collector (c) goes low. The l.e.d. (D2) is now enabled because there is a conducting path from the common cathode (k) to the 0V line.

When a higher temperature than the upper fixed point is detected, the input conditions are reversed and IC1 pin 14 will be low. With TR1 off, the conducting path is removed and the l.e.d. will not operate. A full description of how the tri-colour l.e.d. works is given later.

Preset VR2 is adjusted so that the voltage at IC1a non-inverting input (pin 3) is more than that at the inverting one (pin 2) for temperatures above 2°C (the lower fixed point). During this period, pin 1 is high and current can flow through current-limiting resistor R8 and the green l.e.d. section. Green will, therefore, show between the upper and lower fixed points.

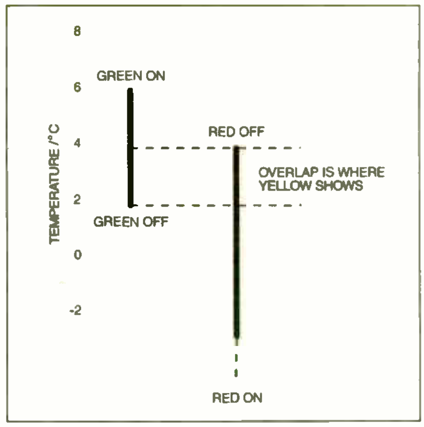


Fig.2. Tri-colour l.e.d. switching levels.

Preset VR1 will be adjusted so that the inverting input voltage of IC1b (pin 6) is less than that at the non-inverting one (pin 5) below 4°C (the intermediate fixed point). During this time, pin 7 will be high and the red l.e.d. section operates through current-limiting resistor R9. Red will show with temperatures below the intermediate fixed point.

This is best illustrated with the diagram shown in Fig. 2. The overall effect is that nothing will happen above the upper fixed point (because the l.e.d. is disabled), *green* will show down to the intermediate fixed point, *yellow* down to the lower fixed point (because both l.e.d. sections are on) and *red* below the lower fixed point (because the green section goes off).

COLOURFUL DESCRIPTION

For those who are not familiar with the tri-colour l.e.d., a brief description follows. Unlike a conventional l.e.d. this has *three* pinout leads – not two. The centre one is the common cathode (k) and is connected

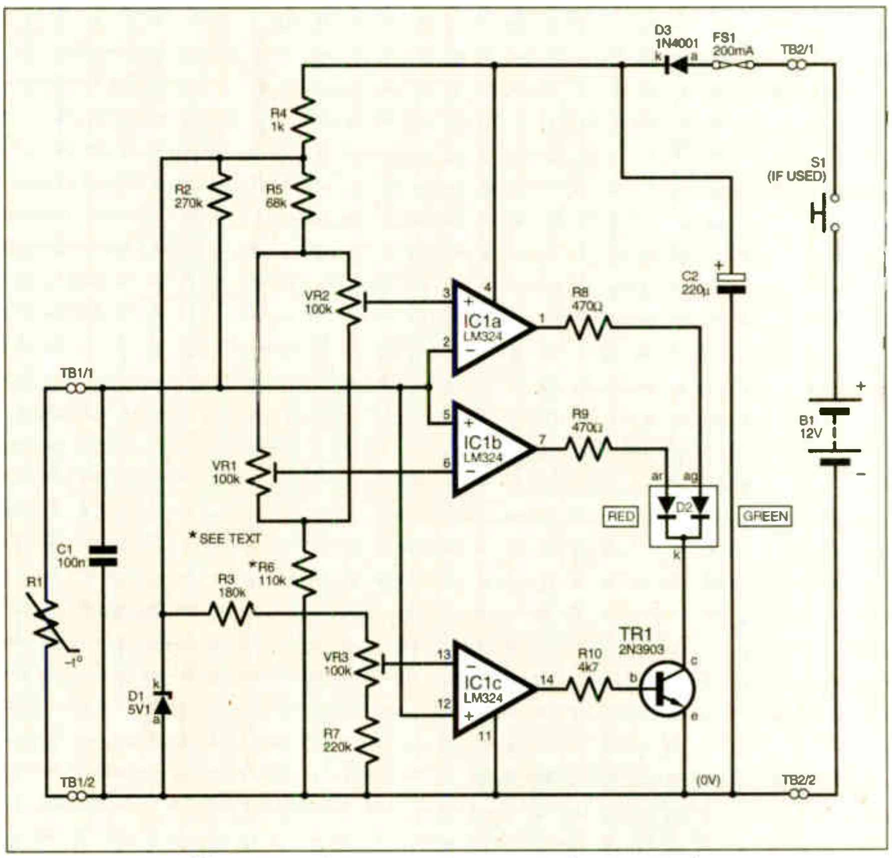


Fig.1. Complete circuit diagram for the Ice Alert.

to 0V. The other leads are the anodes of separate red and green l.e.ds. (ar and ag respectively) contained within a white translucent plastic package.

With current flowing through the red section only, the effect will obviously be red. Similarly, when current flows through the green section only, the effect will be green.

However, if *both* l.e.d. sections pass current, the red and green light diffuse and mix in the milky white plastic body to give a "yellow". Any student of physics will know that red light (a primary colour) mixed with green light (a primary colour) gives the secondary colour, yellow. Note that this is not the same as mixing red and green paint!

COMPONENTS

Resistors

R1	miniature bead thermistor: resistance at 25°C 150k and at 0°C 535k approx.
R2	270k
R3	180k
R4	1k
R5	68k
R6	110k (or 100k and 10k in series – see text)
R7	220k
R8, R9	470Ω (optional 330Ω for 9V battery – see text) (2 off)
R10	4k7

All 0·25W 5% carbon film, except R1

See SHOP TALK page

Potentiometers

VR1, VR2 VR3	100k multiturn preset, vertical mounting, top adjustment. Pins to be in line and having a spacing of 2·5mm (3 off)

Capacitors

C1	100n metallised polyester
C2	220μ radial elect. 25V

Semiconductors

D1	5V1 0·5W Zener diode
D2	3mm tri-colour l.e.d.
D3	1N4001 rect. diode
TR1	2N3903 *npn* transistor
IC1	LM324 quad op.amp

Miscellaneous

FS1	200mA 20mm quick-blow fuse and p.c.b. mounting fuse clips
S1	miniature s.p.s.t. push-to-make switch (for internal battery use)

Printed circuit board available from *EPE PCB Service*, code 287; plastic box, external size 75mm x 56mm x 25mm (larger if using an internal battery); 14-pin d.i.l. socket; 3A automotive-type wire; 2-core stranded connecting wire as required; auto-type connectors; silicone sealant (see text); solder etc.

Approx. Cost Guidance Only **£16** *excluding batt.*

PROTECTION

A supply is connected to the circuit through on-off switch S1 (if powered using an internal battery), fuse FS1 and diode D3. This latter component provides reverse-polarity protection. Thus, if the supply were to be connected in the opposite sense, the diode would fail to conduct and nothing would happen.

Fuse FS1 will blow if the current rises excessively in the event of a short-circuit. This is vital when a car battery is used because these can deliver an enormous current under short-circuit conditions. This could melt p.c.b. tracks, cause burns and be a general fire hazard.

Since the car charging circuit provides a rather unsmooth output, capacitor C2 is included to condition it and provide a suitable supply for the rest of the circuit.

CONSTRUCTION

Construction is based on a single-sided printed circuit board (p.c.b.). The topside component layout and full-size underside copper foil track master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 287.

All components, apart from the thermistor (R1) and on-off switch S1 (if used) are mounted on the p.c.b. Begin construction by drilling the two fixing holes and soldering the link wire in place as indicated. Note that this is difficult to do after preset VR2 has been soldered in position.

Add the pieces of screw terminal block, the 14-pin d.i.l. socket for IC1 (but do not insert the i.c. itself yet) and the fuse clips. If fuse clips such as those shown in the photograph are not available, use a p.c.b. mounting fuseholder or a small fuseholder mounted off-board.

Solder all fixed resistors and capacitor C1 in position. Note that if a 9V battery is to be used as the power supply, resistors R8 and R9 could be reduced to 330 ohms if the l.e.d. does not turn out to be bright enough in use. In the interests of long battery life, however, leave them as they are.

To make up the specified value for resistor R6, you could use a 100k (kilohms) and a 10k unit connected in series (as in the prototype unit). Add capacitor C2 and diodes D1 and D3 taking care over the polarity of these components. The orientation of D1 is correct as shown.

To the beginner, it may seem as if it is the wrong way round. However, because it is a Zener diode it operates in reverse bias. The negative lead of C2 is clearly indicated and is slightly shorter than the positive one.

Next, solder the preset potentiometers in place. These should be mounted as shown in Fig.3 and the photograph (with the adjustment screw on VR1 and VR2 at top right and for VR3 bottom right). The circuit will work if they are mounted in the opposite sense but the instructions given later regarding their adjustment will be incorrect and the effect might be confusing.. Note that the preset potentiometers should be of the type having a top adjustment screw and with the pins in line (rather than in the form of a triangle).

TRI-COLOUR L.E.D.

Now look at the tri-colour l.e.d. (D2). The common cathode (k) lead is the centre one and the red and green anode (ar and ag respectively) are on each side of it. It is important to solder this device with the anode leads located correctly. If they are incorrectly placed, the colours will be interchanged and this would give strange results at the setting-up stage.

The longer of the two anode leads is the red and the shorter one green, see inset diagram in Fig.3. After taking note of which is which, cut them to a length of 10mm, bend them carefully through right angles and solder them in position.

If you lose track of which lead is which, the specified unit is different in the way the end leads enter the body. If you look carefully, you will see that the red one is bent though a right angle whereas the green one makes an obtuse angle.

Adjust the preset potentiometers in the following way (assuming they are of the specified pattern and have been mounted as indicated in Fig.3): VR1 and VR2 fully clockwise and VR3 full anti-clockwise. Note that these devices usually click if the screw continues to be turned after the sliding contact has reached the ends of its track.

Finally, place a 200mA quick-blow fuse between the fuse clips and insert IC1 into its socket taking care over the orientation.

TESTING

Do not test the unit by immersing the thermistor in water. This is because tap water is a reasonably good conductor of electricity and it would effectively short-circuit the leads. This would give an apparent reduction in the resistance of the thermistor and lead to totally incorrect results.

Do not wait until the thermistor has been waterproofed or the slower response time would make calibration inconvenient.

The circuit should be tested and adjusted using a 9V battery (an alkaline PP3 type would be suitable). This should be done before mounting the p.c.b. in its case. In this way, any small faults may be corrected more conveniently.

Since water must be avoided for the reason stated above, use cooking oil for calibration. This is a non-conductor so will not interfere with correct operation. Place a small amount of this in a small plastic container to provide a depth of 30mm approximately. Put it in a freezer for 15 minutes or so until the temperature has fallen to –5°C or thereabouts.

While waiting for the oil to cool, prepare the thermistor. Using two sections of a 2A screw terminal block, connect the thermistor to a short piece of light-duty twin wire. Connect the other ends to terminal block TB1 on the p.c.b. Connect a PP3 battery snap (or as required) to TB2 taking care over the polarity – red (+) wire to TB2/1 and black (–) wire to TB2/2.

When the cooking oil is taken out of the freezer, it may have partially solidified. If necessary, wait until it softens then place the thermometer bulb and thermistor in it. Make sure both the thermometer bulb and thermistor are well covered. Connect the battery – the l.e.d. should light up *red*.

STIRRING IT

With the aid of an assistant, keep the oil stirred constantly and take a continuous note of its temperature.

When the temperature rises to 2°C, adjust preset VR2 anti-clockwise to the point where the green l.e.d. just comes on (the display will now show *yellow*). When the temperature reaches 4°C, adjust VR1 anti-clockwise so the red l.e.d. just goes off (the colour is now *green*). When 6°C is reached, adjust VR3 clockwise until the l.e.d. goes off (no colour shows).

You may need to repeat the procedure several times to obtain the required operating points.

BE PREPARED

The following assumes that the Ice Alert circuit is to be used in a vehicle. If not, work accordingly.

Decide on a suitable position for the main unit. The l.e.d. should be clearly visible from the driving position. Attach it using a "Velcro" pad.

Decide on a suitable site for the sensor. This needs to be placed as low as possible or the temperature indicated may not be a true reflection of that near the road. Also, it must be kept as far away as possible from the exhaust system or anything else which becomes hot.

There will probably be a suitable site in the region of the front bumper. Try to find a place where there will be a free flow of air around the sensor unit while the car is moving.

very small and will not cause any problems. Note, however, that the l.e.d. will go *off* if this were to happen. Should the wire break, the l.e.d. would show red.

PROTECTION RACKET

The thermistor (R1) now needs to be waterproofed and protected. Use a short piece of plastic tube to contain it. In the prototype unit, the end of an old phono plug was used.

Push the ends of the connecting wires through the hole in one end of the tube and solder them to the thermistor using minimum heat to prevent damage. Do not cut down the leads (or if you have to, remove the minimum amount) since even more heat would reach the thermistor during soldering and there would be a greater risk of damage.

Push the thermistor and soldered connections so they are completely inside the tube. Making certain the soldered joints are kept well separated, fill the tube with clear silicone sealant. This must be of a type which cures to become tough and rubbery. Use the material available in a small tube from various manufacturers (such as *Loctite Clear Adhesive Sealant*). Products such as "bathroom sealant" have not been tested and might not be suitable.

the material to harden. It must now be handled with care. Take care not to put the connecting lead under any strain.

CASING UP

The p.c.b. should now be attached inside a small plastic case. Where the unit is being used in a car, the box need only be large enough to accommodate the circuit panel plus a little extra to allow for connections to be made to the p.c.b.-mounted terminal blocks.

If an internal 9V battery is used, you will need a larger box. You also need to include a push-to-make switch (S1) in the positive supply lead to conserve battery life.

Measure the position of the l.e.d. on the p.c.b. and drill a hole in the front of the box to correspond with it. This should only be large enough to allow the tip of the l.e.d. to pass through.

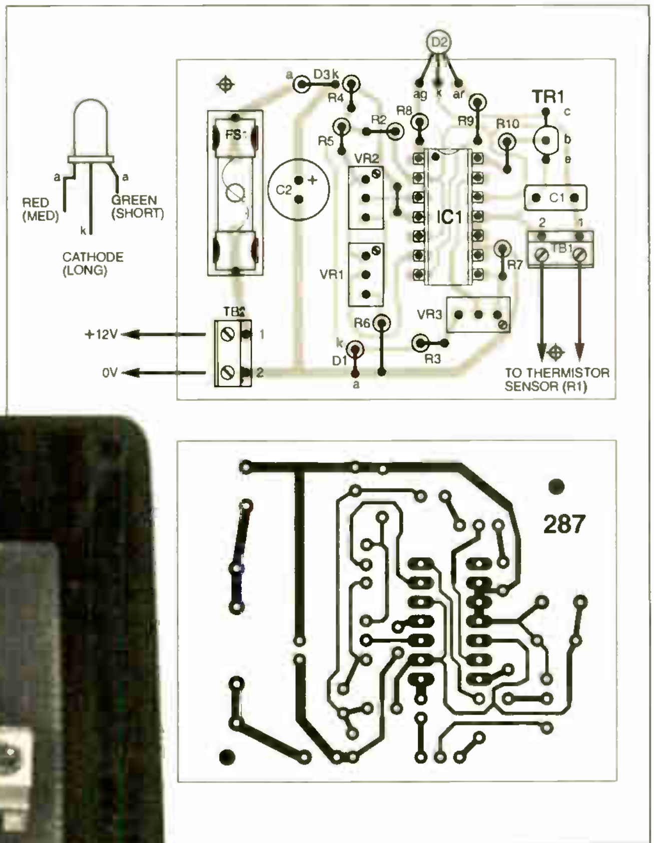
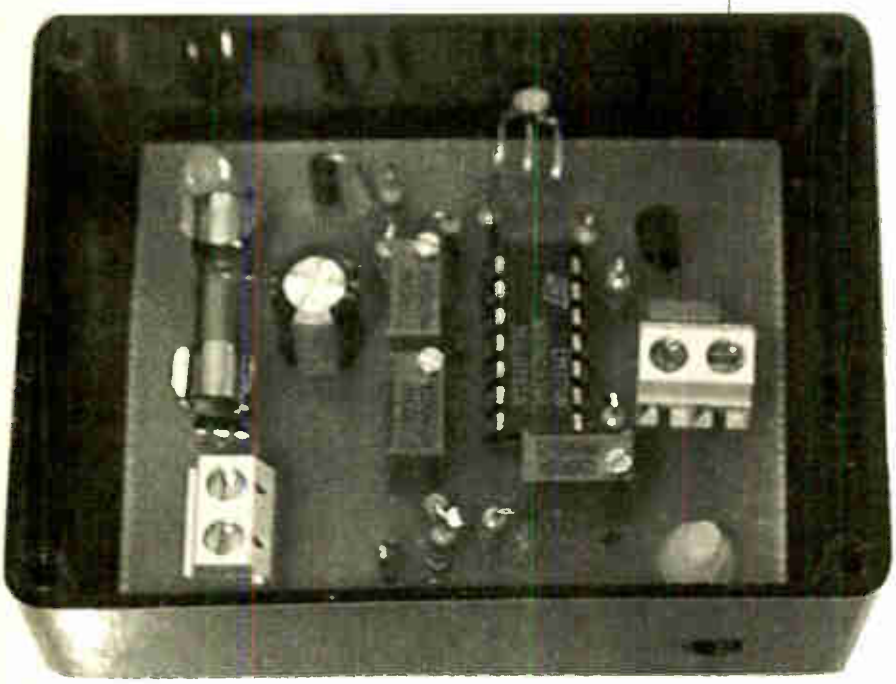


Fig.3. Printed circuit board component layout and full size foil master pattern.



Ice Alert completed circuit board secured inside a small plastic box with nylon fixings. The tri-colour l.e.d. can be seen at the top.

Measure the length of light-duty two-core wire needed to connect the thermistor sensor to the main unit. This does not need to be of automotive quality but it must be of the *stranded* type. Do not use single-core wire or it would break easily in service.

"Ordinary" (non-automotive) wire may be used because, in the event of a short-circuit between the "live" sensor wire and the car chassis (0V) or between the wires, the maximum current which can flow is limited by resistors R2 and R4 in series. This will be

Check that all bare wires and the thermistor itself are deeply embedded in the silicone material and allow it to harden. It is absolutely essential for the thermistor and its end leads to be completely waterproofed and great care must be taken over this process. The operating points will be greatly affected by even small traces of moisture. The completed sensor appears in the photograph.

Leave the sensor for 24 hours (or whatever curing time is shown on the tube) for

The bead thermistor temperature sensor encased in a phono plug.

Hold the p.c.b. in position just above the base of the box and *gently* bend the l.e.d. leads as necessary so its tip takes up the correct position in the hole drilled for it. Mark the positions of the p.c.b. fixing holes. Remove the p.c.b. again and drill these through.

Make a hole for on-off switch, S1 (if used). Drill a small hole in the side near terminal block TB2 position for the power supply wires (unless an internal supply is used) and a further one near TB1 for the sensor wires.

Attach the p.c.b. using small *nylon* fixings. Place plastic washers on the bolt shanks to keep the soldered joints on the underside clear of the base of the box. Make sure the l.e.d. leads are not left under any strain.

INSTALLING

Attach the thermistor sensor in its chosen position. This can possibly be done using a small plastic clip or some epoxy resin adhesive. It is important to support the connecting wire close to the sensor using a further clip. This will remove the strain at the point where it enters the tubular "casing".

Route the sensor wire back to the main unit. *Note: whenever it passes through a hole in metal, a protective rubber grommet must be used.* Pass the wires through the appropriate hole in the box and connect them to TB1.

CONNECTING UP

Connections now need to be made to the car electrical system. ***Before proceeding, the car battery must be disconnected. (Check the car's manual to make sure it is OK to disconnect the battery before proceeding.) This is essential procedure. If you do not do it, there is risk of causing a short circuit which could result in wires becoming red hot and burns to the skin.*** The supply must be made using light-duty *auto-type* cable and with proper car-type connectors.

If you have a radio of the type having a numerical code, make sure you have this available to re-enter it when the supply is re-established. Also make sure you know how to do this by referring to the instructions supplied with the radio.

A safer alternative to making direct connections would be to plug the unit into the cigar lighter socket. This method is rather less attractive but does have the advantage of being quick and easy.

WIRING UP

For permanent wiring, connect TB2/1 to a point via an existing fuse which is live only when the ignition is switched on and TB2/2 to an existing earth point (car chassis). It may be that the easiest place to obtain a feed to the circuit is at the rear of the radio or audio system. Connections to existing wires may be made using "snap-lock" connectors.

If you decide to use the wires leading to the radio, identify the correct positive one to use because there are likely to be two of them. One is a constant +12V feed to maintain the memory settings and the other will probably be via the "car radio" position on the ignition switch. The latter would be suitable for the new circuit.

If any wire passes through a hole in metal, a rubber grommet must be used to prevent cutting by the sharp edge and possibly causing a short-circuit. Apply strain relief to both the sensor and power supply wires inside the case by applying tight cable ties to them.

Re-connect the car battery and switch on the ignition. The l.e.d. should be off (assuming the temperature outside is above the upper fixed point). You could wait for a cold day to make a final test. However, a rough check on operation could be made by using a freezer spray applied to the sensor. Remember, it will take some time to respond.

When using the Ice Alert for other than car purposes, it may be necessary to place the sensor more than 10m from the main unit. This could be necessary, for example, if you wished to monitor the temperature in a remote greenhouse from a point inside the house. In cases such as these, check that the l.e.d. sections operate relatively "cleanly" (without too much flickering).

This type of problem could probably be reduced by using light-duty single *screened* cable for the inter-connecting lead instead of ordinary twin wire. The screening would be connected to 0V (that is to TB1/2) and the inner core to TB1/1. Note that the resistance of any wiring used will be much less than that of the thermistor. The effect of the resistance of the connecting lead is therefore negligible.

CHOICE OF THERMISTOR

The circuit will work correctly if the specified thermistor is used. However, it is appreciated that some readers will be restricted in their choice of thermistor.

If you must use one of a different pattern, use the usual "negative temperature coefficient" variety (that is, as the temperature *rises*, the resistance *falls*) having a resistance of some hundreds of kilohms at 0°C. Halve this figure and select the nearest available value of fixed resistor. Use this in the R2 position.

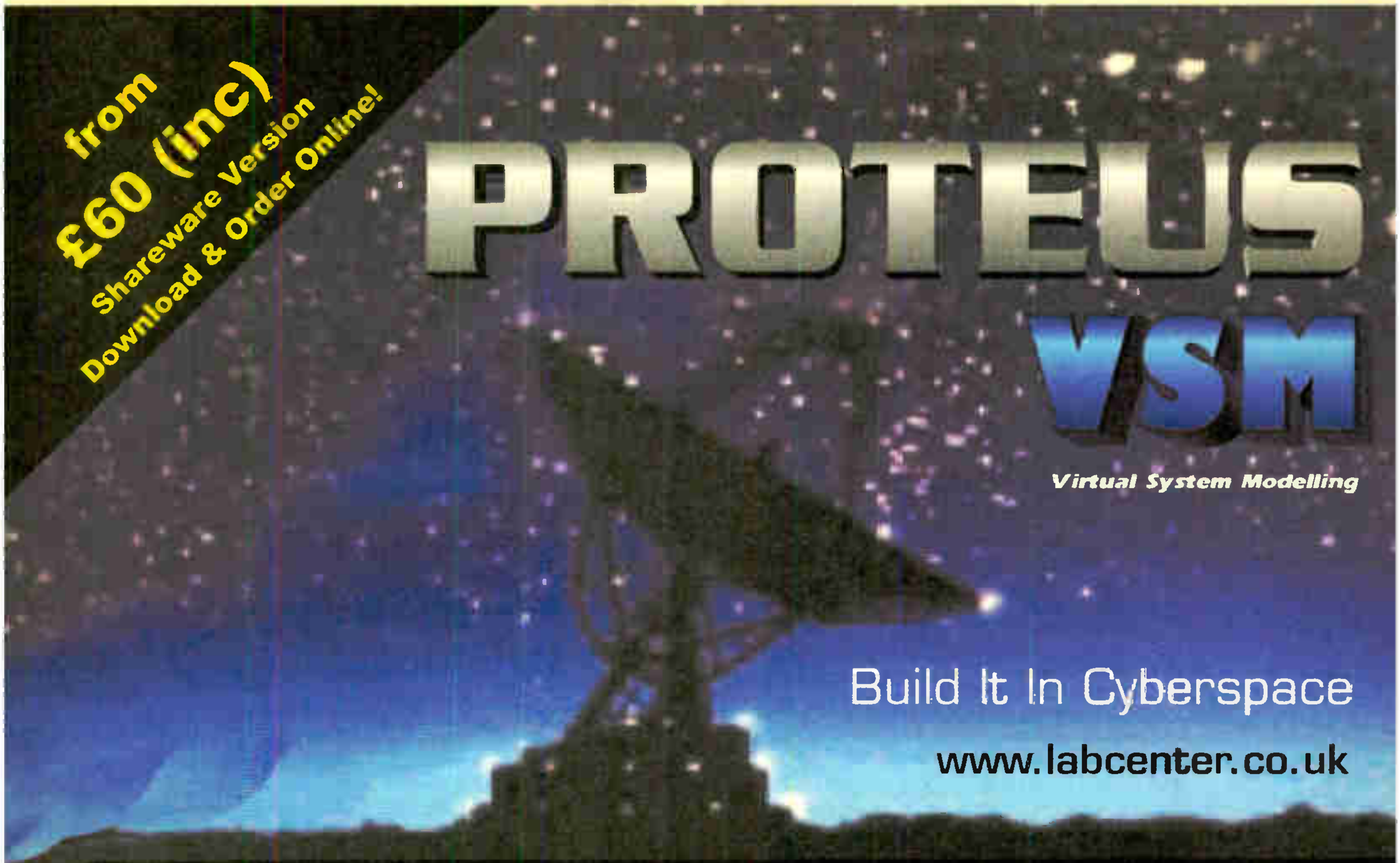
If the circuit now works correctly, all well and good. If not, use link wires instead of resistors R3, R5, R6 and R7. This will give the maximum range of adjustment of the preset potentiometers (from 0V to 5·1V). Although they may be more awkward to adjust, it should now be possible to set up the correct operating points.

RESPONSE TIME

Although it takes a while for the sensor to respond to large changes in temperature, this is not generally a problem. While the car is parked, the sensor will assume the temperature of the surrounding air.

When driving along, the changes will probably not be very great and the sensor should respond within a few minutes. If the sensor is placed in the air flow, the response will be faster.

When used in a vehicle, the Ice Alert *MUST NOT* be relied on by the driver or used as a substitute for normal driving vigilance. It is designed simply to provide additional information which may assist safe driving. □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News . . .

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

TEXT FILES NOT IMMUNE TO VIRUSES

Contrary to what is widely believed, the latest computer viruses *can* live and propagate through text files. Barry Fox alerts us.

VIRUS wars have taken a nasty new twist. E-mail viruses are getting past anti-virus software by disguising themselves as help files which hide in plain text that had previously been thought safe. Anti-virus software must work in completely new ways to trap them. There is widespread confusion over what systems are at risk and how best to protect them.

VIRUS EXECUTIVES

Until recently viruses spread as executable code programs, attached to plain text E-mails. The text message encourages the recipient to open the attachment by clicking on it. This runs the program which deliberately corrupts data on the PC's hard disk, makes copies of itself and attaches them to outgoing E-mails, so as to spread the infection. Traditional anti-virus software scans attachments before they are opened, looking for the "signature" of known viruses. PC users have felt safe to open and read E-mails as long as they do not click on any attached file.

Bubble Boy, the first virus to infect without an attachment, exploited a security loophole in Microsoft's Outlook Internet mail reader. The virus code is written as lines of HTML code which are included in the text message. Outlook treats the text as an Internet page and runs the code to release the virus. Expert PC users who understand the risk, and also understand Microsoft's jargon, can download a program which modifies Outlook to stop it being fooled (**http://www.microsoft.com/technet/security/bulletin/ms00-046.asp**).

BEWARE SILLY TITLES

Now a new virus, confusingly known as Verona, Romeo and Juliet or BleBla plays a much more devious trick which is likely to fool a wider range of Internet mail readers. A text message with a silly title, such as Hey You, Sorry or From Shake-Beer, arrives with two attached files, a Help file called **Myjuliet.chm** and a program called **MyRomeo.exe**. Just reading the text message makes Windows save the two attachments to its standard Temporary folder where the Help file automatically runs and triggers the program to infect the PC. This then tries to send copies to other addresses stored in the mail reader.

Romeo and Juliet does no damage to the hard disk and has not spread because the Polish Internet servers it uses to spread infection were quickly shut down. So there has been very little publicity.

"But the code now exists as a template which the hacker community can share and modify to make it much more dangerous" warns Nick Galea, CEO of GFI, a Maltese company which makes software to protect office networks. "Then we shall see PCs damaged as soon as people read a text message."

Galea thinks that protection software must start checking E-mails for the effects viruses may cause, not just known signatures.

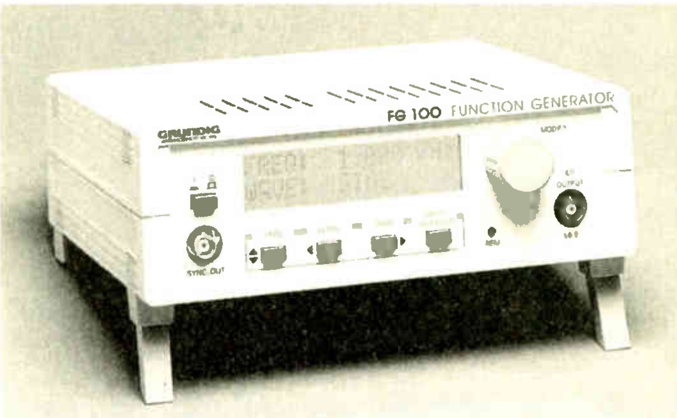
SYMANTEC'S WARNING

Eric Chien, chief researcher at Symantec's Anti-Virus Centre, warns that this is much easier with office networks than standalone PCs. A network server can store and check all incoming E-mails before distributing them to office staff. Individual PCs collect E-mail direct from the Internet. Symantec has developed a system called PopProxy which shunts incoming E-mail into a buffer file on the PC, and checks plain text for tell-tale code. The user only sees the mail after it has been checked. Symantec has built PopProxy into the latest version of its Norton Anti-Virus software, NAV 2001, but done surprisingly little to explain or promote it.

Graham Cluley of Sophos thinks the only long term solution is to use proprietary E-mail services and readers, such as Compuserve, AOL or Cix, which treat text only as text, ignore any lines of code which are embedded and never dress plain text up as HTML.

"Better to choose a safe reader in the first place, than go on spending money on anti-virus software that tries to make unsafe readers safe". Opinions differ on what Internet readers are safe, but the one thing everyone agrees on is that Microsoft, the most widely used, has been the least safe. All too often it sends the text twice in the same message, once plain and safe and once in HTML and risky. The sender is not usually aware of this.

20MHz FUNCTION GENERATOR



VANN Draper Electronics, the manufacturer and world-wide distribution company for Grundig *digimess* Instruments, has announced a new 20MHz function generator.

The FG100 provides a wide frequency range of 0·5Hz to 20MHz with a high accuracy of 0·5 per cent monitored by an internal microprocessor. Output wave shapes include sine, triangle, square and sawtooth, with variable symmetry enabling pulse signals to be produced.

A back-lit alphanumeric display provides concise readings of settings and frequency, as well as communication modes when using the built-in RS232C interface.

Other key features include internal sweep, d.c. offset, variable output level from 10mV to 10V, plus sync output. It operates as stand-alone or PC controlled.

Priced at £199 the FG100 is available direct from Vann Draper or their authorised distributors. For more details contact Vann Draper Electronics Ltd, Dept EPE, Stenson House, Stenson, Derby DE73 1HL. Tel: 01283 704706. Fax: 01283 704707. E-mail: sales@vanndraper.co.uk. Web: www.vanndraper.co.uk.

B.A.E.C. SEEKS PIC ENTHUSIASTS!

THE Editorial of the British Amateur Electronics Club's recent newsletter laments the decline in contributions to it. The Editor, George Burton, expressed the opinion that the B.A.E.C. should follow *EPE*'s example and place a strong emphasis on the use of PIC microcontrollers.

George asks, "How many of our members have seen a PIC chip let alone used one? It is these members I am trying to find. We have to start using these multi-purpose components or shall fade away – reminiscing how we used to do it".

We suggest that any reader who knows about PICs (and there are many thousands of you) and would like to join the B.A.E.C. and share their knowledge with other members through contributions to the Newsletter should do so *now*. You will be warmly welcomed, as will other non-PIC electronics enthusiasts.

The Club is open to anyone interested in electronics – and that's all of you! (We know that a *trickle* of you have joined recently, well done. How about a *flood* – dare we mention the word in the present climate?)

The B.A.E.C. has existed for many decades and deserves your support so that it can progress into the future. We encourage you to contact the Chairman, George Burton, 581 Fishponds Road, Fishponds, Bristol BS16 3AA. Tel: 0117 9654800. E-mail: prontaprint.bristol@cableinet.co.uk. Web: http://members.tripod.com/~baec. Mention *EPE* when contacting George.

TRAFFIC REPORTS COMPETITORS

By Barry Fox

THE cellphone companies are spending billions on licences to spend more billions building third generation networks. The last thing they need is competition from conventional radio services which can offer 3G features at far lower cost.

After ten months of trials a Californian startup, backed by Texas Instruments, Motorola and Paul Allen, is offering digital radio broadcasters a system which competes head-on with 3G. Command Audio lets drivers listen to the latest traffic, weather, sports and news information, the moment they get in the car. While driving they can switch between music in real time, and the latest news updates.

The technology was developed and patented by Command Audio in Redwood City and John Ryan, who heads up Macrovision, the world leader in video copy protection. A control centre compresses a wide selection of conventional radio programmes into 2·4Kbps streams and broadcasts them as data channels. The receiver, which looks like a chubby TV remote control, has memory chips which continually store the last eight hours of sub-channel audio, for instant skip and scan access at the press of a button.

Command has trialled the system in Denver and Phoenix using data subcarriers on FM radio stations and prototype handsets made by RCA and Thomson. Most countries, except the US, are adopting the European digital radio system which can carry much more digital data than FM radio – around 1·5Mbps of which some 75 per cent is used for music and the rest set aside for data (the UK allocation is 20 per cent or 230Kbps but could be increased; Singapore already allows 35 per cent). So far digital broadcasters have used their data capacity to deliver Internet pages but Command believes drivers would prefer on-demand audio.

Quentin Howard, Chief Executive of the UK's commercial digital radio network Digital One, has long enthused over data by radio. He says: "We have built a radio network that can deliver very high data rates to an unlimited number of users from just 70 transmitters. The new cellular networks will each require some 6000 transmitters and will never be able simultaneously to serve the same number of consumers as we can".

Howard thinks Command Audio is a "neat idea" but questions whether listeners will be prepared to pay the $12 a month subscription which Command is talking about.

MAPLIN CD-ROM

MAPLIN Electronics' latest CD-ROM catalogue has recently been released. It contains around 15,000 products, ranging from individual components to state-of the-art electronic equipment.

The CD-ROM, which has been developed in HTML, is designed with the same functions as Maplin's website and runs on Internet Explorer 5 (available to download from the CD-ROM).

The new "Web-enabled" CD-ROM allows you to construct your order offline. Once Submit has been pressed the browser is launched automatically allowing orders to be stock checked and processed for sameday despatch.

To receive a copy of the CD-ROM, which costs £1.99, contact the Order Line on 0870 264 6000 and quote order code CQ07, or click on the icon at **www.maplin.co.uk**. Maplin's press release states the contact address as Maplin Electronics, Valley Road, Wombwell, Barnsley S73 0BS. Mention *EPE* when contacting Maplin.

RIPPING MUSIC

By Barry Fox

MP3 ripping is now a living room reality. Korean electronics giant Samsung is the first big brand name in household audio to offer a range of mini, midi and micro hi-fi systems with integrated MP3 ripper. Until now consumers have had to use a PC to download MP3 music from the Internet or "rip" CDs by converting the content into MP3 (MPEG-1, Layer 3) code. The PC must then be connected to a portable solid state player like the Diamond Rio, to transfer the music for portable playback.

Three new home audio stacks from Samsung (costing between £350 and £500) have a CD player, built-in MP3 encoder and dockable Yepp solid-state player with 32MB SmartMedia card for 30 minutes recording time. The owner just plays a disc while transferring the music to the portable, without needing to own a PC or know anything about computers and computing.

ROBOT KITS

AN E-mailed newsletter from Quasar Electronics informs us that "We have introduced a range of educational electronic robot kits. We really like them. They are high quality, excellent designs, good fun and educational. What more could you ask for in life . . .". Indeed!

Quasar have lots more educational kits (and others). You will find info about them at: **www.quasarelectronics.com/educational-electronic-projects.htm**. There is also a mirror site at **www.electronic-kits-and-projects.com/home.htm**.

Tel: 01279 306504.
E-mail: sales@quasarelectronics.com.
Note Quasar's fax: 07092 203496.

SQUIRES TOOLS

SQUIRES Model and Craft Tools 2001 catalogue has recently arrived at HQ. It contains an excellent (dare we say "fully comprehensive"?) variety of the tools and associated modelling accessories that any self-respecting hobbyist requires. The electronic components range has been expanded and all goods are available by post-free mail order.

In over 400 well presented and itemised pages, Squires' cat is a *must* to have on your workbench. It's also *free of charge* – just contact Squires and they'll send you a copy:

Squires Model and Craft Tools, Dept EPE, 100 London Road, Bognor Regis, W. Sussex PO21 1DD. Tel: 01243 842424. Fax: 01243 842525. (No Web as yet, but it's on its way!)

EOCS Website Launched

THE Electronic Organ Constructors Society website **www.eocs.org.uk** is now on-line. So far as is known, the EOCS is the only international society devoted to amateur electronic organ building. If this is your interest, have a good browse of the site, and even participate in the EOCS equivalent of our Chat Zone.

You can also contact the Society via Trevor Hawkins, Hon. Sec., EOCS, 23 Blenheim Road, St Albans, Herts AL1 4NS. Tel: 01727 857344. Mention *EPE*.

New Technology Update

Last month Ian Poole discussed organic lasers. He now looks at the emerging technology of organic l.e.d.s.

SURPRISINGLY the cathode ray tube still offers the best performance for many display applications. Modern alternatives, including liquid crystal displays, electro-luminescent displays and a variety of other types, have not managed to capture the market to the degree achieved by the c.r.t.

Organic Displays

However, a new breed of displays is beginning to appear. Termed Organic Light Emitting Diode (OLED) displays, they offer some real advantages over displays that are currently available. Unlike traditional liquid crystal displays (l.c.d.s) these OLED displays are self-luminous and do not require back-lighting. As back-lights take up additional space it means that OLED displays can be made thinner and more compact than many other types.

A further advantage is that OLED displays have a very wide viewing angle. This can be up to 160 degrees, even in bright sunlight.

They also consume relatively little power, and can run from supplies between 2 and 10 volts. This makes them very attractive for many applications where voltage supplies and power consumption are an issue.

A further advantage of the low power consumption is an improvement in EMC performance. As drive levels are low, the risk of radiating signals is much reduced, and this is particularly useful when designing products for which regulations on emissions are relatively tight.

Operation

There are two basic types of display, active and passive. However, they both rely on the same basic principles. The basic OLED cell structure consists of four layers of organic material positioned between a metallic cathode and a transparent anode. The organic layers comprise a hole injection layer, a hole transport layer, an emissive layer and an electron transport layer, as shown in Fig.1.

A voltage is applied across the cell and positive and negative charges recombine in the emissive layer as in an ordinary diode. As a result of the recombination light is produced. Most of the recombination takes place in the emissive layer, although some does occur elsewhere. To improve the efficiency the design of the structure is optimised to ensure this recombination takes place in the emissive layer where light is produced. Further enhancement of the light output is gained by doping the emissive layer with a small level of highly fluorescent molecules.

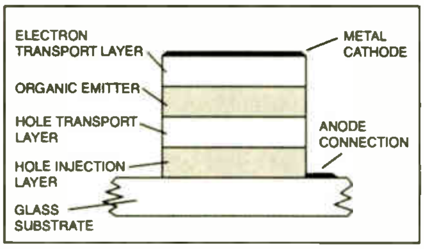


Fig.1. OLED Structure

Passive displays

Passive OLED displays are less complicated than their active counterparts. They are well suited for low cost and low information content applications like alphanumeric displays. They are formed by providing an array of OLED pixels. The cathodes and anodes are arranged in rows and columns and by selecting the relevant row and column the required pixel can be activated. These can be scanned and successively lit to give the required pattern.

Kodak have developed a unique method for fabricating these devices. The simplicity of the process means that costs are kept to a minimum.

First a "rib" or "base and pillar" structure is pre-formed on patterned anode lines. The organic materials are then deposited and the nature of the deposition process means that the OLED display panel with the required electrical isolation for the cathode lines is automatically formed.

One of the major advantages of this method of fabrication is that no new processes have been introduced and it can be easily be adapted to high throughput manufacturing.

Active displays

As the name suggests, the passive display does not include any additional electronics. This limits its application to the more simple displays where the individual rows and columns can be easily accessed. Once the pixel count rises to the level that graphics can be displayed it becomes necessary to include the drive circuitry within the display itself. This is normally included in the substrate where a back plane can be constructed. In this way a very sophisticated high resolution graphics display can be created, suitable for applications like television screens, computer monitors and the like.

The use of polysilicon technology is key to the manufacture of these displays because it provides a high carrier mobility. This gives the thin film transistors (TFT) that are used a high current carrying capacity and fast switching speed essential for the correct operation of these displays.

Each individual pixel in the display can be addressed separately via the electronic circuitry in the back plane that consists of the TFTs and associated capacitors.

The basic circuitry is relatively simple and combined with the straightforward fabrication of the display itself, there are no intrinsic limitations to the pixel count, resolution or actual size of the display. This makes it particularly attractive for high resolution displays of the types needed for televisions and computer monitors.

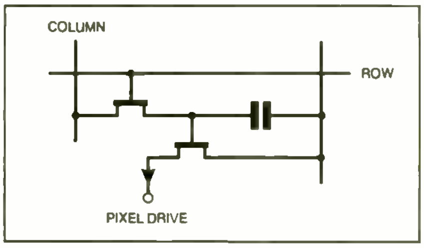


Fig.2. Active display driver circuit

Missing pixels

Missing pixels occur on any large display. It is normal to allow displays to be sold that have a small number of defects. If this were not done then the yields would be unacceptably low and prices exceedingly high. When this occurs with an OLED display the pixel is left dark, and this is unlikely to be noticed by the eye. Faulty l.c.d. displays often produce a point of light and this is far more visible.

Future

Whilst much of the work that has been described has been undertaken by Kodak, other companies are also working on the displays and forming alliances that will enable production to move forward more swiftly.

In one development, DuPont Displays have acquired Uniax Corporation of California. Other companies are active as well. In an alliance, Covion Organic Semiconductors GmbH from Frankfurt have linked up with eMagin Corp in New York. In this alliance Covion will provide the display technology for use in eMagin's current and future display products. This alliance is in turn partnering IBM to further develop OLED-on-silicon technology for use in a number of advanced display based applications.

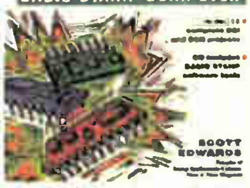
In view of the level of work being undertaken, it can be seen that the industry is taking this new development very seriously, and soon OLED displays should start to appear in products on the market in large quantities.

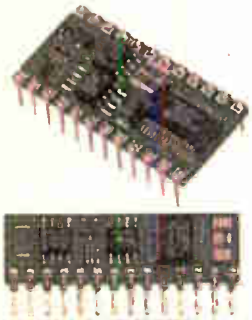
CONTROL & ROBOTICS

Milford Instruments

BASIC Stamp Microcontrollers

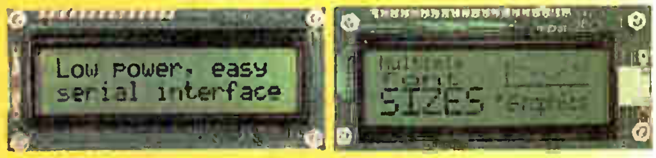
Still the simplest and easiest way to get your project or development work done. BASIC Stamps are small computers that run BASIC programmes. With either 8 or 16 Input-Output pins they may be connected directly to push-buttons, LEDs, speakers, potentiometers and integrated circuits such as digital thermometers, real-time clocks and analog-digital converters. BASIC Stamps are programmed using an ordinary PC running DOS or Windows. The language has familiar, easy-to-read instructions such as FOR...NEXT, IF...THEN and GOTO. Built-in syntax make it easy to measure and generate pulses, read push-buttons, send/receive serial data etc. Stamps from **£25** (single quantities), Full development kits from **£79**





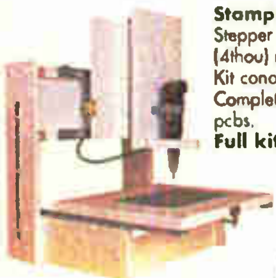
Full information on using BASIC Stamps plus lots of worked projects and practical electronics help. CD-ROM also includes 30+ past magazine articles and Stamp software. **£29.95**

New to PICs or just wanting to learn more tricks? We stock the excellent PIC primer books from David Benson- suitable for the complete beginner to the advanced user.



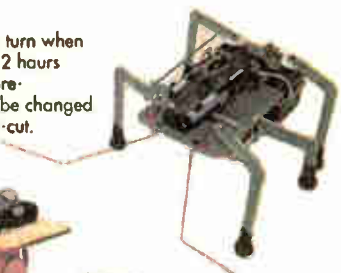
SERIAL LCDs

Bannish the hassle of interfacing to LCD displays. We stock a comprehensive range of alphanumeric and Graphic LCDs - all with an easy-to-use standard RS232 serial Interface. Sizes from 2x16 to 4x40 plus 128x64 graphic panels. Prices start at **£25** (single quantity)

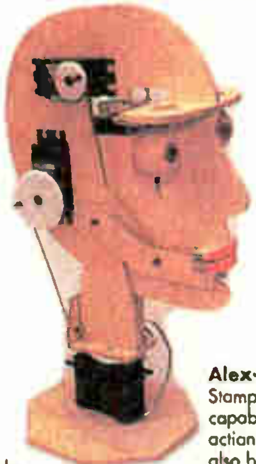


Stamp2 based 3-axis machine
Stepper drive to X, Y and Z axes with 0.1mm (4thou) resolution.
Kit conoins pre-machined frame components.
Complete with Windows software for drilling pcbs.
Full kit at £249, Part kit at £189

StampBug
Stamp1 based walking insect
Forwards,backwards and left/right turn when feelers detect object in path. Up to 2 hours roving from 4xAA Nicads. Chips pre-programmed but programme may be changed (software supplied). Body parts pre-cut.
Full kit £68



TecArm4
New range of robotic arms for educational and hobbyist use with super powerful servos. Controlled from PC (Windows freeware provided) or from optional keypad. Stands about 450mm high when fully extended. Kit includes all pre-cut body parts, servo controller board, servos and software. Requires 9v Dc. Kits start at **£189**

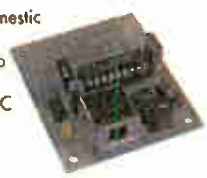


BigFoot
Stomp1 based walking humanoid
Walks forwards/backwards with left and right turn when detects obstacles. Electronics pcb pre-built and tested. Programme pre-loaded but may be changed with supplied software.
Full kit £68

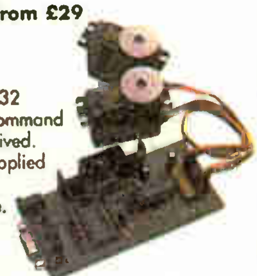
Alex- Animated Head
Stamp2 based controller with voice record-playback capability, PIR input and/or random playback. 4-servo actions are recorded/edited one track at a time. May also be controlled from PC.
Head kits start at £29. Controllers from £29

On Screen Display
Superimpose text onto standard CCTV from simple RS232 serial line.
Ready built/tested at **£59**

IR Decoder Board
Control your project using a standard domestic IR remote.
7 Output lines (5v @ 20mA) may be set to momentary or toggle action.
Simple teaching routine. Requires 9-12vDC
Supplied built and tested.
£29 single quantity



Servo Driver Board
Control up to 8 standard hobby servos from an RS232 serial data line using this controller board. Simple command structure holds servos in position until update is received. Fully built and tested- requires 9vDC and servos. Supplied with Windows freeware.
£29 single quantity. Optional keypad available.



Milford Instruments
120 High Street, South Milford, LEEDS LS25 5AQ
Tel: 01977 683665 Fax: 01977 681465

All prices exclude VAT and shipping.
BASIC Stamp is the registered trademark of Parallax Inc. For further details on the above and other interesting products, please see our web site- **www.milinst.demon.co.uk**

Top Tenners

SIMPLE METRONOME

OWEN BISHOP

Project 6

This short collection of projects, some useful, some instructive and some amusing, can be made for around the ten pounds mark. The estimated cost does not include an enclosure. All of the projects are built on stripboard, and most have been designed to fit on to boards of standard dimensions. All of the projects are battery-powered, so are safe to build. In a few cases in which, by its nature, the project is to be run for long periods, power may be provided by an inexpensive mains adaptor. Again, the cost of such a unit is not included.

As well as its obvious benefit to musicians (aspiring or arrived), this project can be used as a pacer by those busy with aerobics or other on-the-spot exercises. Its display consists of a row of light-emitting diodes (l.e.d.s). These are flashed one at a time, in order from left to right and repeating continuously.

A rotary switch selects the number of l.e.d.s flashed, which is equal to the number of beats in a bar. It allows the user to choose between 2/4, 3/4 and 4/4 time signatures:

1, 2, 1, 2, 1, 2, ...
1, 2, 3, 1, 2, 3, 1, 2, 3, ...
1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4,...

Another common time signature is 6/8 but, as the fourth note in each bar is often slightly accented, this can be obtained by using the 3/4 setting and doubling the tempo. The Tempo (Rate) is set by a variable resistor (potentiometer) and covers the range from *Largo* to *Presto*.

The Simple Metronome also has an audio output. This is provided by a piezoelectric sounder which emits a short beep at the beginning of each bar, that is, on the count of "one", which is when the left-most l.e.d. comes on.

HOW IT WORKS

The full circuit diagram for the Simple Metronome is shown in Fig.1. The basic tempo is provided by timer IC1. This i.c. is a dual version of the well-known 555 timer. The other timer within IC1 is used to switch on the piezoelectric sounder WD1 when triggered.

The timer that controls tempo is wired as an astable multivibrator, which means that it generates a continuous series of pulses at a definite rate. Its frequency is controlled by the setting of Rate control VR1.

With the values shown in Fig.1, the frequency of the astable is variable from just over 1Hz up to 6Hz. A polyester capacitor is used for C4 because the capacitance of this type does not vary with age and with use, as does that of the electrolytic type.

The output signal at pin 9 from the astable goes to the clock input (pin 14) of a divide-by-eight counter, IC2. The counter is incremented on the rising edge of each pulse. It has eight outputs, of which one goes to logic high at each count. The others remain at logic low.

For the counter to run, its reset input (pin 15) must be held low. A brief high level on the reset input triggers the counter to reset to zero.

As counting proceeds, the outputs would normally go high in order from 0 to 7, repeating. However, we use only the first five outputs in this circuit. For example, if we set Beat switch S2a for four beats to the bar, IC2 outputs 0, 1, 2 and 3 go high in that order. Then, when output 4 goes high, the high level is fed through S2 to the reset pin (IC2 pin 15).

Thus, as soon as output 4 (which would be a count of 5) goes high, the counter is

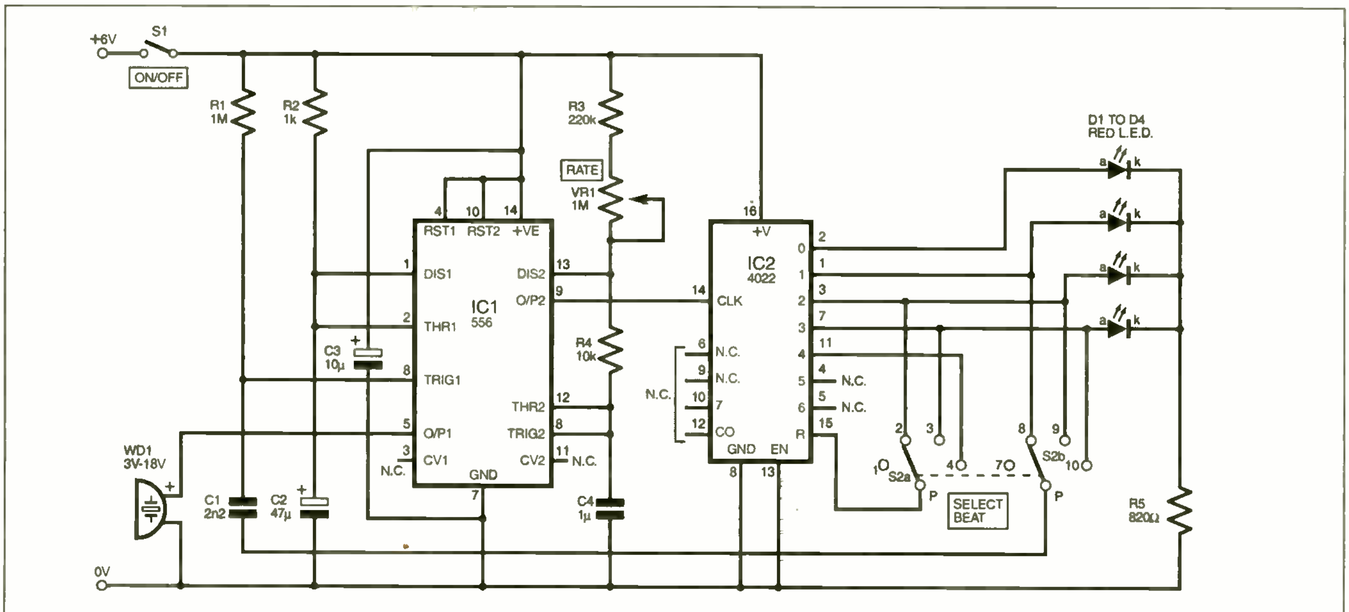


Fig.1. Complete circuit diagram for the Simple Metronome.

reset to zero. This takes only a few milliseconds, so it appears that the counter goes straight from count 4 to count 0. Similarly, we can use S2a to select outputs 3 and 2 to make the counter reset on the counts of 4 and 3 for 3/4 and 2/4 times.

AUDIO COUNT

The audio bleep, count one, is produced by piezoelectric sounder WD1 that normally produces a high-pitched tone when it is switched on. To make the short "bleep", we use the second timer within IC1, wired as a monostable multivibrator.

With the values chosen for resistor R2 and capacitor C2, the monostable delivers a single high pulse of 0·05s duration every time its trigger input (pin 6) is made low. Note that we need a low-going input to trigger the timer (compare this to resetting, which requires a high input).

To make the "bleeps" coincide with the first count of each sequence, we need to trigger the timer as the l.e.d. goes *out* in the *final* count of each sequence. If there are four beats to the bar, for example, the monostable is triggered when the count of three ends.

The required connections are made by switch S2b. The pole (p) or wiper of S2b is connected through a capacitor (C1) to the trigger pin (pin 6) of IC1. This input is normally held high by the pull-up resistor R1. A low-going level at the pole of S2b is sufficient to pull the input voltage down below 2V for long enough to trigger the monostable.

When IC2 switches the l.e.d.s on or off, this alters the load on the supply and may cause voltage spikes that upset the action of the counter. To avoid these, capacitor C3 is connected across the supply rails.

CONSTRUCTION

The Simple Metronome circuit is built on a 0·1 inch matrix rectangle of stripboard, having 29 copper strips by 39 holes. The component layout, interwiring and details of breaks required in the copper tracks are shown in Fig.2.

The unit runs on 6V, which may be provided by four 1·5V dry cells in a battery box. Alternatively, use a 6V mains power supply adaptor. An inexpensive one supplying 100mA at 6V d.c. unregulated is adequate.

If you are intending to house this project in a case, there are three items that should be mounted on the case: the power On/Off switch S1, the variable potentiometer VR1, and the rotary selector switch S2.

COMPONENTS

Resistors

R1	1M	
R2	1k	
R3	220k	
R4	10k	
R5	820Ω	

See **SHOP TALK** page

All 0·25W 5% carbon film or better.

Potentiometer

VR1 1M rotary carbon, linear

Capacitors

C1	2n2 polyester film
C2	47µ elec. 16V, axial
C3	10µ elect. 16V, axial
C4	1µ polyester

Semiconductors

D1 to D4	5mm red l.e.d. (other sizes or colours optional)
IC1	556 dual timer
IC2	4022 CMOS divide-by-8 counter, with 1-of-8 outputs

Miscellaneous

S1	s.p.s.t. toggle switch
S2	2-pole 6-way rotary switch (see text)
WD1	single-tone piezoelectric sounder, 3V to 16V

Stripboard 0·1 inch matrix, size 29 copper strips by 39 holes; 14-pin i.c. socket; 16-pin i.c. socket; battery holder, with 4 × 1·5V cells or unregulated mains adaptor, see text; 1mm solder terminal pins (10 off); pointer knobs for VR1 and S2; multistrand connecting wire; solder, etc.

Approx. Cost Guidance Only **£10** excluding case

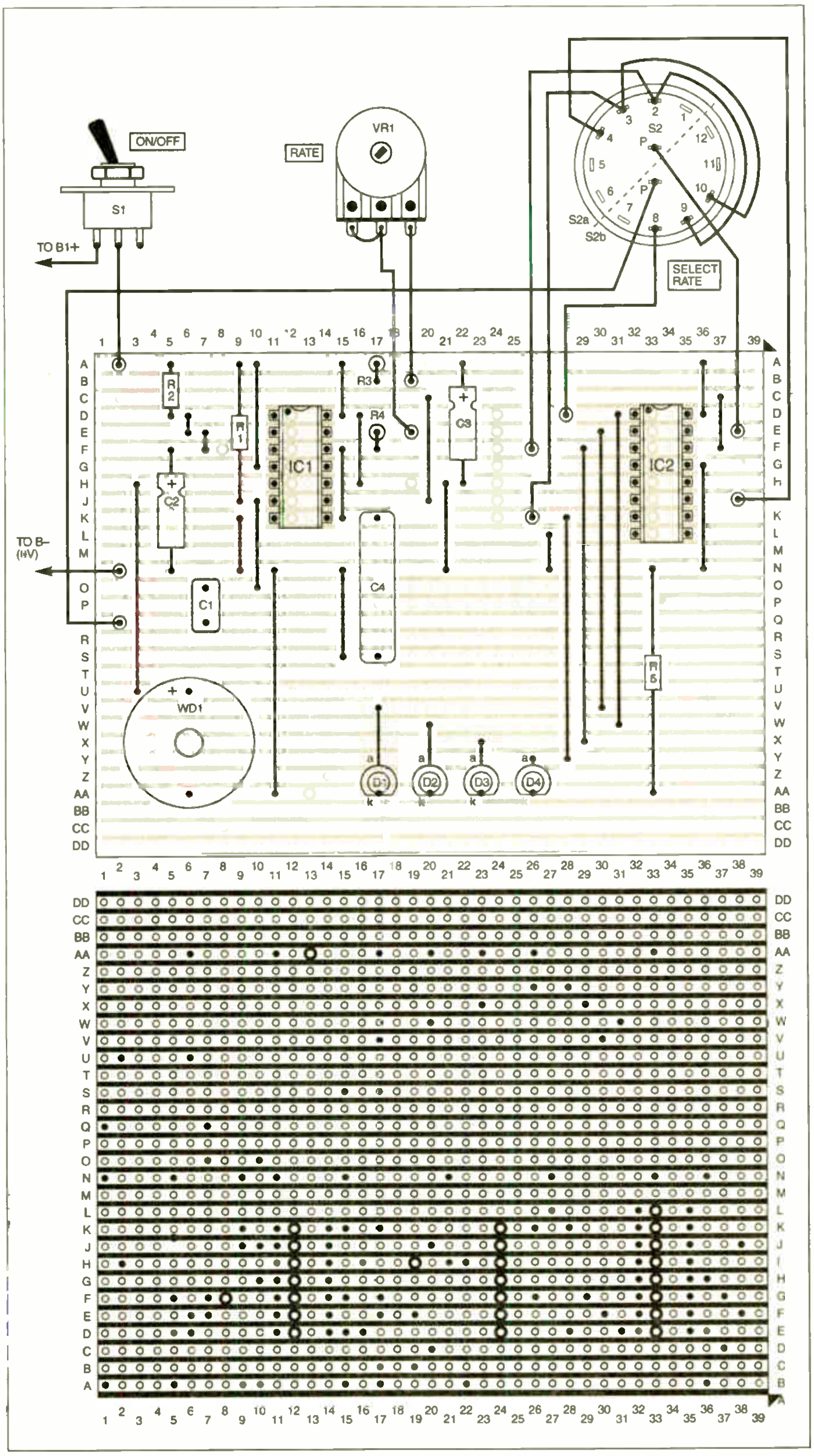
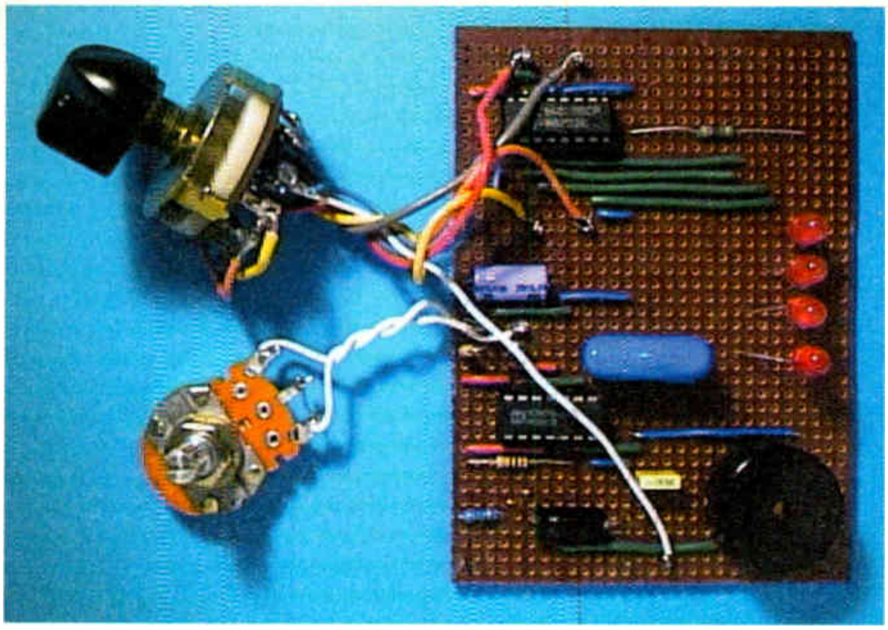


Fig.2. Simple Metronome stripboard component layout, interwiring to off-board components and details of breaks required in the copper tracks.



Component layout on the prototype circuit board. The finished unit can be mounted in a plastic box, with holes drilled for the l.e.d.s.

The rotary switch is relatively expensive and may put the cost of the project just above the £10 limit if you cannot find a cheap one. The component wiring diagram of Fig.2 shows a 2-pole 6-way switch, but a 3-pole 4-way switch or a 4-pole 3-way switch can be used equally well.

Alternatively, instead of a switch, you can solder a "flying lead" to each of the solder pins at points *Q2* and *E38* in Fig. 2. Terminate each of the flying leads with a miniature crocodile clip. These clips are used for connecting to two of the terminal pins at *D28*, *F26*, *K26* and *J38*, depending on the "beat" setting required.

FINAL ASSEMBLY AND CHECKING

Following the component layout in Fig.2, first assemble the two circuits connected to IC1. When it is complete, temporarily connect the solder terminal pin at *Q2* to the positive supply. If you then transfer the connection briefly to the 0V line, a short "bleep" should be heard.

Use a voltmeter or logic probe to monitor the output from the astable circuit at pin 9. Check that the frequency of the signal varies according to the setting of Beat control VR1.

Now complete construction of the project by adding the components associated with IC2 and the l.e.d.s. Wiring for the 2-pole 6-way Beat select rotary switch (S2) is also shown in Fig.2. Try to mount the l.e.d.s in as straight a row as possible and at the same height above the board. Check that the circuit now works as described earlier.

Finally, mount the off-board components (if the project is cased) and add labels for S2 and VR1. The latter may be calibrated in frequency or in musical terms. □

SHOP TALK
with David Barrington

How To Use Graphics L.C.D.s with PICs (Supplement)

The main point of consideration encountered when checking out components for the Graphics L.C.D. Demo Board, given in this month's special supplement, will be the graphics l.c.d. module. The author used a Powertip PG12864 graphics display purchased from RS Components, and is currently priced at £27.92 (excl VAT/p&p). This can be ordered through **Electromail** (☎ ***01536 304555*** or ***http://rswww.com***), code 329-0329.

We understand that **Magenta** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) are hoping to supply graphic displays, with pin a connector at a reasonable cost in the near future. We suggest readers track their web site or give them a call for the latest news.

Contrary to the components list, you need an *unprogrammed* PIC16F877 chip; three lots of software will be installed and manipulated as you progress. A scan through our advertising pages should produce suppliers of PICs. Also, it follows that you must have a PIC programmer (such as the *PIC Toolkit Mk2* – May/June '99) to accompany this design.

The printed circuit board is available from the *EPE PCB Service*, code 288. 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 charges see page 149). It is also available free via the *EPE* web site:
ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/graphicslcd.

Using The LM3914-6 L.E.D. Bargraph Drivers

Being popular devices, you should have no trouble ordering the National Semiconductors' LM3914 (linear), 3915 (log.) and 3916 (VU) family of l.e.d./bargraph display driver i.c.s, called for in the LM3914-6 feature, through your local component supplier.

It is a good idea to coat adjoining walls of the l.e.d.s with black paint to prevent "light spread" if making up your own bargraph display. It was found that 3mm dia. low current l.e.d.s gave the best results, probably due to less material thickness of the plastic body/shell.

The small, resistor-like, 4·7mH and 1mH r.f. chokes for the Relay Control unit link cable should be well stocked. The three printed circuit boards are available from the *EPE PCB Service* as a set, codes 289, 290, 291 (see page 149).

Ice Alert

The specified Philips bead thermistor used in the *Ice Alert* project has a rating of 150kΩ at 25°C and about 535kΩ at 0°C. This device%was purchased from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code FX43W.

There is some latitude in the range of the thermistor used and it is appreciated that in some areas constructors will be limited in their choice. If you must use a different type, select one of the "negative temperature coefficient" variety – that is, as the temperature rises the resistance falls – having a resistance of hundreds of kilohms at 0°C. Halve this figure and select the nearest fixed value resistor for R2.

The rest of the components for this unit should be readily available from our component advertisers. Do not forget, if you are installing the unit in a vehicle, the supply connections must be made using light-duty auto-type cable and with proper car-type connectors. Also, make sure you use nylon fixings when mounting the p.c.b. in its case.

The small printed circuit board is available from the *EPE PCB Service*, code 287 (see page 149). Finally, if installing the unit in a vehicle, check the car's manual to make sure it is safe to disconnect the battery before installation.

PC Audio Power Meter

Several components called for in the *PC Audio Power Meter* could cause local sourcing problems. Most of the items used in the author's model came from Maplin (☎ ***0870 264 6000*** or ***www.maplin.co.uk***).

They supplied the 3W and 50W wirewound resistors. To order write/quote "W" then value (i.e. W0·1) for the 3W type and "X" then value (X3R9) for the 50W type. Suitable twin spring-loaded loudspeaker terminals are also stocked, code BW71P. They do not give an electrical rating for the terminal.

The Analog Devices AD7896AN 12-bit 8µs ADC chip and the ICL7660CPA switched capacitor voltage converter i.c. should be fairly widely stocked. Try **Cricklewood** (☎ ***0181 452 0161***) and **Maplin** (codes NP36P and NR54J respectively). The choice of case is left to individual taste. But it ***must*** be a *metal* type, due to heat generated within the case.

The software for this project 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 149). It is also available *free* via the *EPE* web site:
ftp://ftp.epemag.wimborne.co.uk/pubs/audiomet.

Simple Metronome

We do not expect any component buying problems to arise when shopping for parts for the *Simple Metronome*, this month's Top Tenner project.

The component wiring diagram shows a 2-pole 6-way rotary switch, but a 3-pole 4-way or 4-pole 3-way type can also be used in this circuit. Likewise with the single-tone piezoelectric buzzer, most of these sounders operate from a broad range of d.c. voltages and many of our component advertisers will be able to offer a suitable device.

PLEASE TAKE NOTE

Versatile Mic/Audio Preamplifier *May '00*

In a recent issue we highlighted the problems of sourcing the SSM2166P mic. preamp chip for the *Versatile Mic/Audio Preamplifier* project and asked for help in finding some. We have just received news that **FML Electronics** (☎ ***01677 425840***) now have some in stock.

£1 BARGAIN PACKS
Selected Items

CROCODILE CLIPS. Small size, 10 each red and black. Order Ref: 116.

PLASTIC HEADED CABLE CLIPS. Nail in type, several sizes. Pack of 50. Order Ref: 123.

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

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

HIGH POWER 3in. SPEAKER (11W 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 contacts. Order Ref: 1026.

2-CORE CURLY LEAD. 5A, 2m. Order Ref: 846.

3 CHANGEOVER RELAY. 6V A.C., 3V D.C. Order Ref: 859.

3 CONTACT MICRO SWITCHES, operated with slightest touch. Pack of 2. Order Ref: 861.

HIVAC NUMICATOR TUBE. Hivac ref XN3. Order Ref: 865.

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.

1000W FIRE SPIRALS. In addition to repairing fires, these are useful for making high current resistors. Price 4 for £1. Order Ref: 223.

BRASS ENCASED ELEMENT. Mains working, 80W standard replacement in some fridges but very useful for other heating purposes. Price £1 each. Order Ref: 8.

PEA LAMPS, only 4mm but 14V at 0·04A, wire ended, pack of 4. Order Ref: 7RC28.

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 very flexible lead. Order Ref: D86.

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

MES LAMP HOLDERS, slide onto 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 MICRO SWITCHES, 20mm x 6mm x 10mm, changeover contacts, pack of 2. Order Ref: 826.

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 ICs etc. to drive it to give 2 rows of 8 characters, price £1. Order Ref: 1085.

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 multimeter 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

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.

12V 8A DC POWER SUPPLY. Totally enclosed with its own cooling fan. Normal mains operation. Price £11. order Ref: 11P6.

TWIN 13A SWITCHED SOCKET. Standard in all respects and complete with fixing screws. White, standard size and suitable for flush mounting or in a surface box. Price £1.50. Order Ref: 1.5P61.

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.

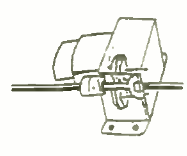
BUY ONE GET ONE FREE

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.

1·5-6V 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 £3.50 service charge.

J & N FACTORS

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Stairbridge Lane, Bolney
Sussex RH17 5PA
Telephone: 01444 881965
E-mail: jnfactors@aol.com

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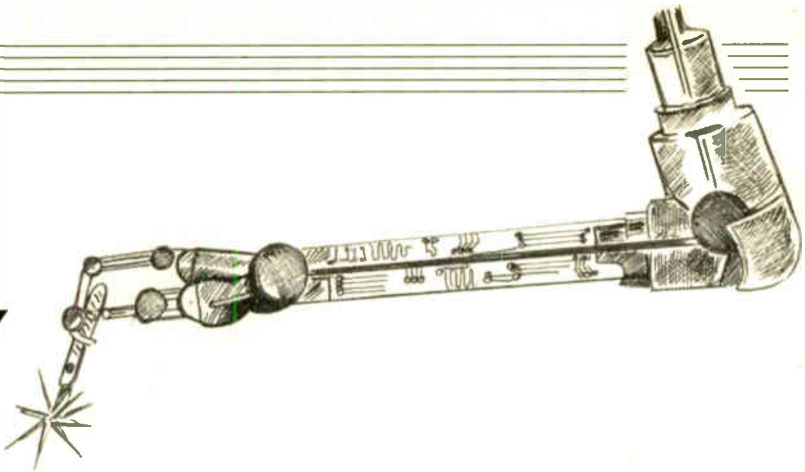


CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

Our intrepid surgeons pump up the power, plus more on multimeter polarity.

Charge Pumps

VOLTAGE multipliers require an a.c. input, but it is also possible to use transistors or logic gates to control the capacitor charging and switching required for voltage "multiplication". Such circuits are called **charge pumps** and are, in fact, available as i.c.s, including the TPS60100 series from Texas Instruments. These chips are typically used for low voltage conversion (e.g. +1·8V to +5V), or negative supply generation (e.g. –5V from +5V) and commonly they have fixed output voltages.

For non-standard conversions and higher output voltages, a charge pump can be built from basic components – an example is outlined in Fig.1. In this circuit CMOS inverters are used to drive a network of capacitors and diodes to achieve (ideally) a quadrupling of the input voltage. The circuit is best understood by remembering that CMOS inverters consist of two transistors in a "push-pull" configuration such that at a given time only one transistor is switched on.

This is basically equivalent to two complementary switches, as illustrated in Fig.2, which in turn can be considered as a two-way switch connecting the output to either ground (0V) or the positive supply alternately. Re-drawing Fig.1 in this form results in the circuit of Fig.3, from which we can see that one end of each capacitor is alternately connected to ground and $+V_{DD}$.

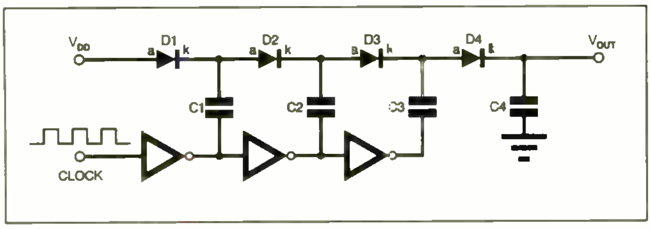


Fig.1. Example circuit of a CMOS inverter-based charge pump d.c. voltage multiplier. Note V_{OUT} is approx. four times V_{IN}.

How It Works

In the following description of how this circuit works we'll ignore diode voltage drops to keep things simple. In practice they will mean that the actual voltages are not quite the exact multiples of the input.

To begin with let's consider capacitor C1. When the input clock is high ($+V_{DD}$), this is inverted by switch S1 which connects one end of C1 to ground (0V), so C1 charges up to $+V_{DD}$.

When the clock goes low again, it is inverted by S1, so the negatively charged plate of C1 is now at $+V_{DD}$. The voltage that currently exists across C1's plates means that the total voltage at point *A* is pushed up to $+2 \times V_{DD}$, i.e. a combination of $+V_{DD}$ from the supply, and $+V_{DD}$ from C1.

While point *A* is at $+2\ V_{DD}$ (i.e. when the clock is low), one end of capacitor C2 is connected to ground via switch S2 and the other end to point *B*. So C2 will charge to $+2 \times V_{DD}$ with current flowing from Point *A* via D2. During this time D1 is reverse biased.

The process of charging C2 will actually discharge C1 to some extent. Thus it will actually take several clock cycles for C2 to charge to the point that it has $+2 \times V_{DD}$ across it. When the clock goes high again, C1 will again charge to $+V_{DD}$ via D1, replenishing the charge it pumped into C2.

Meanwhile (with clock high), the negative side of C2 will be connected to $+V_{DD}$ so the voltage at point *B* will be $+3 \times V_{DD}$ and capacitor C3 will charge to this voltage via diode D3, just as C2 charged to $+2 \times V_{DD}$ via D2. In a similar way C3 will charge to $+4 \times V_{DD}$.

The voltage at point *A* switches between V_{DD} and $+2 \times V_{DD}$, the voltage at *B* switches between $+3 \times V_{DD}$ and $+2 \times V_{DD}$, and the voltage at point *C* switches between $+3 \times V_{DD}$ and $+4 \times V_{DD}$ as the clock switches high to low. In order to get a d.c. output, diode D4 is used to charge capacitor C4 to $+4 \times V_{DD}$ from C3.

Negative output voltages can be obtained by reversing the diodes in the chain and connecting the V_{in} point to ground. In practice the output voltages obtained will be less than those described due to diode drops and other "losses" in the circuit.

Upstaged Multipliers

This circuit (Fig.1) can be extended by adding further stages so you can multiply the input voltage by quite a large amount (10 or more stages are quite feasible). The current available from the output depends on the current available from the inverters and on the values of the capacitors. If you use 4049s this will be a couple of milliamps. You can wire

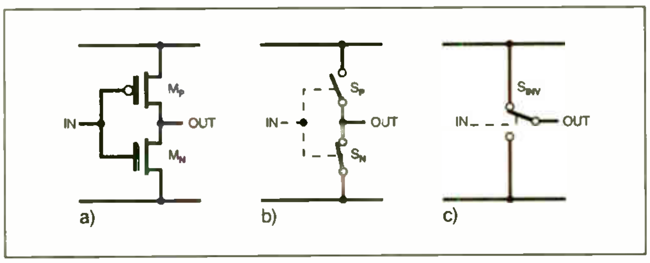


Fig.2. The CMOS inverter (a) can be viewed as two voltage controlled switches such that when one is on the other is switched off (b), this in turn can be viewed as a changeover switch connecting the output to either +V or 0V depending on the input voltage (c).

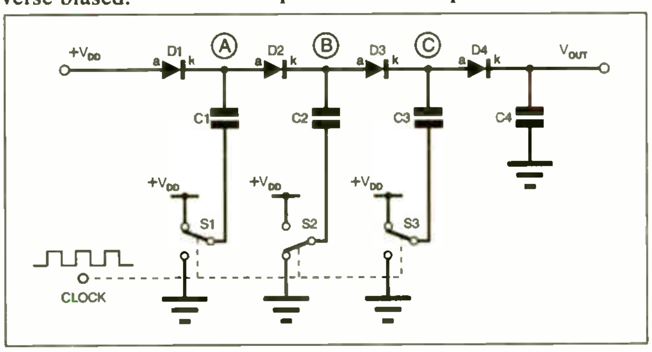


Fig.3. The multiplier circuit of Fig.1 re-drawn to show the switching action of the CMOS inverters in a voltage multiplier.

CMOS inverters in parallel to increase the current capacity.

For a practical circuit you can also consider using an inverter to make a simple CMOS oscillator to provide the clock for the pump chain; the frequency is not particularly critical and should typically be 50kHz to 100kHz. The capacitor values in the charge pump circuit are also not crucial at this frequency, 10nF to 100nF should be suitable.

When constructing these circuits you *must* take note of the voltage ratings of the capacitors – for example do not use a 25V rated capacitor for an output at 48V! The output voltage will have some ripple, so the use of a larger output capacitor will reduce the ripple voltage. The diodes should be switching diodes such as 1N4148, rectifier diodes (e.g. 1N4001) are unsuitable.

Making Headroom

One of the problems with this circuit is poor load regulation – the output voltage will drop as the load current increases. This can be overcome using a Zener diode at the output or by using a simple feedback circuit as shown in Fig.4.

In this circuit the final stage of the pump uses a *tristate* device to allow the pump to be switched off or isolated by the comparator when the output reaches a certain voltage. This voltage should be set to be somewhat lower than the "open circuit" voltage with no load and the pump on all the time. This gives the circuit some "headroom" to cope with load variations. Notice that we incorporated a clock circuit as well.

Under very light load conditions the final stage in Fig.4 will be off most of the time, with the pump switching on now and then to replenish the charge in the output capacitor. As the load current increases the output capacitor will discharge more rapidly and the pump will have to be on more often to keep the output voltage at the required level. If the load increases further still, the pump will have to be on all the time, after which regulation will be lost and the output voltage will drop as the load increases, just as it will do with the original circuit.

The values of resistors R1 to R4 are chosen so that the same voltage appears at the output of both potential dividers. For example if V_{DD} was +9V and R1 and R2 were equal, they would produce a +4·5V reference level. If the desired output was 48V – which is the value mentioned in the question last month – R3 and R4 would be selected to give +4·5V too. The comparator would then switch on the output stage of the pump when the output voltage fell below 48V (i.e. the comparator input fell below 4·5V).

Note that the need for "headroom" for the regulated circuit will mean the effective "multiplication factor" for the input to output voltage will be reduced in this version of the circuit and this should be borne in mind when deciding how many stages are required. *I.M.B.*

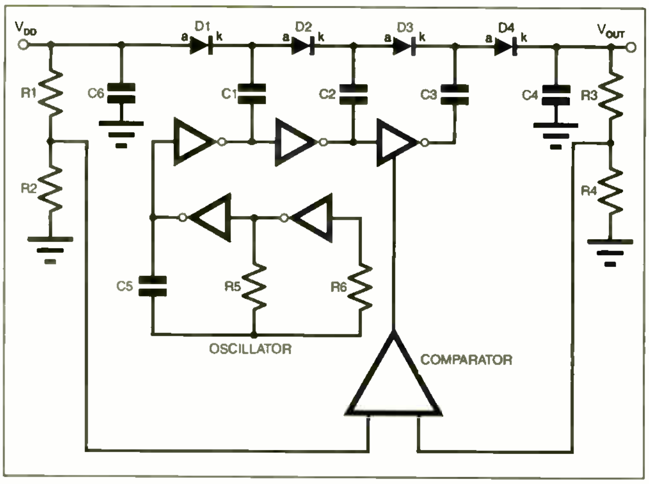


Fig.4. Charge pump circuit with the output regulated to be a fixed multiple of V_{IN}.

Darlington Drivers

I am going to be using a ULN2803A Darlington array in a forthcoming project. I am planning initially to use only four of the transistors, so I would like to know if the remaining ones should be left open circuit or connected to V_{CC}. ***John Pickard,*** by E-mail.

These devices are useful general-purpose buffers containing eight Darlington transistor drivers which enable higher power (and higher voltage) loads to be driven directly by low voltage logic circuits. Each buffer is rated at 500mA continuous output *sink* current, and you can parallel the outputs to handle even higher loads: they are ideal for lamps, l.e.d. arrays, stepper motors etc.

The ULN28xx range pinouts are shown in Fig.5. They have open-collector outputs, with built-in clamping diodes for back-e.m.f. protection – see how all the diode cathodes (k) are commoned to pin 10. A dual-in-line package can handle as much as 300 watts of load, provided that the buffers are strobed at a suitable duty cycle.

I checked the Allegro data book for clues, and it shows that each buffer has internal resistors, presumably to make the buffers 5V TTL/ CMOS compatible. The 2803 uses a 2k7 resistor on each base, plus a 10k divider biasing it to ground (0V).

On that basis, I would say that it is safe to leave device inputs floating. You can also download a data sheet from Allegro at **www.allegromicro.com**. *ARW.*

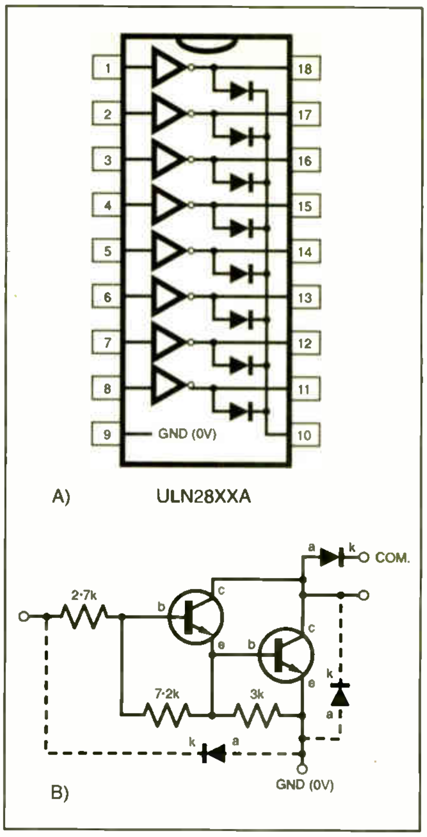


Fig.5. (a) Pinout details for the ULN28XX Darlington array and (b) basic circuit.

More on Multimeters

Following up on the item on using multimeters to test transistors (*Circuit Surgery* October 2000), my thanks to ***Peter Hemsley*** who writes by E-mail:

The polarity of the positive and negative leads of an analogue meter (i.e. positive comes out of the negative terminal) *are not as expected due to the simple circuitry employed and no-one considers it necessary to have extra switching to correct the polarity. The circuit consists of a current meter, a variable resistance (to set the zero) and a battery all in series, so the negative connection of the meter is connected to the negative test lead, and the positive test lead is be connected to the negative of the battery. Hence the reversal of polarity. Digital multimeters use a completely different method, the test leads are effectively connected to the input of the DVM i.c. measuring voltage.*

One method of producing a voltage proportional to resistance is to pass a constant current through the resistor being measured, but this has the disadvantage that the current source needs to be stable and not suffer from drift. The usual way of measuring resistance is to use the ratiometric method, where the resistor being measured is connected in series with a reference resistor across a voltage source (usually a few hundred millivolts).

The resistor under test is connected to the measuring input and the reference resistor to the reference input of the DVM i.c., the resulting reading is then the ratio of the voltage across the unknown and the reference resistor. Thus the accuracy of the reading is determined by only the accuracy of the reference resistor.

Thank you for the extra information. For reference Fig. 6 is the internal circuit of a typical moving coil resistance meter. Notice how the battery's negative terminal is indeed connected to the positive test socket. *ARW.*

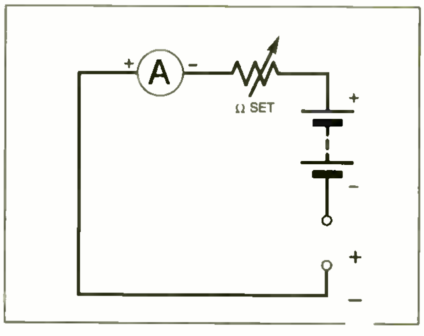
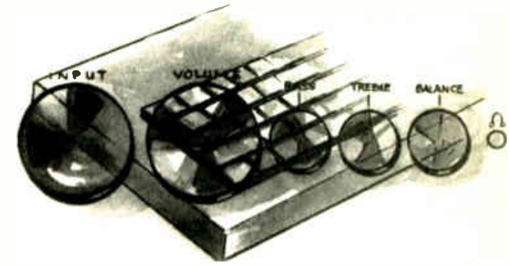


Fig.6. Internal view of an analogue multimeter set for resistance measurement. The positive terminal is connected to the battery negative pole.

Constructional Project

PC AUDIO POWER METER



ROBERT PENFOLD

PC computer interface for measuring power output from audio amplifiers

THIS project is the latest in the occasional series of PC-based test equipment. Previous units were based on circuits from the *Interface* series of articles. This device is based on an analogue-to-digital converter (ADC) featured in the series, but it is otherwise original.

It enables a PC to measure power, and it is primarily intended for use with audio power amplifiers. However, the interface uses d.c. coupling and it could probably be modified for use in some d.c. power measuring applications.

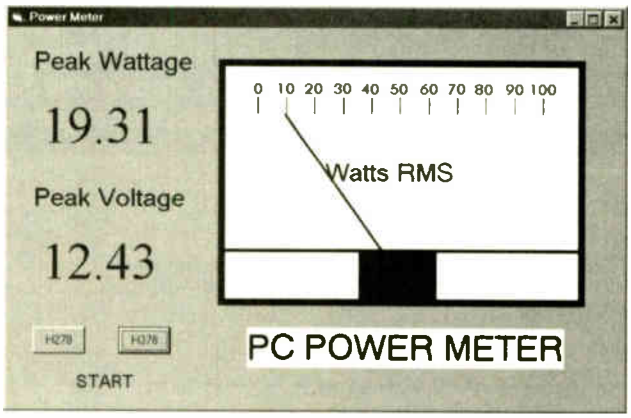
When used for audio power measurement it provides an 8Ω dummy load, and shows the peak power and voltage delivered to the load. It also has a virtual panel meter that shows the r.m.s. power level when using sinewave test signals. With sinewave test signals the r.m.s. power level is easily calculated, since it is exactly half the peak power level.

The 12-bit ADC is scaled to read voltages from 0V to 40·95V. With 40 volts into an 8Ω load it equates to 200 watts (40 × 40 = 1600, 1600/8 = 200), or 100 watts r.m.s. when using a sinewave test signal. The 8Ω dummy load can handle a little over 100 watts r.m.s. provided it is equipped with adequate heatsinking.

The circuit connects to the printer port of the host PC, and the port does not need to be a bidirectional type. The power meter program is written in ***Visual Basic 6***, and it requires Windows 95, 98 or ME to run. Note that it will ***not*** work with other versions of Windows. Visual Basic 6 produces programs that are incompatible with 16-bit versions of Windows such as version 3.1. Windows NT and 2000 do not permit the form of direct port access, which is essential to the operation of this software.

DUMMY LOAD

The block diagram of Fig.1 shows the system used in the PC Audio Power Meter. The input signal is connected to a dummy load, which is simply an 8Ω resistor that takes the place of a loudspeaker. This avoids having unduly loud test tones coming from a loudspeaker used as the load, and it also simplifies measurements.



Virtual screen display of the PC Power Meter.

The main problem with using a loudspeaker as the load is that its actual impedance can vary considerably from its nominal figure of 8Ω. The actual impedance tends to vary significantly with changes in the input frequency. Measurements made on the assumption of an 8Ω load impedance could have huge errors if the impedance of the loudspeaker was actually more like 6Ω or 12Ω at the test frequency.

Another problem in using a loudspeaker as the load is that the load would not be purely resistive. There would also be elements of capacitance and inductance, and this slightly complicates matters. With a load that is pure resistance the output current is precisely in-phase with the output voltage.

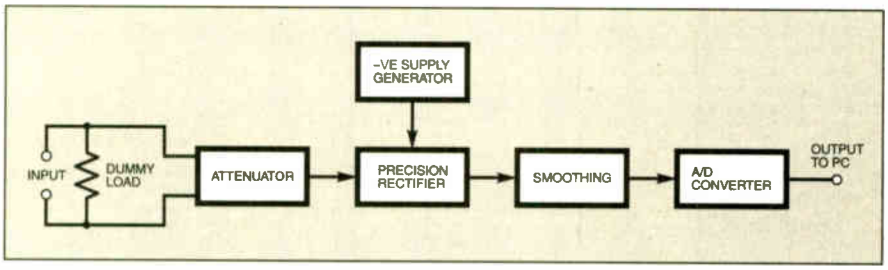


Fig.1. Block diagram for the PC Audio Power Meter system.

PEAK PRACTICE

In order to calculate the peak output power it is merely necessary to measure the peak output voltage. From this voltage and the load resistance it is possible to calculate the output power using the method used previously (square the voltage and divide this figure by the load resistance).

Things are more complicated when using a loudspeaker as the load. Because the precise impedance is an unknown quantity, the output voltage and current must both be measured. Simply multiplying the peak voltage by the peak current may not give an accurate figure for peak power, because maximum current might not coincide with maximum voltage.

With capacitance and inductance in the load there are so-called imaginary currents to deal with, as well as the real currents. The point to remember here is that current can flow into and out of theoretically perfect capacitors and inductors, but they do not dissipate any power. To be sure of accurate results the output current and voltage must be continuously sampled and processed by a multiplier circuit to produce a power reading that is always accurate. The peak reading from the multiplier will truly reflect the peak output power from the amplifier.

SYSTEM OPERATION

To avoid complications and ensure consistent test conditions, most audio power amplifier testing is undertaken using a dummy load resistor. For the reasons outlined previously, it is essential to the operation of this power measuring system that the load is a resistor and not a loudspeaker.

The signal fed to the load is also fed to an attenuator that is used to give the correct scaling. The ADC has a full-scale reading of 4095, which is achieved at an input potential of 5V. By reducing the input potential by a ratio of a little over 7-to-1 the full-scale input voltage of the circuit as a whole is increased to the required figure of 40·95. The attenuation is adjustable so that the unit can be calibrated against an accurate reference voltage.

With symmetrical waveforms it is only necessary to measure the peak positive or negative input voltage, but not both as they will be the same. With asymmetric waveforms there can be a substantial difference between the peak positive and negative voltages, making it necessary to measure both in order to guarantee accurate results.

In this unit the output of the attenuator is fed to a precision full-wave rectifier so that both sets of half-cycles are measured. The rectifier circuit requires a negative supply, and this is derived from the 9V battery via a simple switch-mode circuit.

The output of the rectifier feeds a smoothing circuit that has a short attack time and a much longer decay period. The effect of this is very much like a peak-hold circuit, with a d.c. output voltage that is equal to the peak input potential.

Resistors R1 and R4 each take little more than one percent of the total power fed to the load, and a rating of two or three watts is therefore adequate for these.

The input attenuator consists of fixed resistor R5 and preset VR1. The latter enables the full-scale sensitivity to be adjusted so that the unit can be accurately calibrated.

IC1 is a dual operational amplifier and it is used in the precision rectifier. Simply feeding the signal through a diode does not give the desired result due to the non-linearity of all semiconductor diodes. An ordinary silicon diode requires a forward bias of about 0·6V before it will start to conduct significantly, and the forward resistance then plummets with only a small increase in the applied voltage.

This means that around 0·6V is needed before any output signal is produced, and applies the feedback if the output goes negative. This gives what is virtually a standard voltage follower circuit, but the output signal, whatever its polarity, is boosted by about 0·6V.

On positive half cycles D3 feeds the output signal to the smoothing circuit. The voltage added at the output of IC1a by D1 counteracts the losses through D3, giving accurate half-wave rectification via IC1a and D3. IC1b operates as an inverting amplifier having unity voltage gain, and this inverts the output signal from IC1a. On

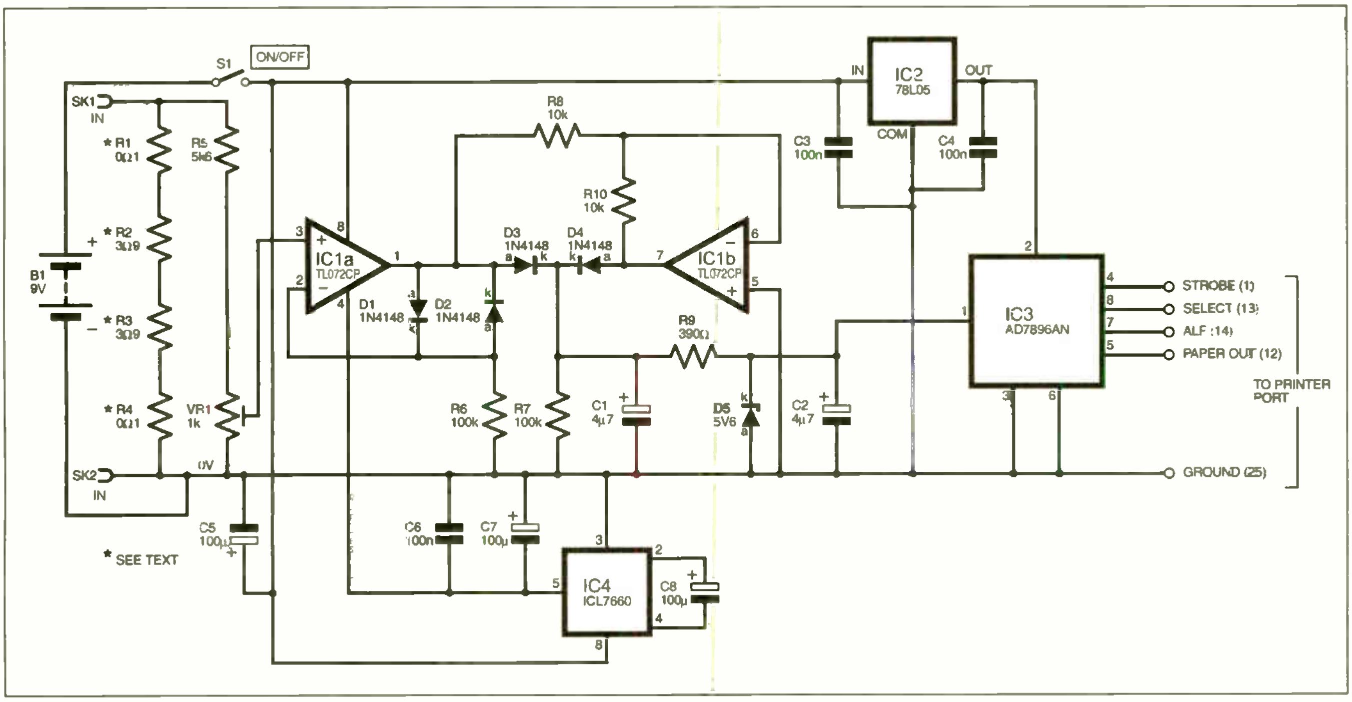


Fig.2. Complete circuit diagram for the PC Audio Power Meter. Note that resistors R1 to R4 must be high wattage types.

The ADC is a 12-bit type that uses serial interfacing to the PC. This enables 12-bit values to be read by way of just two input lines and two output types. Four of the printer port's handshake lines are adequate to provide the interfacing, making it unnecessary for the port to have bidirectional data lines.

CIRCUIT OPERATION

The full circuit diagram for the PC Audio Power Meter appears in Fig.2. The required value for the dummy load is 8Ω, but this is not a "preferred" value. To make up the value of 8Ω, four resistors (R1 to R4) are connected in series. R2 and R3 provide most of the resistance and therefore have to dissipate most of the power. Accordingly, they have power ratings of 50 watts each.

at higher input potentials the output voltage is about 0·6V or so lower than it should be. There are diodes that offer lower forward voltage drops, but none give adequate performance where good linearity is required.

The standard solution to the problem is to include two diodes in the negative feedback circuit of a non-inverting amplifier. In this case the diodes are D1 and D2, and the amplifier is IC1a. At input potentials of less than about 0·6V there is no significant feedback through D1 and D2, which results in IC1 operating at its open loop voltage gain.

This gain is very high, so only a small input voltage is needed to send the output about 0·6V positive or negative. Diode D1 then starts to apply strong negative feedback if the output goes positive, or D2

negative input half cycles the output of IC1b therefore produces positive half cycles that are fed to the smoothing circuit via diode D4.

The negative voltage added at the output of IC1a by D2 produces a positive voltage at the output of IC1b. This voltage counteracts the voltage drop through D4, giving the required precision rectification. The combined output of D3 and D4 does, of course, provide full-wave rectification.

The smoothing circuit has the smoothing capacitance provided by C1 and C2 in parallel. The low source impedance of the rectifier circuit provides a fast attack time, but the high value of resistor R7 produces a much slower decay time.

The value of the smoothing capacitance has to be a compromise. A high value is needed in order to avoid jittery readings at low frequencies, but also makes the unit slow to respond to a reduction in power level. The specified values for C1 and C2 represent something close to the minimum that should be used. Resistor R9 and diode D5 form a protection circuit that limits the input voltage to the converter to about –0·65 volts and +5·6 volts.

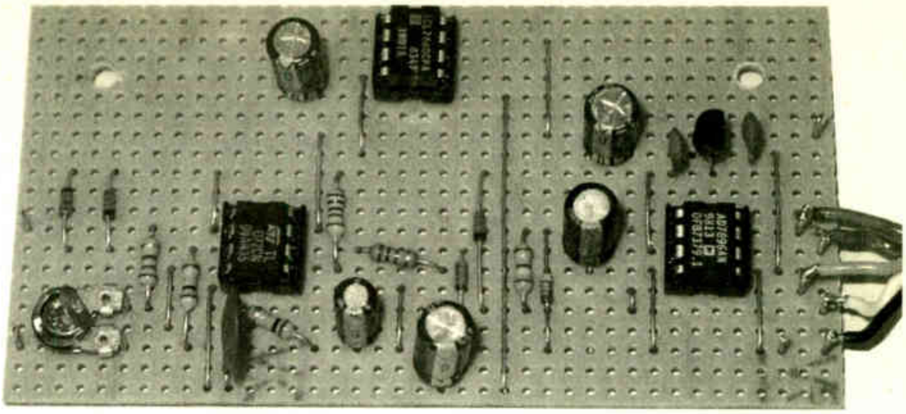
DIGITAL CONVERSION

The ADC device, IC3, requires no discrete components. It requires a 5V supply, and this is derived from the 9V battery by way of a 5V monolithic voltage regulator (IC2). The full-scale input voltage of the converter is equal to the supply potential.

The chip interfaces to the PC via a simple four-wire serial system. The computer pulses pin 7 low to start a conversion and then monitors pin 8, which goes low when the conversion has been completed.

The first bit is then read from pin 5, a clock pulse is supplied to pin 4, the next bit is read from pin 5, another pulse is supplied to pin 4, and so on until 16 bits have been read. Note, though, that the first four bits are always at zero, and that the converter only provides 12 valid bits of data.

The negative supply for IC1 is provided by a simple switch-mode power supply based on IC4. This chip uses a d.p.d.t. electronic switch to first connect C8 to the 9V supply, and then connect it to the output. The switching is arranged so that a negative supply is produced on smoothing capacitor C7, and despite losses through IC4 the negative supply voltage is only marginally lower than the positive supply potential.



Component layout on the completed circuit board.

There is a slight imbalance in the supply potentials, but the difference is not large enough to be of any practical consequence. The current consumption of the entire circuit is about 8mA to 10mA. A PP3-size battery is just about adequate to supply this, but six AA size cells in a holder is a more practical choice if the unit will receive a great deal of use.

CONSTRUCTION

Most of the components are assembled on a stripboard that measures 39 holes by 20 copper strips. This can conveniently be cut from a standard 39 by 29 or 39 by 39 stripboard. The component layout for the board and the underside view showing the breaks in the copper strips are given in Fig.3.

Construction follows along the usual lines with the two mounting holes being drilled in the board, the breaks being made in the strips, and then the components and link wires are fitted. The chips used for IC3 and IC4 are MOS types that require the standard anti-static handling precautions.

In particular, they must be fitted in holders (sockets), and the use of a holder for IC1 is also recommended.

Do not fit the integrated circuits into the holders until all the wiring has been completed, and try to touch the pins as little as possible. Keep the integrated circuits away from any likely sources of strong static charges.

The link-wires are made from 22 or 24 s.w.g. tinned copper wire. It is a good idea to insulate the longer wires with p.v.c. sleeving to ensure that there are no accidental short-circuits. Fit single-sided solder pins at the points where connections to the off-board components such as SK1 and SK2 will be made. Generously tin the tops of the pins with solder, and it should then be easy to make reliable connections to them later on.

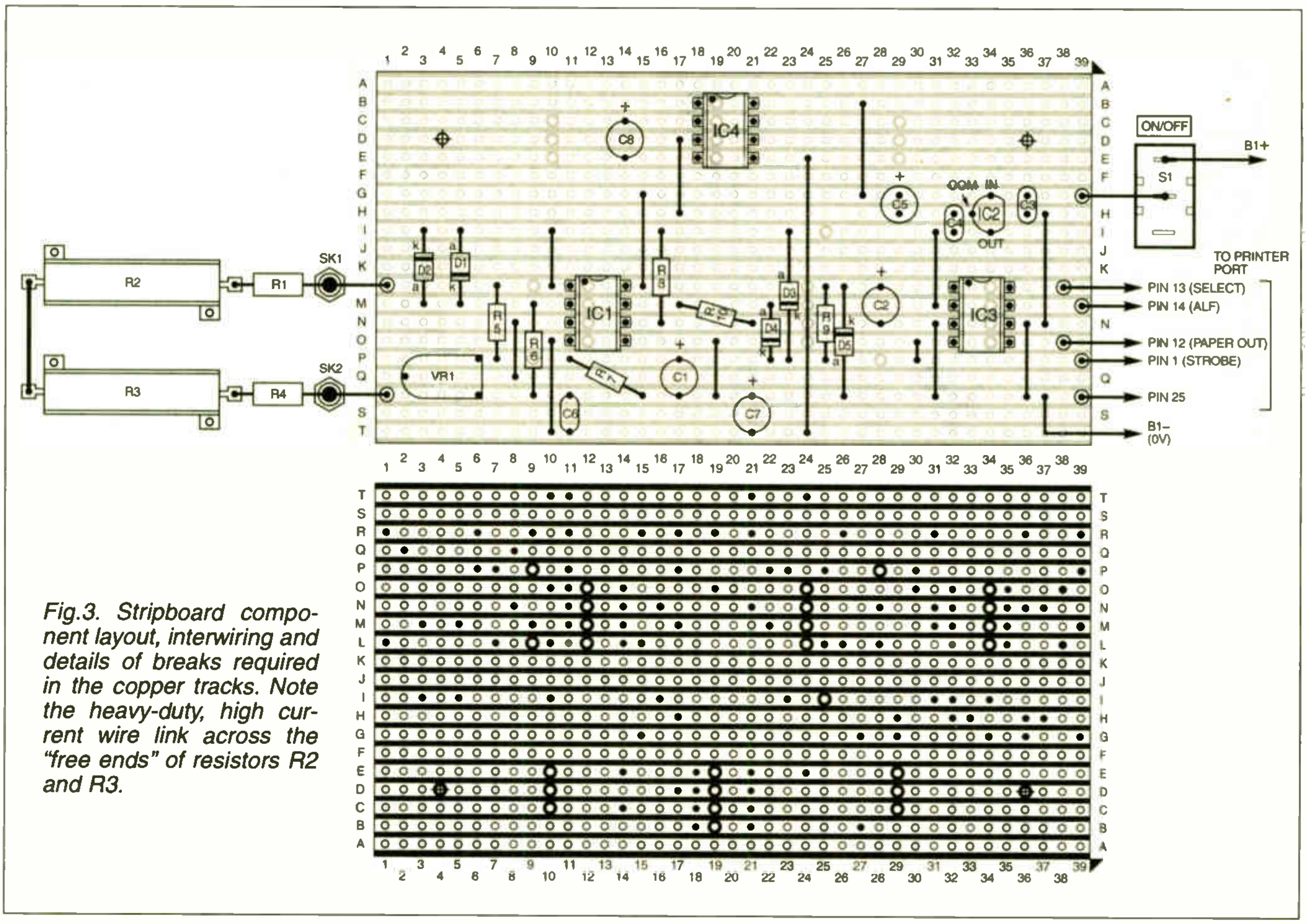


Fig.3. Stripboard component layout, interwiring and details of breaks required in the copper tracks. Note the heavy-duty, high current wire link across the "free ends" of resistors R2 and R3.

ENCLOSURE

A metal case must be used for this project due to the substantial amount of heat generated by R2 and R3 when measuring high power levels. Note that these resistors can only be used continuously at their rated powers if they are fitted on substantial heatsinks rated at about 3°C per watt.

Provided the unit is housed in a reasonably large metal case having ventilation grilles the case should provide adequate heatsinking. If it is likely that the unit will be used with high output powers for long periods it is safer to fit the resistors onto large heatsinks.

The resistors, with or without heatsinks, are fitted on the base panel of the case near the rear of the unit, leaving sufficient space for the circuit board at the front (see photograph). It is advisable to use heatsink compound to ensure that there is a good thermal contact between the resistors and the heatsink or chassis.

The fixings for the circuit board must include spacers about 6mm or more in length so that the connections on the underside of the board are kept well clear of the metal case.

Switch S1 is mounted at any convenient point on the front panel. SK1 and SK2 must be heavy-duty sockets that are capable of handling the high currents involved in this application. The types of connector that are normally used for loudspeaker outputs are the best choices, such as terminal posts or heavy-duty spring terminals.

Resistors R1 and R4 are connected between the sockets and the two high-power resistors, as shown in Fig.3. A wire to connect R2 and R3 is also needed, and is included in Fig.3, as is all the hard wiring. This wire carries high currents of up to about 5A r.m.s. and a fairly heavy gauge of wire must therefore be used. Ordinary hook-up wire is suitable for the connections from sockets SK1 and SK2 to the circuit board, since this is a low current connection.

COMPONENTS

Resistors

R1, R4	0Ω1 3W 5% wirewound (2 off)
R2, R3	3Ω9 50W wirewound (2 off)
R5	5k6 0·25W 5% carbon film
R6, R7	100k 0·25W 5% carbon film (2 off)
R8, R10	10k 0·6W 1% metal film (2 off)
R9	390Ω 0·25W 5% carbon film

Potentiometer

VR1	1k miniature preset, horizontal

See SHOP TALK page

Capacitors

C1, C2	4μ7 radial elect. 50V (2 off)
C3, C4, C6	100n disc ceramic (3 off)
C5, C7, C8	100μ radial elect. 10V (3 off)

Semiconductors

D1 to D4	1N4148 signal diode (4 off)
D5	5V6 400mW Zener diode
IC1	TL072CP dual op.amp
IC2	78L05 +5V 100mA voltage regulator
IC3	AD7896AN 12-bit ADC
IC4	ICL7660 voltage converter

Miscellaneous

S1	s.p.s.t. min. toggle switch
B1	9V battery (PP3 type – see text)
SK1, SK2	spring terminals (see text)

Metal case, 175mm x 160mm x 85mm (approx); 0·1-inch matrix stripboard, 39 holes x 20 strips; 8-pin d.i.l. socket (3 off); battery connector; 25-pin male D-type connector and 5-way lead (see text); connecting wire; fixings; solder, etc.

Approx. Cost Guidance Only **£27** excluding case & batt.

LINKING-UP

The easiest way to make the connections to the printer port of the PC is to hard wire one end of the cable to the circuit board, and to connect the other end to a 25-way male D-type connector. This type of connector is the standard type for the printer ports of desktop PCs. Virtually any 5-way cable is suitable, but about one metre of ribbon cable is probably the best choice.

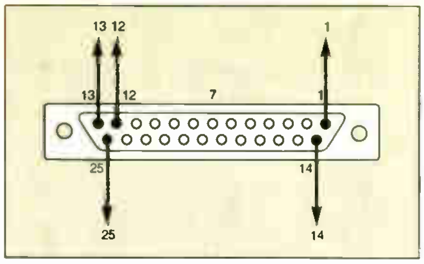


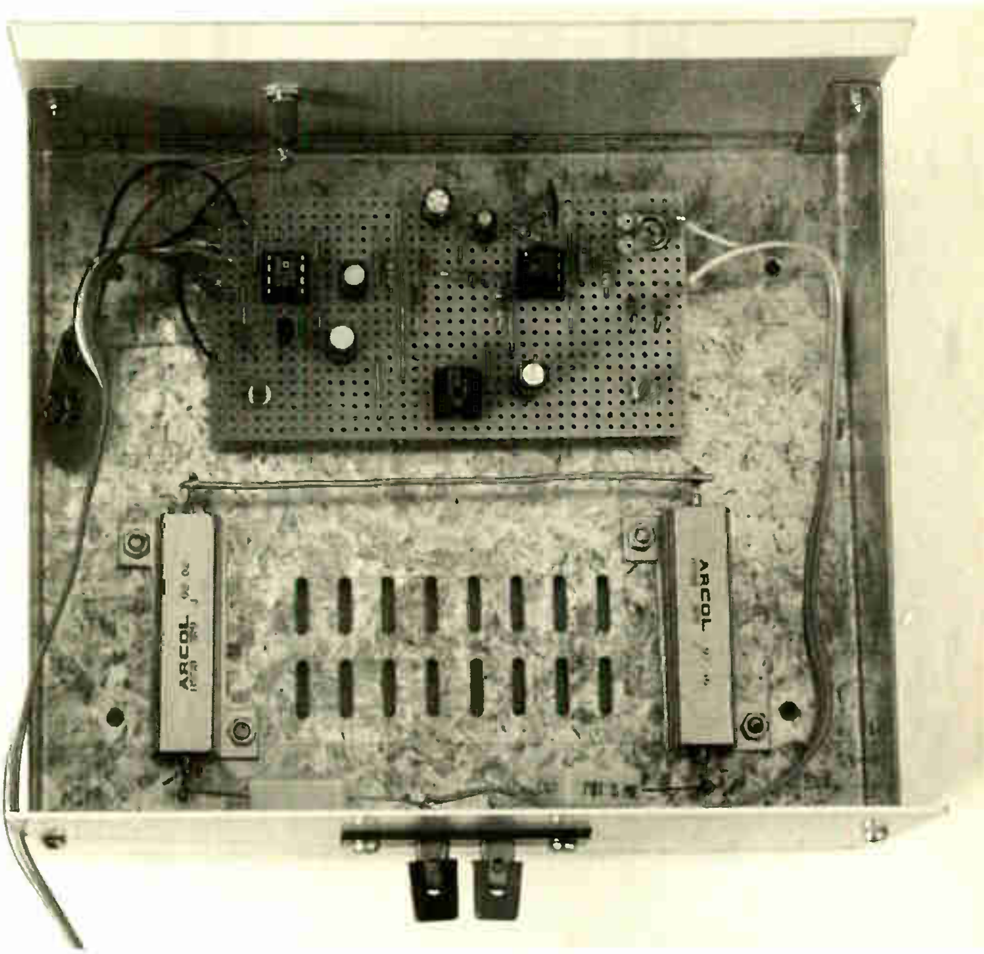
Fig.4. The five connections to the 25-way male D-connector.

The pin numbering and connections to the 25-way connector are shown in Fig.4, which shows the connector viewed from the rear (i.e. the side to which the connections are made). An exit slot for the cable must be filed in one side of the rear panel.

The alternative method is to wire the circuit board to a 25-way D-connector fitted on the rear panel. The interface is then connected to the PC via a suitable 25-way D-connector lead. This is in some ways the neater way of doing things, but is more difficult and expensive to implement. Also, great care has to be taken to ensure that all the connections are carried through correctly to the PC.

CALIBRATION AND USE

Since the unit is d.c. coupled, the easiest calibration method is to feed the input from a bench power supply unit. An accurate multimeter is used to set a known output voltage, and preset VR1 is then adjusted to give the appropriate voltage reading



General internal layout of components inside the metal case. The high power resistors (R2, R3) are bolted to the metal base panel, either side of the vent slots.

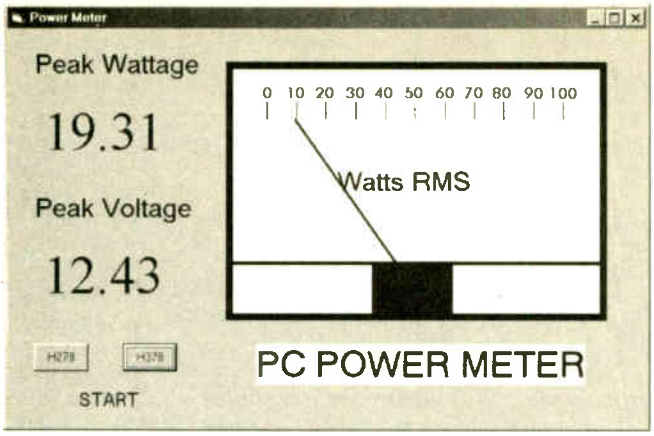


Fig.5. Screen dump of the PC Audio Power Meter in action.

from the on-screen voltage display. Bear in mind that the dummy load will give quite high current flows when using even quite low input voltages. If loading of the power supply is a problem, temporarily disconnect the dummy load while the unit is calibrated.

Also bear in mind that one input socket (SK2) connects to earth. If one output of the power supply is also earthed it is essential to connect the supply with the correct polarity or it will be short-circuited.

When testing most ready-made amplifiers it does not matter which way round the outputs are connected to the inputs of the power meter interface. Ready-made amplifiers usually have double insulation and no connection to the mains earth lead. It would clearly be prudent to check this point before connecting an amplifier to the interface. If one output is connected to the mains earth lead, then this output must connect to the earth rail of the interface, which will almost certainly be earthed via the PC.

Home constructed power amplifiers that are mains powered normally have one output connected to the mains earth, and it is then imperative that this output connects to the earth rail of the interface. Home built amplifiers that use the bridging technique usually have an earthed chassis, but neither output connected to earth. **Amplifiers of this type must not be used with this interface, and very high output currents would flow if they were connected to the unit.**

FOUR-OHM LOAD

It is easy to modify the unit to provide a 4Ω load. The simplest method is to replace R1 and R2 with a shorting link, or to have a heavy duty switch connected across them so that the unit can be switched from 8Ω to 4Ω operation. Obviously this method halves the power rating of the dummy load to a little over 50 watts.

The alternative is to add another set of four resistors in parallel with the existing dummy load. These could be connected via a heavy-duty switch to permit switching between 4Ω and 8Ω operation. The advantage of this method is that the power rating of the dummy load is doubled when the extra resistors are used. Of course, a given input voltage produces double the current flow and power level when a 4Ω load is used. The digital display will then read equivalent r.m.s. power and not the peak power level.

PROGRAM OPERATION

A screen dump of the program in operation is shown in Fig.5. Clicking on either of the buttons sets the printer port address range used and starts the program. Printer port 1 is normally at base address H378, and port 2 is usually at H278.

The digital readouts provide readings of peak power and voltage, and the analogue readout on a virtual panel meter gives the equivalent r.m.s. power value. *Note that the r.m.s. reading is only valid when using sinewave test signals with no serious clipping of the output signal.*

The routine that reads the converter and updates the displays is assigned to a timer. Initially the timer is disabled, but operating one of the command buttons assigns the appropriate values to the variables that store the port addresses and then enables the timer. The routine assigned to the timer starts by generating a pulse to start a conversion. A hold-off is then needed to allow time for the conversion to be completed.

This can be provided by monitoring the Busy output of the converter, which goes low when a conversion has been completed. This method was used for previous *EPE* designs that used the AD7896 converter chip, but it seems to result in the program tending to hang when used with some printer ports.

The Busy line is connected to the printer port so that this method can be tried by those who like to "do their own thing", but the use of a delay loop seems to be the safer option. This is the method used here, and the delay subroutine is also used to lengthen all the control signals from the computer. This reduces the risk of problems with stray coupling in the connecting cable.

Next the data is clocked out, read bit by bit, and assembled into a 12-bit value. Dividing the value from the converter by 800 and 100 respectively provides the current and voltage readings. The software provides no current readout, but this value is available in the Current variable for anyone who wishes to use it in his or her own version.

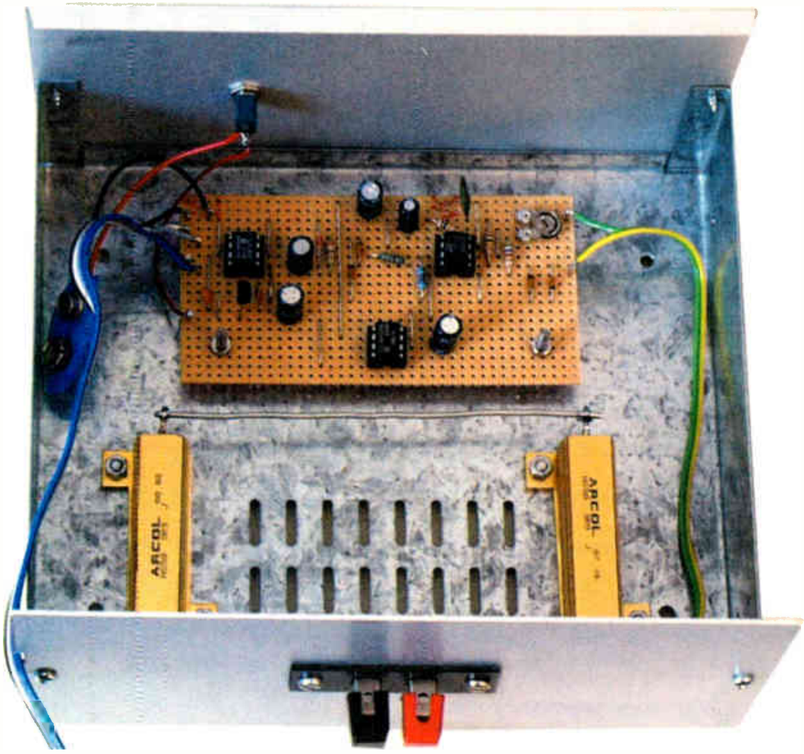
Multiplying the current and voltage readings provides the measured power level, and some further mathematics then limits readings to a manageable two decimal places. Some further mathematics then produce a value that can be used as the X2 co-ordinate of Line1, which is the pointer of the virtual panel meter.

OBTAINING SOFTWARE

The PC Audio Power Meter's software is available from the *EPE* web site (free) or from the Editorial Office (a small charge applies). See this month's *Shoptalk* page. You need to have Visual Basic 6 already installed on your computer.

The program has been compiled to what is almost a stand-alone .EXE file (source code is also supplied). There are no INP and OUT commands in Visual Basic 6, and these are added using a Freeware file called **INPOUT32.DLL**. This file should be included in the same directory as the program file, or in the Windows/System directory.

No installation is required and the program can be run using the usual Start button followed by the Run option. Alternatively, find the program file using Windows Explorer and then double click on it. □



Completed unit showing the two heavy-duty, spring-loaded loudspeaker output terminals fixed to the rear panel.

FREE SUPPLEMENT

HOW TO USE GRAPHICS LIQUID CRYSTAL DISPLAYS WITH PICS

JOHN BECKER

A step-by-step guide to understanding and using pixel-matrixed graphics l.c.d.s with your PIC microcontroller projects.

GRAPHICS liquid crystal displays have been available for several years. It would appear, though, that *EPE* readers have not successfully explored them. At least, that seems the logical conclusion since we have never been offered a design which uses them.

One reason may be that the prices of such devices have, in many instances, been somewhat expensive. Whilst many continue to be pricy for the average hobbyist, less expensive ones have been making their appearance.

Possibly the principal reason we have not been offered working designs is that readers have not been able to obtain, let alone interpret, the data sheets associated with them.

The latter stumbling block very much faced the author when he decided that he would like to know how to use graphics displays. Intermittently over several days, he scoured the Internet in search of their manufacturers and suppliers. As it turned out, there are quite a few around the globe, but when it came to obtaining data sheets – well, that was a totally different matter.

DATA DENIAL

Farnell appeared to have a selection of displays within a reasonable price range, but stated "no parametric data available". Attempting to Net-search for the manufacturer of these devices, Perdix, only revealed countless sites to do with *partridges* (a bird for which the Latin and Greek name is *perdix*!)

Whilst research had showed that RS Components supplies graphics displays, the only data sheet (RS 298-4613) available turned out to be specific to a development kit which uses them.

However, in the RS catalogue, the manufacturer of their displays is quoted as Powertip. Doing a Net-search, and eventually accessing Powertip's web site in Taiwan, rudimentary data on the devices was located. But, frustratingly, Powertip denies access to its data sheets by those who are not registered distributors.

Contacting the technical department at RS, the author was put in touch with an agent who imports from Powertip. This company sent Powertip's data sheet, a document which might, perhaps, be understandable to those already familiar with graphics l.c.d.s but is certainly not conducive to teaching those who do not. Its intelligibility is also marred by having been translated by someone inadequately familiar with English. Gross errors of fact were spotted as well.

To cut short a lengthy and convoluted tale, no manufacturer or supplier could be found who had adequate data for graphics displays available for download.

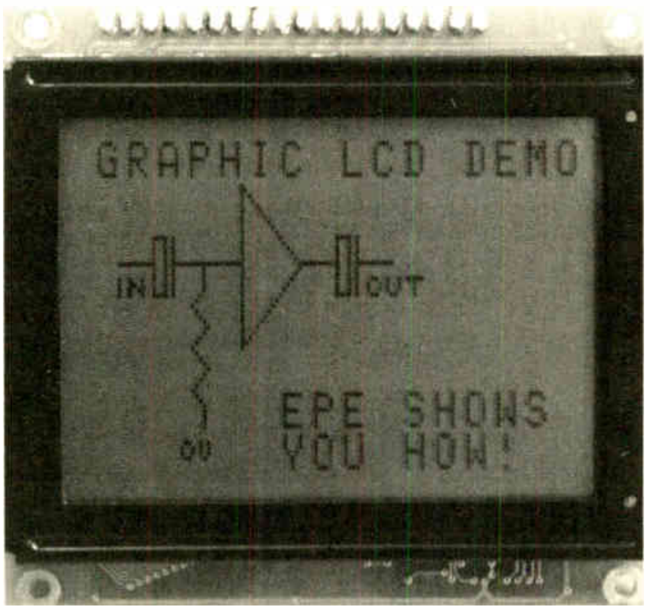


Photo 1. Graphics l.c.d. screen showing the display generated by the author's first demo program.

TOSHIBA T6963C

During the Net searches, however, various manufacturers had stated that their displays were controlled by the Toshiba T6963C chip, the same device as used by Powertip. Seemingly, then, the control architecture offered by the T6963C could be regarded as an "industry standard", and thus worth pursuing further through a Powertip display, the PG12864.

Toshiba state that the T6963C is an l.c.d. controller that has an 8-bit parallel data bus plus control lines for reading or writing through a microcontroller interface (such as a PIC).

It has a 128-word character generator ROM (read only memory) which can control an external display RAM (random access memory) of up to 64 kilobytes. It can be used in text, graphic and combination text-and-graphic modes, and includes various attribute functions.

Searching Toshiba's web site, the T6963C was eventually located (under Analogue & Peripherals/LCD Driver!), and its 46 page data sheet downloaded.

This data turned out to be the key to getting to grips with graphics l.c.d.s. Not so much because the data sheet was intelligible (which it did not become until much later), but because it gave programming examples of controlling the T6963C, albeit written in a microcontroller command language unknown to the author.

There were, though, sufficient commands whose structure appeared to be close to some other machine code dialects with which the author is familiar, for a translation to PIC microcontroller language to be attempted.

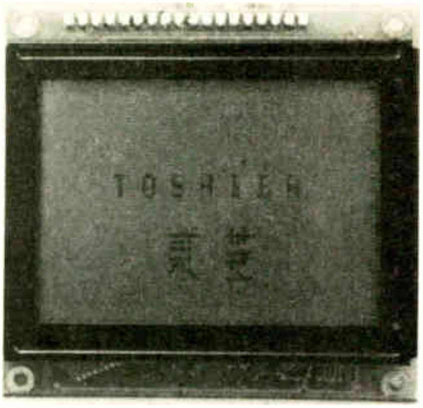


Photo 2. Toshiba's demo display.

Success was achieved when the display in Photo 2 appeared on the author's Powertip PG12864 64 × 128 pixel graphics l.c.d. screen – eventually!

POWERTIP PG12864

Whilst it is the Powertip PG12864 graphics display (RS 329-0329) used in the demos discussed, the commands are relevant to *any* graphics l.c.d. which uses the Toshiba T6963C controller, although the pin count/order may differ between display types. The PG12864 has the pinouts shown in Fig.1.

The PG12864 has a full dot-matrix l.c.d. structure consisting of a visible screen area having 128 dots × 64 dots (8192 dots in total). There are eight data lines, D0 to D7, and six control lines comprising WR, RD, CE, CD, RST and FS, names which will be clarified shortly.

The display has a single positive supply line (Vdd) at pin 3. The recommended working voltage is 5V, with an absolute maximum of 7V. There are two 0V connections, of which GND (pin 2) is the signal ground (Vss), and FG (pin 1) is the ground connection for the display's metal frame (bezel).

Display contrast is controlled via pin 4, named as CX in Fig.1 but can also be referred to as V0. This pin is normally connected to a negative voltage supply, of about –5V, via a contrast-adjusting preset potentiometer of typically 10kΩ to 25kΩ.

A summary of the pin functions is given in Table 1.

Which brings us to the first of the major discrepancies found in Powertip's own data sheet (be warned if you obtain it!):

1. Powertip quote data line D0 as being MSB. It's not. D0 is LSB (see Table 1).

2. Powertip also show an incorrect circuit diagram for the control of the screen contrast. The control pot is shown wrongly connected across pin 3 (+5V) and pin 9 (RST) with the wiper on pin 4 (CX). Furthermore, pin 9 is marked as V_{EE} (–VE). This configuration does not work.

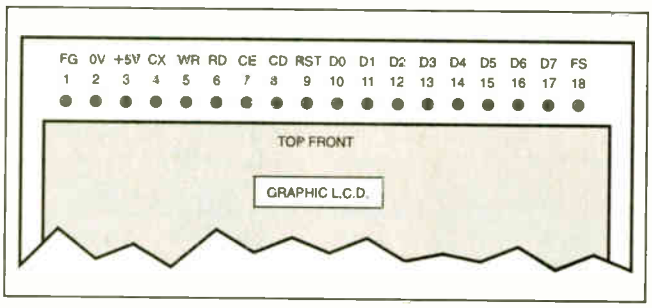


Fig.1. Pinouts of the Powertip PG12864 graphics l.c.d. module.

Table 1. Graphics l.c.d. pinout functions.

Pin	Symbol	Function
1	FG	Frame ground (connected to metal bezel)
2	GND	Signal ground supply (Vss)
3	+5V	Positive supply for logic (Vdd)
4	CX	Negative supply (V0) for l.c.d. contrast (–3·5V approx)
5	WR	Data write (active low)
6	RD	Data read (active low)
7	CE	Chip enable (active low)
8	CD	CD = 1, WR = 0: command write
		CD = 1, WR = 1: command read
		CD = 0, WR = 0: data write
		CD = 0, WR = 1: data read
9	RST	Module reset (active low)
10–17	D0–D7	Data bus (D0 = LSB, D7 = MSB)
18	FS	Font select:
		FS = 0: 8 × 8 dots font
		FS = 1 (or open–circuit): 6 × 8 dots font

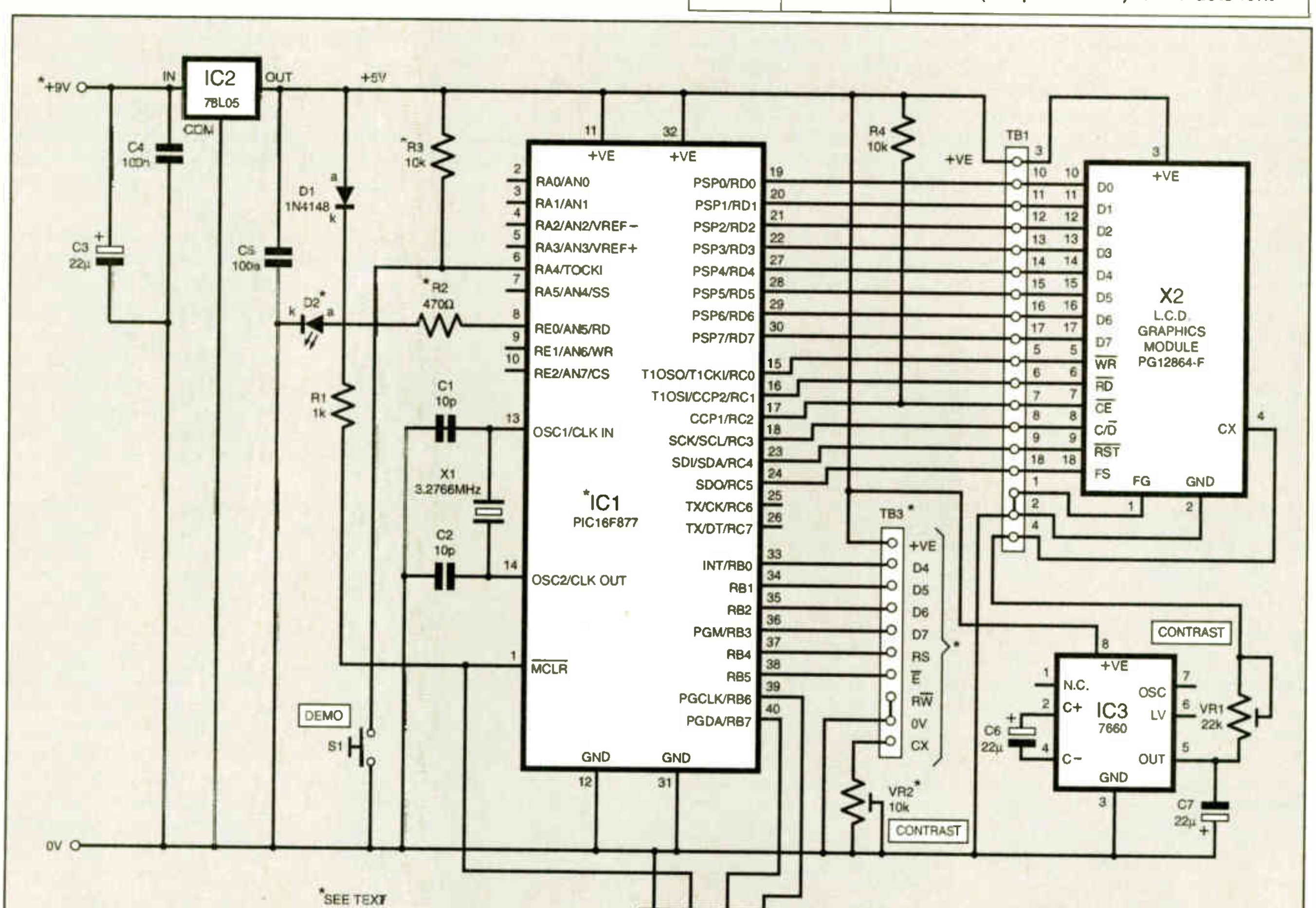
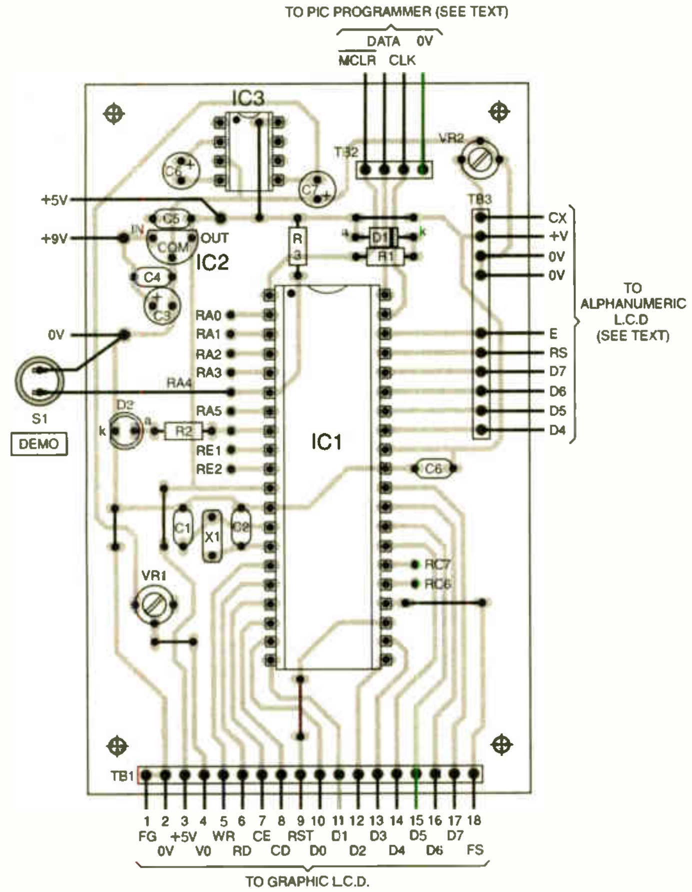


Fig.2. Circuit diagram for the PIC-controlled Graphics L.C.D. Demo.



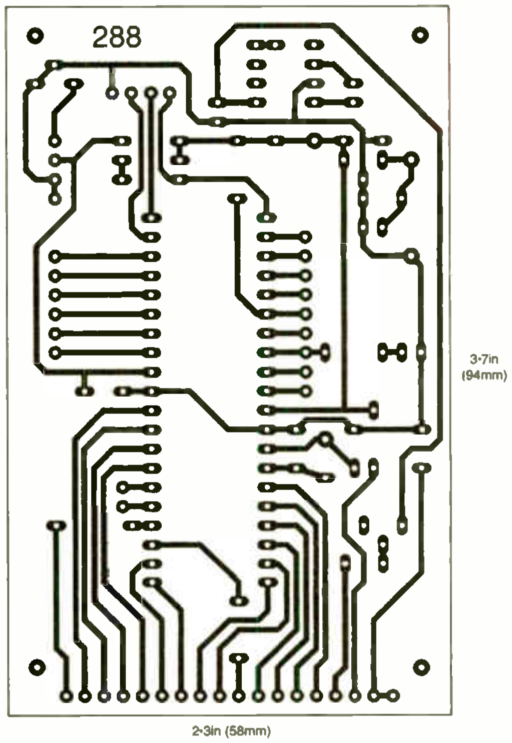


Fig.3. Component and full size copper foil track master pattern for the Graphics L.C.D. Demo printed circuit board.

Pin 9 (RST) does not go to –VE. It is held at logic 1 (+5V) for normal control chip operation and may be taken (briefly) to 0V to reset the chip, but it *must never be taken negative*, nor should one side of the control pot ever be connected to this pin.

Experimentation showed that the control pot's wiper *should* be connected to pin 4. One outer terminal of the pot then connects to a negative supply of, for example, –5V. The unused pot terminal is best connected to the wiper. This is illustrated in the demo circuit diagram (Fig.2.). The preset is adjusted until the desired contrast is observed.

The Toshiba data sheet does not discuss l.c.d. contrast setting, whilst that from RS is highly ambiguous on the subject.

DEMO CIRCUIT

The circuit diagram which the author used in his examination of the PG12864 display is shown in Fig.2. The circuit includes a PIC16F877 microcontroller (IC1), a crystal (X1) and its two capacitors (C1, C2), a 5V voltage regulator (IC2), a negative voltage inverter (IC3) with its two capacitors (C6, C7), the PG12864 l.c.d. display (X2) which is connected to the PIC via connector pins TB1, contrast controlling preset (VR1) and switch S1.

Components R1 and D1 are included so that the PIC may programmed on–board via connector TB2 and a suitable PIC programmer, such as the author's *PIC Toolkit Mk2* (May–June '99).

Resistor R2 and l.e.d. D2 were used by the author when originally translating the Toshiba demo program, the l.e.d. being set on or off at strategic points in the developing software. They have been left in and may be similarly used by readers when writing their own software. The control line is PORTE pin 0 (RE0).

Resistor R4 is included to keep the l.c.d.'s CE line high when the PIC is being programmed (so avoiding random displays appearing on the screen during that operation).

Resistor R3 biases high open-collector pin RA4 allowing demo-stepping switch S1 to operate correctly.

Components VR2 and TB3 are discussed in a moment.

A d.c. supply of between about 7V and 12V (nominally stated as +9V) can be used for powering the circuit via the 5V regulator, IC2.

Incidentally, the crystal clock frequency is not a critical matter and other frequencies could be used. If a crystal of greater than 4MHz is used, though, the PIC's configuration bit OS1

COMPONENTS

Approx. Cost Guidance Only **£50** *excluding case & batt.*

Resistors

R1	1k
R2	470Ω
R3, R4	10k (2 off)

All 0·25W 5% carbon film.

Potentiometers

VR1	22k (or 25k) min. preset, round
VR2	10k min. preset, round (see text)

See SHOP TALK page

Capacitors

C1, C2	10p ceramic, 5mm pitch (2 off)
C3, C6, C7	22µ radial elect. 16V (3 off)
C4, C5	100n ceramic, 5mm pitch (2 off)

Semiconductors

D1	1N4148 signal diode
D2	red l.e.d. (see text)
IC1	PIC16F877 microcontroller, pre-programmed (see text)
IC2	78L05 +5V 100mA regulator
IC3	7660 negative voltage converter

Miscellaneous

S1	min. s.p. push-to-make switch
X1	3·2768MHz crystal (see text)
X2	graphics l.c.d. module, Toshiba T6963C-based, 64 x 128 pixels, e.g. Powertip PG12864-F (see text)

Printed circuit board, available from the *EPE PCB Service*, code 288; 8-pin d.i.l. socket; 40-pin d.i.l. socket; terminal pin header strips and connectors (see text); 18-way ribbon cable (a few centimetres); p.c.b. supports (4 off); solder, etc.

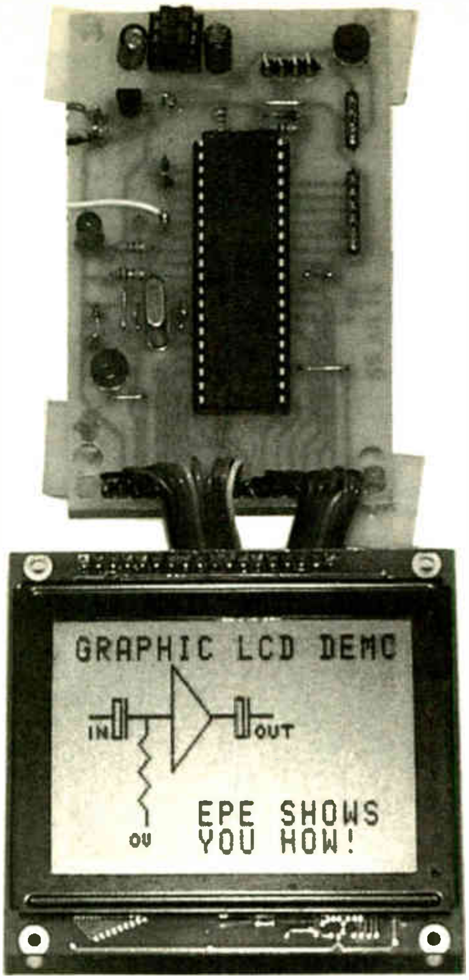


Photo 3. Demo printed circuit board assembly.

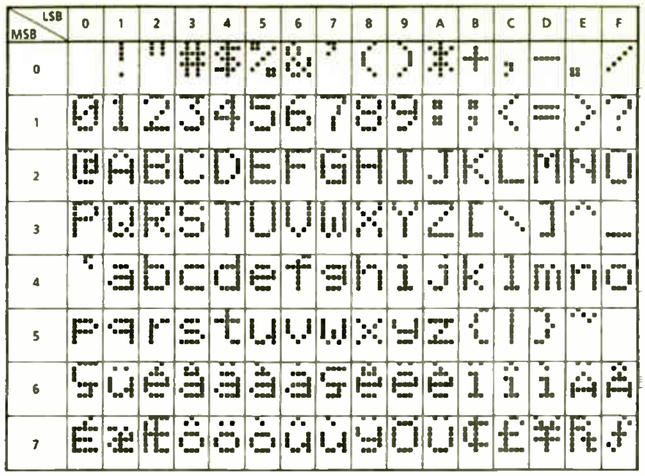


Fig.4. Character set for the Powertip PG12864 display (note that the last two lines may differ in some modules).

should be set high and OS0 set low (see later).

For his own demo board, the author in fact uses a 5MHz crystal, which does fractionally speed up Demo 8.

It may also be worth bearing in mind that the author's forthcoming follow–up constructional article, in which a PIC16F877 and the same graphics l.c.d. are used, also requires a 5MHz crystal.

PRINTED CIRCUIT BOARD

It is emphasised that unless you have a PIC programmer, there is no point in building this design since much of the discussion here concerns experimental software changes that you are recommended to try. These changes, once made, need the software to be re-assembled and downloaded to the PIC.

A printed circuit board design and its component layout are shown in Fig.3. This board is available from the *EPE PCB Service*, code 288.

You will observe that the p.c.b. includes components VR2 and TB3 towards the right. These are the points at which the author also included an ordinary alphanumeric l.c.d. so that various routines could be monitored during the development of the software translation from Toshiba to PIC.

The holes and tracks have been left intact so that the p.c.b. could be used as a future general-purpose development board with either type of l.c.d., and in conjunction with a PIC16F877.

A circuit diagram for the second l.c.d. is not included here, but the pin order and functions, and the controlling software subroutines, are the same as used in other recent "normal" l.c.d. projects designed by the author and published in *EPE*. The connections can be ascertained by studying any of those. In Fig.2, the connections are shown as TB3, with VR2 as the contrast control.

CONSTRUCTION

It is expected that all who build the circuit will be sufficiently experienced not to need constructional advice. It is recommended, though, that sockets are used for IC1 and IC3, and that pin header strips are used for the TB1 to TB3 connections.

Ideally, a graphics l.c.d. should be purchased that already has a suitable pin connector wired to it (see this month's *Shoptalk* page). The connections to the p.c.b. are in the "natural" order of the PG12864 l.c.d. used (as shown previously in Fig.1).

PIC PROGRAMMING

Having built the board and proved its workability, three lots of software need to be programmed into the PIC, one now and two later.

Before doing so, though, the PIC needs to be configured with the following settings (which are all *PIC Toolkit Mk2* default settings for a PIC16F877 running at 4MHz):

CP1	CP0	DBG	NIL	WRT	CPD	LVP
1	1	1	1	1	1	0
BOR	CP1	CP0	POR	WDT	OS1	OS0
0	1	1	0	0	0	1

Note that Logic 1 and Logic 0 in the settings do NOT necessarily mean that the function is on/off respectively – refer to the PIC '87 data sheet if you need to know more (also see earlier regarding the oscillator rate).

For the first part of the discussion that follows, you need the Toshiba demo program loaded into the PIC, GRAPHEPE.OBJ (source code name GRAPHEPE.ASM). The software is written in TASM, but *PIC Toolkit Mk2* can translate between TASM and MPASM if the latter is the programming language you are used to.

Two other program files will be loaded into the PIC later on.

The software is available free via the *EPE* web site, or on 3·5-inch disk (for which a nominal handling charge is made) from the Editorial office. See *Shoptalk* for details of both matters.

Having loaded the Toshiba demo, the display shown earlier in Photo 2 should be seen. It may be necessary for preset VR1 to be adjusted before the image is clearly visible.

It is this demo result which is first discussed before moving on to the author's demos, for which various exercises are suggested at some points.

DISPLAY STRUCTURE

Before starting to discuss programming detail, it is necessary to understand the physical arrangement of the ways in which data can be shown on the l.c.d. screen. There are three options, which can be summarised as:

1. **Alphanumeric text display** using the built–in character generator (as with any standard alphanumeric l.c.d.). 128 characters are available, as shown in Fig.4, and which are called by their own location numbers. In a very loose sense they can be regarded as the equivalent of ASCII characters. The addressing number order runs from zero to 127. Writing any of these values to the screen displays the "text" character associated with it. The characters in lines 7 and 8 may be slightly different in some variants of the PG12864 display.

2. **User–defined character generation and display**. Again this is similar to the facilities available on standard alphanumeric l.c.d.s, but the quantity of characters that can be simultaneously stored is far greater, 128 compared to the typical eight. The addressing order runs from 128 to 255. Writing any of these values to the screen displays the character that the user has created and allocated to the address value.

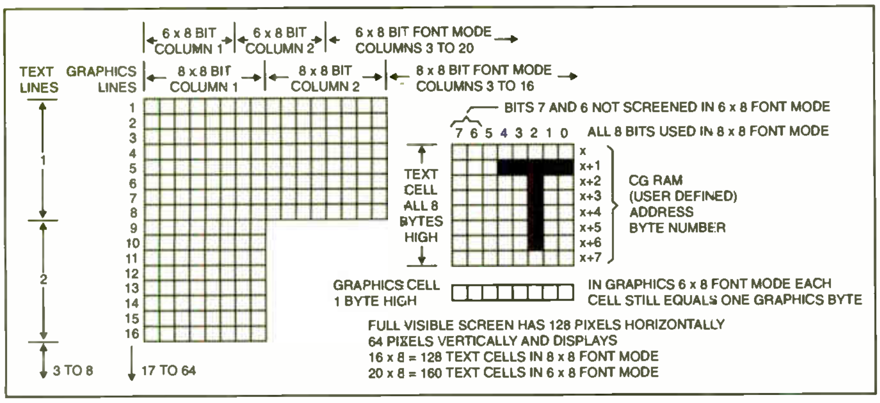


Fig.5. Pixel, column and row distribution for the graphics l.c.d.

3. **User–defined graphics detail generation** in which the "character" size is one pixel high by eight pixels wide (i.e. a single byte). Any value between zero and 255 can be written to the screen and the setting of the binary bits that make up that value determines whether a screen pixel is turned on or off.

For both character modes, the characters are all eight pixels high, but the width can be specified as six or eight pixels. That is, the character generation (font) can be set for 6 × 8 or 8 × 8 format.

Line FS controls the font choice, FS = 0 for 8 × 8, FS = 1 for 6 × 8. The pin has an internal pull–up resistor that holds it high (FS = 1) and the pin may be left unconnected if the 6 × 8 font is required (also see later).

In 8 × 8 font mode (FS = 0), the screen can display 16 characters horizontally and 8 vertically. In 6 × 8 font mode (FS = 1), the display format is 20 horizontal × 8 vertical characters. It is conventional to refer to the character display in terms of lines (horizontal) and columns (vertical). See Fig.5.

For the graphics mode, 64 character locations can be written to vertically. Horizontally, the quantity is determined by the width mode set for the characters, i.e. 20 or 16.

There are two screen memory areas to which data is written, known as the Text screen and the Graphics screen. The Text screen displays the built–in and user-defined characters. The Graphics screen displays only graphics data.

The l.c.d. can be programmed to display Text only, Graphics only, or Text and Graphics combined.

There are many additional display attribute features that can be implemented, such as highlighting, blanking, flashing, panning etc.

COMING NEXT

The next several sections of this discussion relate to the T6963C l.c.d. controller, and how Toshiba's example programs are interpreted using the PG12864 graphics display and a PIC16F877 microcontroller, resulting in the display shown earlier in Photo 2.

Following this, the author's own examples of PIC-microcontrolling the l.c.d. in a variety of situations will be described. In a future issue, this same graphics l.c.d. will be the display used in a PIC-controlled audio frequency oscilloscope (currently having the working title of *PIC G-Scope*).

There is lot of information discussed from hereon, but it is illustrated with working program examples, and with many points at which you can experiment with various commands in the author's own demos.

As usual with this type of article, the author tries to lead you carefully from step to step.

CONTROL MATTERS

Those of you familiar with alphanumeric ("intelligent") l.c.d. displays will be aware that they can be operated in either 4-bit or 8-bit data mode. They can also be controlled by just two control lines, RS and E, and rely on a predetermined delay between sending bytes or nibbles of data.

The same is not true of graphics displays. Those using the T6963C can only be operated in 8-bit mode. They use five control lines and *require status check routines to be performed before each action*. Timed delays are not used, nor can they *be* used between data transfers.

There are, though, delay requirements concerning the order in which the data and control lines are taken high or low, a matter which is discussed now. Status checking will be examined shortly.

CONTROL LINES

Data is written to or read from the l.c.d. via the eight data lines D0 to D7. Three control lines are used in most read or write situations:

CD: selection of data or command function, 0 = Data, 1 = Command

CE: chip enable, 0 = enabled, 1 = disabled

RD or WR: read or write functions. These are two separate lines and the relevant one is taken low to be active, with the other remaining high.

The timing characteristics for the setting of the data and control lines are shown in Fig.6 and Table 2.

Since the l.c.d. includes its own oscillator, the timings shown are independent of the clock rate controlling a PIC microcontroller.

PIC PORT SETTINGS

In the demo programs, PIC PORTC is used for setting the l.c.d. control lines, and PORTD for the data input/output lines.

Some microcontrollers and microprocessors have internal registers which allow the same data port to be used either for input or for output without the user having to specify the port's function, other than by the *write* or *read* command.

For example, the required port (e.g. parallel port connector on a PC computer) has two separate register addresses, one for inputting data, the other for outputting it. These would be equated as values at the head of the program, e.g. OUTPORT = &H378 (output register), INPORT = &H379

Table 2. Toshiba T6963C Timing Values

Item	*Symbol*	*Min*	*Max*	*Unit*
C/D Set-up Time	t_{CDS}	100	–	ns
C/D Hold Time	t_{CDH}	10	–	ns
$\overline{CE}$, $\overline{RD}$, $\overline{WR}$ Pulse Width	t_{CE}, t_{RD}, t_{WR}	80	–	ns
Data Set-Up Time	t_{DS}	80	–	ns
Data Hold Time	t_{DH}	40	–	ns
Access Time	t_{ACC}	–	150	ns
Output Hold Time	t_{OH}	10	50	ns

Test Conditions: V_{DD} = 5·0V ± 10%, V_{SS} = 0V, Ta = –20 to 75°C

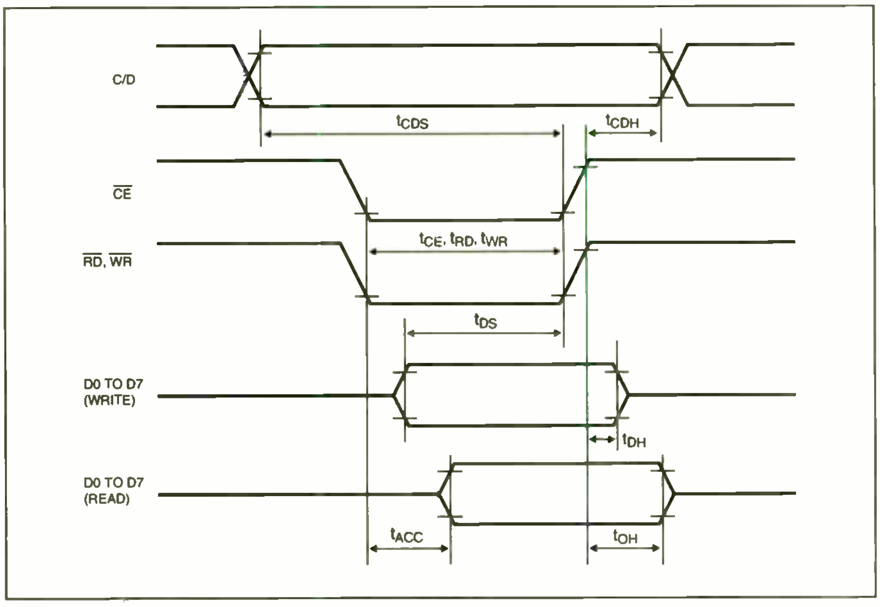


Fig.6. Timing waveforms for the Toshiba T6963C graphics l.c.d. controller, see also Table 2.

Table 3. Toshiba T6963C Status Register Settings

STA0 D0	Check command execution capability	0 : Disable 1 : Enable
STA1 D1	Check data read/write capability	0 : Disable 1 : Enable
STA2 D2	Check Auto mode data read capability	0 : Disable 1 : Enable
STA3 D3	Check Auto mode data write capability	0 : Disable 1 : Enable
STA4 D4	Not used	
STA5 D5	Check controller operation capability	0 : Disable 1 : Enable
STA6 D6	Error flag. Used for Screen Peek and Screen copy commands	0 : No error 1 : Error
STA7 D7	Check the blink condition	0 : Display off 1 : Normal display

Listing 1. CHECK3 – Status check for PORTD RD0/RD1 (STA0/STA1) = 3. See also flow chart Fig.9.

```
CHECK3:
PAGE1               ; set for Bank 1 (DDR bank)
MOVLW 255
MOVWF TRISD         ; set PORTD for input
PAGE0               ; set for Bank 0 (Data port bank)
                    ; RST  CD  CE  RD WR
MOVLW %00011001     ;  1    1   0   0  1
MOVWF PORTC         ; set CE, RD low
NOP                 ; pause to allow port to stabilise
CK3:
BTFSS PORTD,0       ; PORTD bit 0 set?
GOTO CK3            ; no
CK3A:
BTFSS PORTD,1       ; PORTD bit 1 set?
GOTO CK3A           ; no
                    ; RST  CD  CE  RD  WR
MOVLW %00011111     ;  1    1   1   1   1
MOVWF PORTC         ; set controls high
NOP                 ; pause to allow port to stabilise
PAGE1
CLRF TRISD          ; set PORTD as outputs
PAGE0
RETURN
```

(input register), both numbers referring to the same physical port.

To read data from the port, a command such as VALUE = INP(INPORT) would load the data present on the port connector and store it into the variable VALUE.

Similarly, to write data held in variable VALUE to the port, a command such as OUT(OUTPORT), VALUE would be used.

PIC microcontrollers, though, do not have this dual-function automatically available. A port's data direction register (DDR) has to have its input/output directions actively set from within the program prior to data input or output.

As you are no doubt aware, this is where PAGE and TRIS commands come into use in the PIC16x84, for example, setting the STATUS register Page (Bank) address through which the DDR is changed (STATUS bit 5 = high).

The PIC16F877, as used for this demo, has *two* STATUS register bits to be manipulated in order to enter the DDR setting mode, STATUS bits 5 and 6 (RP0 and RP1 – their full use will be discussed in a forthcoming *EPE* feature article). To set for Bank 1 (to access the DDR register), RP1 is set low, and RP0 is set high. To return to Bank 0 (for accessing the data port itself rather than its DDR), RP0 is returned low.

When Banks 2 and 3 are not used (as with this demo), it is convenient to define the setting of RP0 using the familiar PAGE commands, e.g.:

```
#DEFINE PAGE0 BCF STATUS,5
#DEFINE PAGE1 BSF STATUS,5
```

With RP1 held low, switching back and forth between DDR and data port addresses is simplified, and is the technique used in the demo programs.

STATUS CHECKS

Just as a PIC microcontroller has a STATUS register which informs of the results following various functions or commands (through bits C, DC and Z), so too does the T6963C. It is an 8-bit register of which seven bits are used, having the functions shown in Table 3.

In practice, there are only three forms of status check normally required, depending on the type of control function being used at that moment. There is an easy logic to status checks and examples of those used for different circumstances are illustrated in the author's own demo routines.

Let's take the most frequently used status check as a first example. It is used immediately prior to writing data (of any sort, display data or command data) to the l.c.d. It simply entails reading the STATUS register to check whether bits STA0 and STA1 are high (= 1), and if not, then waiting until they are. This is shown in the flow chart of Fig.7.

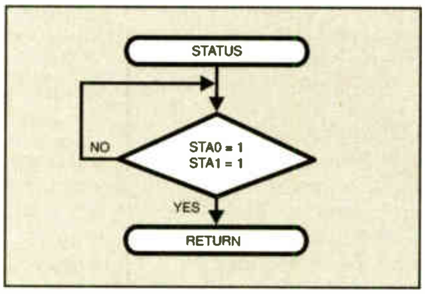


Fig.7. Flow chart for the most commonly used status check, which waits for bits STA0 and STA1 to become high (logic 1).

To explain the convention of the flow charts used in this discussion, the entry and exit points of the routine are indicated by the oval shapes enclosing, for example, the name of the routine and its end point.

Thus in Fig.7, the "working" aspect of the chart is simply that within the diamond shape. Here the question being represented is what status do STA0 and STA1 have. The question is repeated until they are both at logic 1, whereupon the routine ends.

An example of writing data to the l.c.d. is shown in the flow chart of Fig.8. It shows the status check, and then a rectangle stating the next action to be taken (write data) following the successful status check. After which the routine ends.

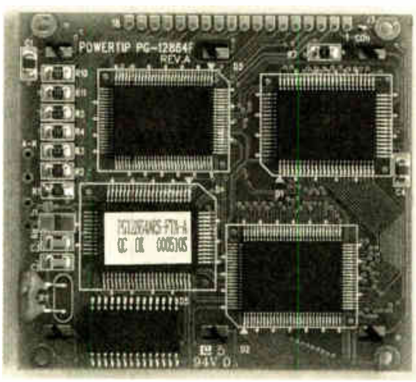


Photo 3. The minutely detailed rear view of the Powertip PG12864 display.

Immediately prior to reading the status register, command lines are set for CD and WR high, with CE and RD low:

CD	CE	RD	WR
1	0	0	1

This condition remains throughout the repeated checking of the status. Upon its successful conclusion, all four lines are returned high:

CD	CE	RD	WR
1	1	1	1

In the PIC program, the status checking flow chart becomes that in Fig.9.

Note that the square brackets statement [CALL CHECK3] indicates the command the PIC software issues in order to access the routine. Square brackets statements are used in other flow charts for a similar purpose.

The entry point address label of CHECK3 has been given because the routine checks if the value of input bits 0 and 1 is equal to 3 (binary 11, i.e. both high).

The PIC source coding involved is shown in Listing 1. Note that the RST bit is that which controls the reset of the T6963C (but does not perform such functions as

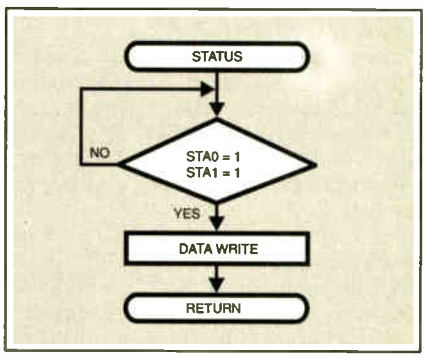


Fig.8. Flow chart for writing data to the l.c.d.

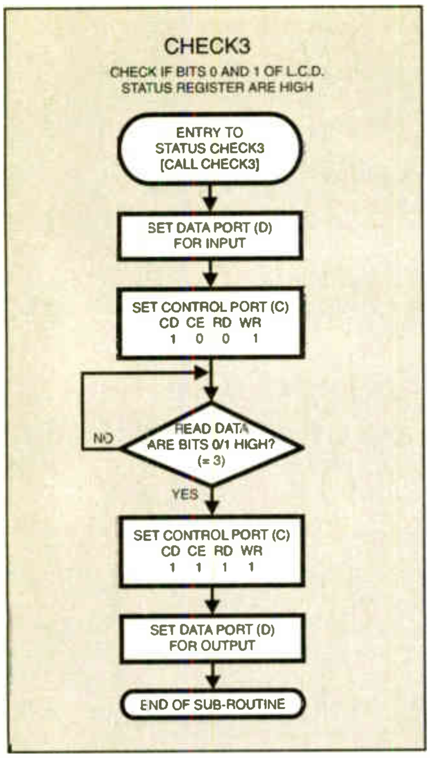


Fig.9. Flow chart for status check named as CHECK3.

screen or memory clearing). It is held high throughout the normal use of the l.c.d., only being cleared briefly when the program commences.

In the Listings, note that the Labels are placed above the commands in order to conserve page space. In the full source code, they are to the left and the commands are indented as usual. In preparing this text for publication, other minor cosmetic changes have been made to some listings compared to the actual source code itself.

DATA WRITE

On entry to the data write routine (OUTDATA) the control lines are first set for data output in which line CD is taken low, with the other control lines set high:

CD	CE	RD	WR
0	1	1	1

The data to be sent is then placed on the data port output lines. Now, with CD remaining low, the CE and WR command lines are taken low, leaving RD high:

CD	CE	RD	WR
0	0	1	0

Next, and still leaving CD low, the CE and WR lines are again taken high:

CD	CE	RD	WR
0	1	1	1

After which the data write routine can be exited, leaving CD low. However, the author chooses to leave all control lines in the known setting of all high, so the previous routine is followed by returning CD high before exiting or performing the next required command:

CD	CE	RD	WR
1	1	1	1

The PIC source coding lines for the OUTDATA routine are shown in Listing 2 and associated flow chart in Fig.10.

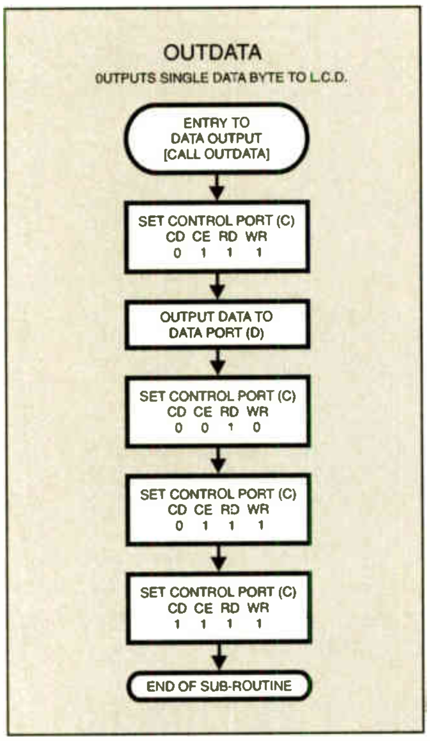


Fig.10. Flow chart for outputting data to the l.c.d.

Listing 2. OUTDATA – send data to l.c.d. routine. See also flow chart Fig.10.

```
OUTDATA:
MOVWF TEMPA          ; temp store val brought in on W
                     ; RST  CD  CE  RD  WR
MOVLW %00010111      ;  1    0   1   1   1
MOVWF PORTC          ; set CD low
MOVF TEMPA,W         ; get stored data
MOVWF PORTD          ; send data
NOP                  ; pause to allow port to stabilise
                     ; RST  CD  CE  RD  WR
MOVLW %00010010      ;  1    0   0   1   0
MOVWF PORTC          ; set CD, CE, WR low
NOP                  ; pause
                     ; RST  CD  CE  RD  WR
MOVLW %00010111      ;  1    0   1   1   1
MOVWF PORTC          ; set CE, WR high
NOP                  ; pause
                     ; RST  CD  CE  RD  WR
MOVLW %00011111      ;  1    1   1   1   1
MOVWF PORTC          ; set CD high
RETURN
```

TOSHIBA'S DEMO

Having set the first simple scenes, it seems best to illustrate the capabilities of a graphics l.c.d. controlled by a Toshiba T6963C by first discussing the sub-routines used in Toshiba's own demo program, the results of which you saw in Photo 2.

The program listings shown are the author's translations to PIC control language from the language used in Toshiba's original program (written for their microcontroller type TMPZ84C00P). Slight changes to Toshiba's program have been made apart from the translations.

The program is written for a 20 column × 8 line display, in 8 dots mode (font).

FIXED VARIABLES

As shown in our full program source code listing file, the PIC source code has its usual EQUates and #DEFINEs set at the beginning. Then follow fixed equates values for some specific commands, as specified by Toshiba, and shown in Listing 3.

Then, as said earlier, PORTC is set for control line output, and PORTD for data input/output.

It is worth noting that l.c.d. line FS (that which selects between font widths, FS = 0 = 8-bit, FS = 1 = 6-bit) is controlled by PORTC bit 5. The selection of which font mode is chosen is provided in the subroutine which sets the DDR registers for PORTC and PORTD. As said earlier, line FS has an internal pull-up resistor.

The choice of having FS high or low is then determined by the DDR setting of PORTC bit 5 (TRISC bit 5). With DDR bit 5 set for input (= 1), PORTC bit 5 presents a high impedance to line FS, which thus adopts the logic high status as set by the internal pull-up resistor.

With the DDR bit 5 set for output (= 0), line FS is thus controllable by the output value of PORTC bit 5. With Toshiba's demo, DDR bit is set high to use the 6 × 8 font. All the author's demo routines which write to PORTC have bit 5 set permanently low, which with DDR bit 5 set for output causes FS to be permanently set low, so selecting the 8-bit font.

Should you want 6-bit mode for another design, set DDR bit 5 for input, as with Toshiba's demo. Note that when programming the PIC *in situ*, the l.c.d. will show screen data in 6 × 8 font mode since PORTC is held in high impedance during programming.

DEMO SUBROUTINES

The PIC source code for calling each of Toshiba's demo routines to be discussed is shown in Listing 4. The first four routines are required to be run at the start of any program. They specify the address locations and column area of the Text and Graphics display memory areas.

The l.c.d.'s total available memory runs from addresses $0000 to $FFFF

Listing 3. Toshiba's fixed variables

```
TXHOME:   .EQU $40   ; text home (start) location
TXAREA:   .EQU $41   ; text area, i.e. number of active
                       columns
GRHOME:   .EQU $42   ; graphics home (start) location
GRAREA:   .EQU $43   ; graphics area, i.e. number of
                       active columns
AWRON:    .EQU $B0   ; autowrite on command
AWROFF:   .EQU $B2   ; autowrite off command
OFFSET:   .EQU $22   ; graphics offset
ADPSET:   .EQU $24   ; set address pointer command
PEEK:     .EQU $E0   ; read data from screen command
```

Listing 4. PIC source code for calling Toshiba's demo routines

```
CALL TEXTHOME      ; set Text Home address
CALL GRAPHHOME     ; set Graphic Home address
CALL TEXTAREA      ; set Text Area
CALL GRAPHAREA     ; set Graphic Area

CALL SETMODE       ; set Mode (e.g. OR mode, internal
                     Character Generator)
CALL SETOFFSET     ; set Offset register for character code
                     $80
CALL SETDISPLAY    ; set Display Mode (Text on, Graphics
                     and Cursor off)
CALL CLRTXT        ; clear Text Area
CALL WRITECG       ; write to external (user–defined)
                     character generator RAM
CALL WTDD          ; write Text Display data (internal CG
                     ROM)
CALL WTDD2         ; write Text Display data (external CG
                     RAM) upper part
```

Listing 5. TEXTHOME – set Text Home address. See also flow chart Fig.11.

```
CLRF ADRMSB      ; set Text Home address to $0000
CLRF ADRLSB
CALL CMDADR      ; send 2 bytes of address data
MOVLW TXHOME
CALL SENDCMD     ; send TXHOME command
RETURN
```

Listing 6. CMDADR – send command address to LCD. See also flow chart Fig.12.

```
CALL CHECK3        ; read status for DA0/DA1 = 3
MOVF ADRLSB,W      ; send address LSB
CALL OUTDATA
CALL CHECK3        ; read status for DA0/DA1 = 3
MOVF ADRMSB,W      ; send address MSB
CALL OUTDATA
RETURN
```

(64K bytes). The l.c.d.'s actual *visible screen* area, though, is 1024 bytes (1K) and so 64K of available memory area can be regarded as holding up to 64K/1K = 64 screen pages of data. As will be seen later, this allows for pages of data to be stored "behind the scenes" and then called as required by simply changing the Text Home or Graphic Home addresses.

Toshiba state that Text data, Graphic data and user-defined CG RAM can be freely allocated to the full memory area, a matter on which they do not elaborate. It would seem logical, though, for the total area required for each data set to depend upon the total data required to be stored for that set.

Toshiba's demo, for example, has seven text letters, amounting to 7 × 8 = 56 bytes of data (each letter is eight bytes high) and eight user-created graphic symbols, making a further 8 × 8 = 64 bytes. Toshiba allocate the Text Home address to $0000 and the Graphics Home address to $0200, thus allocating a maximum of 512 bytes available for text use should the demo be expanded upon.

The routines which set these facts are TEXTHOME and GRAPHHOME. Referring to routine TEXTHOME in Listing 5 and Fig.11, the text address value ($0000) is set into the 2-byte address word consisting of bytes ADRMSB and ADRLSB, which in this instance are both cleared to zero.

The routine CMDADR (command address) is then called, in which the

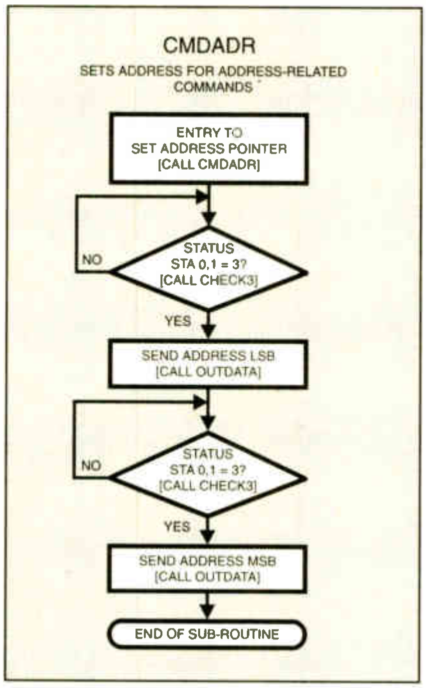


Fig.12. Flow chart for routine CMDADR.

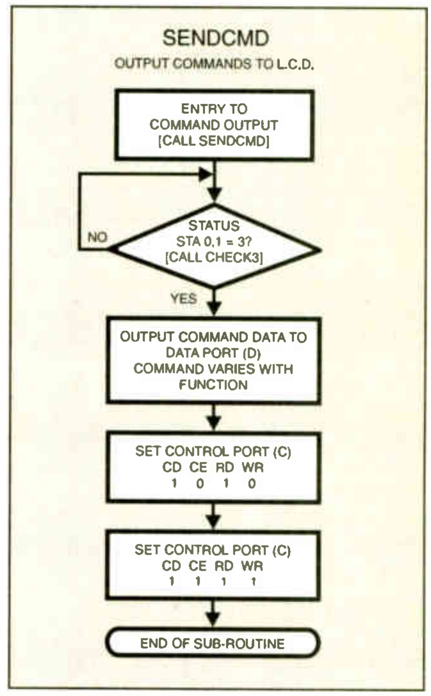


Fig.13. Flow chart for routine SENDCMD.

MSB/LSB address is sent to the l.c.d., as shown in Listing 6, and flow chart CMDADR in Fig.12.

As will be seen, the first action in CMDADR is to check the l.c.d. status via sub–routine CHECK3, as discussed earlier (Listing 1, Fig.9).

Next, the address LSB is sent to the l.c.d. via the OUTDATA routine, also discussed earlier (Listing 2, Fig.10). A further CHECK3 status check is made and the address MSB is sent, again via OUTDATA, and the routine is exited.

The address is now stored in the l.c.d. but has not been acted upon yet. It is brought into action at the end of Listing 5 by sending the TXHOME command to the l.c.d. via sub-routine SENDCMD.

The value of TXHOME, you will recall, was specified at the beginning of the program (see Listing 3) to be $40. This is a fixed command value that must be sent to the l.c.d. via routine SENDCMD each time the Text Home address is changed. Other commands are sent in other situations, as will become apparent as we discuss and illustrate them.

The SENDCMD routine is shown in Listing 7 and its flow chart Fig.13.

Having sent the TXHOME command, a RETURN is made to the calling routine.

From Listing 5, you will have seen that the command to be sent, TXHOME in

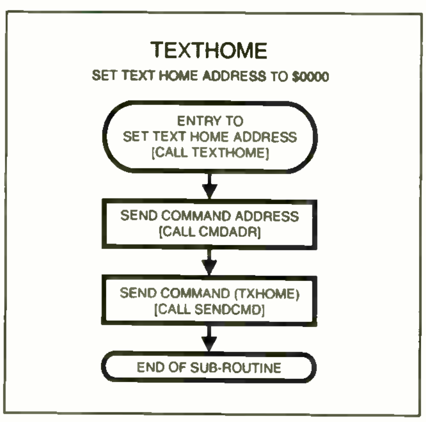


Fig.11. Flow chart for routine TEXTHOME.

Listing 7. SENDCMD – send command instruction to LCD. See also flow chart Fig.13.

```
MOVWF TEMPA        ; temp store val brought in on W
CALL CHECK3        ; read status for DA0/DA1 = 3
MOVF TEMPA,W       ; recall stored data
MOVWF PORTD        ; send stored data
NOP                ; RST  CD  CE  RD  WR
MOVLW %00011010    ;  1    1   0   1   0
MOVWF PORTC        ; set CE, WR low
NOP                ; RST  CD  CE  RD  WR
MOVLW %00011111    ;  1    1   1   1   1
MOVWF PORTC        ; set all high
RETURN
```

LISTING 8. TEXTAREA – set Text Area. See also flow chart Fig.14.

```
CLRF ADRMSB        ; set Text area (columns)
MOVF COLUMN,W      ; column quantity (preset for 20 columns)
MOVWF ADRLSB
CALL CMDADR        ; send 2 bytes of address data
MOVLW TXAREA
CALL SENDCMD       ; send TXAREA command
RETURN
```

Listing 9. SETMODE – set INT/EXT/AND–OR–XOR mode. See Table 4.

```
MOVLW %10000000    ; External CG RAM, OR mode
CALL SENDCMD       ; send command
RETURN
```

Listing 10. SETDISPLAY – set text/graphics/cursor on/off. See Table 4.

```
MOVLW %10010100    ; text on, graphic off, cursor &
                     blink off ($94)
CALL SENDCMD       ; send command
RETURN
```

Listing 11. SETOFFSET – Set Offset register.

```
CLRF ADRMSB        ; address value stated by Toshiba $0002
MOVLW $02
MOVWF ADRLSB
CALL CMDADR        ; send command address
MOVLW OFFSET
CALL SENDCMD       ; send OFFSET command
RETURN
```

this instance, is loaded into PIC register W (MOVLW TXHOME). On entry to SENDCMD (Listing 7), the value is stored in a temporary register, simply called TEMPA, although it could have any other name if preferred.

The now-familiar CHECK3 status check is made, after which the value stored in TEMPA is recalled and output to PORTD, the data input/output port, which is in its default state and set for output.

Following a one cycle pause (NOP) for stabilisation of the port, the command port, PORTC, sets CE and WR low, leaving the other bits high. Again a one cycle pause occurs to allow the l.c.d. to accept the data, and then CE and WR are taken high again, followed by a return to the calling routine. The l.c.d. will now have accepted the Text Home address of $0000.

In routine GRAPHHOME (set the Graphic Home address – not shown), the process is identical to that for TEXTHOME, this time sending $0200 as the address, and GRHOME as the actioning command.

AREA SETTING

Text and Graphics area setting is then performed respectively by routines TEXTAREA (Listing 8 and Fig.14) and the closely similar GRAPHAREA (not shown).

The business of Text and Graphics areas is somewhat subtle, and does not actually refer to the area of the display that is visible. It refers to the areas set aside for Text and Graphics data storage, and determines the way in which data is ultimately shown on screen. The area is specified by the number of columns it contains. A column, as said earlier, is specified as being one byte wide.

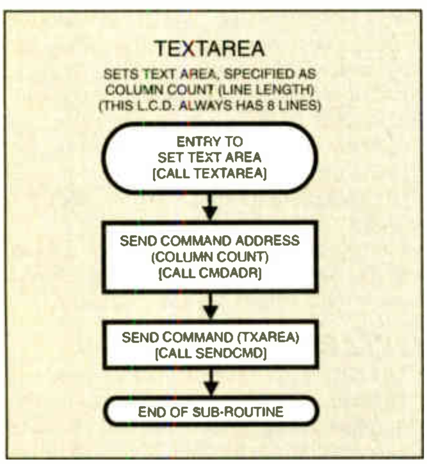


Fig.14. Flow chart for routine TEXTAREA.

Later, a routine (AUTOWRITE) is demonstrated that allows automatic incrementing of addresses when data is repeatedly written to the l.c.d.

When Autowrite is on, addresses are incremented along the length of each allocated screen line right up to the end of the column count set through the relevant Area command. At the end of line, the address is incremented to the start of the next line. The process continues for as many increments as required.

If the Text Area, for example, has been set for 20 columns, the length of each line is 20 columns long. This means that if you start at the beginning of line 1 and write data to the l.c.d. 20 times, line 1 will be filled in incremental order. The 21st write, though, will place the next data byte at the start of line 2.

When the l.c.d. has been set for 6-bit mode, the actual screen area seen is also 20 columns wide, therefore you can repeatedly write text to the l.c.d. 20 (columns) × 8 (lines) = 160 times and the actual screen area will be filled with consecutive data along all 20 character positions through all eight text lines.

If, however, the data screen area has been set to 40 columns, for example, the same writing of 160 characters will have a different visual effect.

Line 1 will be filled up to position 20 and the screen will show the characters as before. The next 20 writes to the l.c.d., though, will be stored in the remaining 20 bytes of the column area allocated, which is "off–screen". These 20 bytes will not be seen. On the 41st write to the l.c.d., the first byte of the next line will be written to, which is once again "in-screen" and will thus be visible on the display.

So, in order to completely fill the actual screen area by writing consecutive data bytes in autowrite mode, 320 writes must be made, and only uneven–numbered groups of 20 characters (1, 3, 5 etc) will be seen. The evenly number groups of 20 characters (2, 4, 6 etc) will remain unseen.

The alternative, when in 40-column mode, is to write 20 bytes of data to line 1, reset the address for the start of line 2 and write another 20 bytes, and so on for the other visible lines.

Of course, using 40-column mode allows addresses to be set for displaying separately in the first 20 bytes of each line, and another batch of data stored separately and unseen into the last 20 bytes of each line. It is then possible to issue commands which cause either the first block to be displayed, or the second. In other words, to switch between l.c.d. blocks (pages) as referred to earlier.

In their demo, however, Toshiba do not illustrate this paging facility (although it is illustrated later in the author's own demo program).

Toshiba simply set the Text Area for 20 columns width, as is performed via subroutine TEXTAREA in Listing 8. At the start of the demo program, the author has allocated variable COLUMN as the store for the column width value, setting it for 20 ($14).

In the TEXTAREA routine, the Text Area is set into the same variables as were used earlier in the address setting routines, ADRMSB and ADRLSB. This double–byte value ($0014 = 20 decimal) is also sent to the l.c.d. via the same command address setting routine (CMDADR), followed by the command TXAREA being sent via the SENDCMD routine. (To set the area for 40 columns would require an address value of $0028 = 40 decimal to be sent.)

Routine GRAPHAREA (not shown) sets the graphics area in the same fashion, also for 20 columns, but with the actioning command becoming GRAREA instead of TXAREA.

MODE SETTING

There are two forms of mode defined by Toshiba which, regrettably, they only define as Mode and Display Mode (see Table 4). The various forms will be demonstrated more fully in the author's demos.

Table 4

Mode itself is subdivided into the following six sub-modes and codes (where X can be 0 or 1):

OR mode	1	0	0	0	X	0	0	0
XOR mode	1	0	0	0	X	0	0	1
AND mode	1	0	0	0	X	0	1	1
Text Attribute mode	1	0	0	0	X	1	0	0
Internal CG ROM mode	1	0	0	0	0	X	X	X
External CG RAM mode	1	0	0	0	1	X	X	X

Display Mode is also split into six sub-modes and codes:

Display off	1	0	0	1	0	0	0	0
Text on, graphic off	1	0	0	1	0	1	X	X
Text off, graphic on	1	0	0	1	1	0	X	X
Text on, graphic on	1	0	0	1	1	1	X	X
Cursor on, blink off	1	0	0	1	X	X	1	0
Cursor on, blink on	1	0	0	1	X	X	1	1

Listing 12. CLRTXT – clear text screen.

```
CLRTXT:
CLRF ADRMSB          ; set address ($0000)
CLRF ADRLSB
CALL SCREENADR       ; set screen write address
MOVLW AWRON          ; autowrite on
CALL SENDCMD         ; send AWRON command
MOVLW 8              ; number of lines to clear
MOVWF LOOPC
CLR2:
MOVF COLUMN,W        ; column length
MOVWF LOOPB
CLR3:
MOVLW 0              ; write 0
CALL AUTOWRITE       ; autowrite and increment
DECFSZ LOOPB,F
GOTO CLR3
DECFSZ LOOPC,F
GOTO CLR2
MOVLW AWROFF         ; autowrite off
CALL SENDCMD         ; send AWROFF command
RETURN
```

Listing 13. SCREENADR – send data read/write address to LCD.

```
CALL CHECK3          ; read status for DA0/DA1 = 3
MOVF ADRLSB,W        ; send address LSB
CALL OUTDATA
CALL CHECK3          ; read status for DA0/DA1 = 3
MOVF ADRMSB,W        ; send address MSB
CALL OUTDATA
MOVLW ADPSET         ; address pointer
CALL SENDCMD         ; send ADPSET command
RETURN
```

Listing 14. AUTOWRITE – autowrite data and increment address.

```
MOVWF TEMPA          ; temp store value brought in on W
CALL CHECK8          ; read status for DA3 = 8
MOVF TEMPA,W         ; recall stored value
CALL OUTDATA         ; output data
RETURN
```

OR mode is required in the Toshiba demo. This allows data to be written to the screen and ORed with any data already existing at the same location. The routine (SETMODE) is shown in Listing 9.

All that is involved is to send the command for OR mode (%10000000 or $80 or 128 decimal) to the l.c.d. via the SENDCMD routine which was discussed earlier.

The setting of the Display Mode (SETDISPLAY) has its routine shown in Listing 10, in which Text is turned on, and Graphics and the cursor are turned off. Again the only action required is to send the appropriate command (%10010100 or $94 or 148 decimal) to the l.c.d. via SENDCMD.

OFFSET SETTING

The Display Mode command, though, is shown in Toshiba's demo as following routine SETOFFSET, in which an offset register value command is issued. Listing 11 shows what is required.

Toshiba's explanation of the use of the offset register is not fully intelligible. The interpretation, however, appears to be that the offset register is used to determine the external (user-defined) character generator RAM area.

The T6963C assigns this generator so that when text character codes $80 to $FF are written to the l.c.d. they are treated in the same way as the "normal" text characters of the internal character generator RAM, which are called through codes $00 to $7F. That is, you write only one value to the screen to display the eight bytes of the character held in the CG RAM.

This is in contrast to writing *true* graphics data to the screen, in which eight bytes of data have to be individually sent.

Toshiba go on to state that setting the offset register to a value of 2 sets the CG RAM address to $1400, which then allows the user–defined characters to be called by their allocated code, between $80 and $FF. The implications of attempting to use different offset addresses have not been explored.

As with setting Home and Area values, and referring to Listing 11, the offset value is set into the 2–byte address as $0002 and the CMDADR routine called. This is followed by the OFFSET command being issued via SENDCMD.

The routine next in order of calling is SETDISPLAY, as discussed in the previous section.

INTO ACTION

This completes the basic initialisation of the l.c.d. and it is now ready to have real data sent to it for display on screen. The first data to be written, though, clears the screen of any previous data which might exist. At switch on, for example, random data could automatically (and unpredictably) be set into the screen and other areas.

Routine CLRTXT is that which clears the Text screen (there is no need to clear the Graphics screen since this has been deactivated in the Display Mode setting).

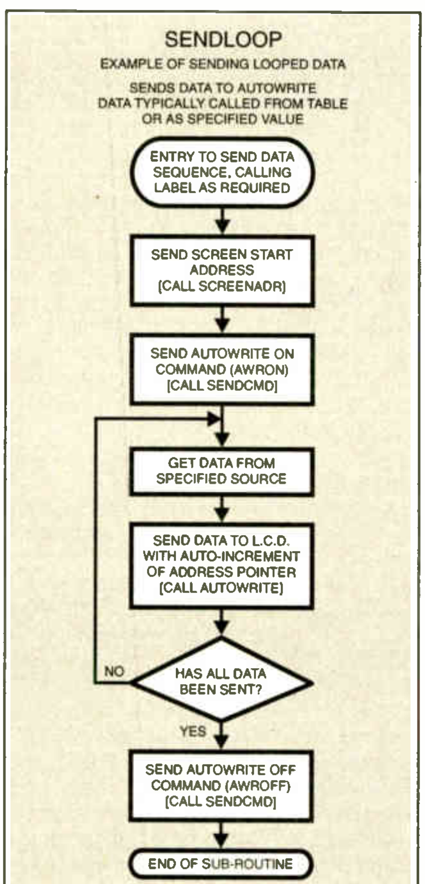


Fig.15. Flow chart for routine SENDLOOP.

The source code is shown in Listing 12, see also flow chart SENDLOOP in Fig.15.

The text address from which data is to be cleared is first set to $0000. Because it is *data* that is to be sent (as opposed to *commands* as with the previous routines), an Address Pointer command has to be sent as well, ADPSET.

A separate routine (SCREENADR) has been written that sets both the data address and the Address Pointer command. It is shown in Listing 13 and its flow chart is identical to the CMDADR routine (Listing 6) except that the sending of ADPSET is added at the end.

Following the call to SCREENADR (from Listing 12), Autowrite is set on by issuing the AWRON command. Next a LOOPC value is allocated, holding the number of lines to be cleared (eight). Then a LOOPB value, which holds the line length (COLUMN) involved, is set.

The subroutine CLR3 is then entered, in which the value of zero is repeatedly written to the l.c.d. for the duration of the nested decrementing loops.

At each write, the data is written to the screen via routine AUTOWRITE (Listing 14), in which the screen address is automatically incremented after each byte is written. As discussed earlier, all addresses are filled in order and in relation to the column value previously set in the initialisation routines. This will be more clearly seen later in the author's Demo 9.

On each entry to AUTOWRITE, the value brought in on W (in this instance zero) is temporarily stored in variable TEMPA. A status check is then called, but not the CHECK3 routine seen previously. This time, because we are in Autowrite mode, it is CHECK8 which is called, in which the status register is checked for the value of 8 (bit 3 high). The process is almost identical to that used in CHECK3 and is not listed here.

On conclusion of the check, the data in variable TEMPA is recalled and sent to the l.c.d. via the usual OUTDATA routine.

SYMBOL CREATION

Toshiba now illustrate the creation of characters (symbols) for storage in the external (user-defined) CG RAM. The data is specified in a table (EXTCG) that holds the 64 byte values that make up the eight component parts of the Japanese characters

Listing 15. WRITECG – write to external (user-defined) character generator.

```
WRITECG:
MOVLW $14            ; set CG RAM start address to
                       $1400
MOVWF ADRMSB
CLRF ADRLSB
CALL SCREENADR       ; send 2 bytes of address data +
                       address pointer
MOVLW AWRON          ; set autowrite on
CALL SENDCMD         ; send AWRON command
MOVLW 64             ; set loop for 8 sets of 8 bytes (= 64)
MOVWF STORE
CLRF LOOPB
EXCG:
MOVF LOOPB,W         ; get loop value
CALL EXTCG           ; get data from table position set by
                       loop val
CALL AUTOWRITE       ; autowrite and increment address
INCF LOOPB,F         ; increment loop counter
DECFSZ STORE,F       ; decrement counter, is it zero?
GOTO EXCG            ; no, so repeat
MOVLW AWROFF         ; yes, turn off autowrite
CALL SENDCMD         ; send AWROFF command
RETURN
```

seen earlier in Photo 2. The routine is illustrated in Listing 15 (WRITECG – see also flow chart SENDLOOP, Fig.15).

On entry to WRITECG, the CG RAM address at which the data writing commences is set at $1400. This is the value referred to earlier when Offsets were discussed. The Autowrite process is used and the address written to is automatically incremented on each data write.

Apart from data being called from a table, the routine is similar to that used for clearing the text screen (in which the written data had a value of 0).

The table is not illustrated here in full, but the following shows the data Toshiba specifies for creating the first user-defined character (the first column is the command and the second shows the value in binary):

```
RETLW $01    $01 = 00000001
RETLW $01    $01 = 00000001
RETLW $FF    $FF = 11111111
RETLW $01    $01 = 00000001
RETLW $3F    $3F = 00111111
RETLW $21    $21 = 00100001
RETLW $3F    $3F = 00111111
RETLW $21    $21 = 00100001
```

If you ignore the 0s in the binary code, concentrate on the 1s and look at Photo 2, you will see that the 1s represent the active pixels of the top left quadrant of the first Japanese symbol.

The remaining aspects of the symbols are similarly created.

For each block of eight data bytes read from the table and stored in CG RAM, a counter (internal to the T6963C) is automatically incremented, from $80 up to, in this table's instance, $87. These eight values are the addresses which are called in order to display the user-generated symbols on screen. In other words, to display the first symbol discussed, a value of $80 would be written to the l.c.d.'s text screen, a value of $81 for the second, etc.

Having been created, the symbols are called in the order specified in another table via routines WTDD2 and WTDD3. Both are very similar to that in Listing 15, relating to different addresses and calls to other tables. They are not shown here. The method is the same as that used during the creation of the symbols – a screen start address is specified and the symbols consecutively written to that and subsequent addresses. Accessing table EXPRT1, routine WTDD2 calls and writes the following data bytes to line 5 commencing at column 8 (address value $6C = 5 × 20 + 8 = 108 decimal):

```
RETLW $80
RETLW $81
RETLW $00
RETLW $00
RETLW $84
RETLW $85
```

Note the inclusion of zero bytes, specifying blank characters (from the text character CG ROM) to be written to the screen. Routine WTDD3 behaves similarly, accessing table EXPRT2 and writing data to the sixth line, again starting at column 8.

The table-specified order of writing can be changed if desired for other display circumstances. The data stored in the character generation table (EXTCG) can also be changed to suit the user's needs. This point will be amply illustrated in the author's later demos.

TEXT WRITING

Toshiba then go on to show how text itself is written to the screen, using the l.c.d.'s own internal character generator (CG ROM).

The following data bytes are accessed from table TXPRT and written to generate the word TOSHIBA, as shown in Photo 2.

```
RETLW $34  ; T
RETLW $00  ; blank
RETLW $2F  ; O
RETLW $00  ; blank
RETLW $33  ; S
RETLW $00  ; blank
RETLW $28  ; H
RETLW $00  ; blank
RETLW $29  ; I
RETLW $00  ; blank
RETLW $22  ; B
RETLW $00  ; blank
RETLW $21  ; A
```

For example, the data byte value of $34 specifies CG ROM location $34 at which the character for letter T is stored (as defined during the device's manufacture), and value $2F specifies letter O, and so on. Again note the inclusion of zero bytes for spaces.

Routine WTDD illustrates the text values being written to the screen. It is practically identical to the WTDD2 and WTDD3 routines except that a different data table (TXPRT) is accessed. It is not listed here.

TOSHIBA TO ASCII

It is reiterated that the values for the CG ROM characters held by the T6963C are not the same numbers as specified by ASCII codes. They are in fact ASCII values less 32. For instance, letter A in ASCII has a value of 65 decimal ($41). Deduct 32 from this and you obtain the value of 33 decimal ($21) for letter A in the Toshiba code, as shown at the end of the table in the previous section.

The author's later demo will illustrate a routine in which alphanumeric characters can be specified in the normal PIC fashion of enclosing the required ASCII character in single quotes (e.g. 'A') and for the routine to then automatically translate its ASCII value into a Toshiba value.

Following the completion of writing the characters to the screen, Toshiba's program ends and no further action occurs.

You might care, though, to change some of the data in Toshiba's demo and see what results occur. There will, however, be much more opportunity for such things in the author's demos, which we move on to now.

AUTHOR'S DEMOS

Before progressing, it is necessary to load two programs into the PIC, the author's demo routines, for which the first file is GEPE456.OBJ (source code GEPE456.ASM). It too is written in TASM.

Additionally, a text file needs to be loaded into the PIC's EEPROM data memory. The file is called DUCK08.MSG (for reasons that will become clear!) and is a Message file of the type recognised by *PIC Toolkit Mk2* for sending to the PIC's EEPROM. Beware that other programmers may not necessarily recognise the format (or be capable of directly accessing the EEPROM data memory).

DEMO CONTENT

The first matter examined is that of substituting different patterns for use as user–generated CG RAM symbols. The resulting display is shown in Photo 1, earlier.

After the PIC setup procedure, the column width (COLUMN) is then set at 34 (see label GRAPHIC) and the l.c.d. SETUP routine is called, in which all the subroutines discussed previously are actioned.

Two new routines, CLRGRAPH and CLRCG, are also sent, in which the graphics and user-defined CG RAM areas are cleared. The routines are closely similar to the CLRTXT routine and not listed here.

Then follow the author's 12 demos in which not only are routines covered that Toshiba did not illustrate, but you are given the opportunity to change various command codes and observe the results via your demo board.

A switch monitoring routine is placed within or between demos so that you can keep the results on screen until the switch (S1) is pressed to action the next demo. Labels are given to each demo call so that some demos can be *remmed* out, or jumps made from one demo to another further down. When Demo 12 has been finished with, a return to Demo 1 is made.

DEMO 1
Diagram and words

In Demo 1, a set of data held in table form (CGTABLE) is read and stored in the user-defined CG RAM, in a similar way to which Toshiba's Japanese symbols were created and shown. These symbols represent the component parts of a

Listing 16. Data for first character ($80) in table CGTABLE, representing the "amplifier" top left, plus first slope down.

```
RETLW %10000000
RETLW %11000000
RETLW %10100000
RETLW %10010000
RETLW %10001000
RETLW %10000100
RETLW %10000010
RETLW %10000001
```

simple electronic circuit, as shown earlier in Photo 1.

There are 15 characters created, each comprising eight bytes, making a total of 120 bytes. They are stored in consecutive CG RAM locations which are called with value codes of $80 to $8E (whereas Toshiba's occupied calling locations $80 to $87). The subroutine SETCG is used for this process. The routine is closely similar to that in Listing 15 and is not shown here. The first part of the symbol creation table is shown in Listing 16.

Unlike Toshiba's demo, the calling table (AMPLIFIER) does not insert blank character cells. Instead the data is written by several subroutines so that it is placed at the exact screen addresses required.

For example, the routine labelled CIRCUIT specifies that the location for the first symbol is to be placed at Column 5 Line 1, in which both lines and columns now start at zero (they started at 1 in Toshiba's demo).

The column required is specified by the value loaded into W. The selection of Line 1 is then specified by the call to LINE1. The LINE call is one of several in which the line number is specified by the called address, i.e. a call to LINE2 would specify that Line 2 was the required line (see the source code for the listing).

Calculation of the screen address at which the first character is to be placed is in relation to the line number called, the number of columns specified for the display (column width), and with the column value as set into W prior to the call added to the total. Readers will no doubt be able to write a more compact routine than is used in the demo.

The routine which reads the table and sends data to screen is SHOWCG (not listed here but similar to Listing 15). Part of the listing for table AMPLIFIER is shown in Listing 17.

Note that the screen displays some small text characters as part of the circuit diagram. These have also been created as user-defined CG RAM symbols. The l.c.d. does not keep small characters as part of its fixed text symbol library.

Listing 17. First part of AMPLIFIER table.

```
RETLW $80      ; amp top left
RETLW $83      ; amp input
RETLW $86      ; cap top
RETLW $83      ; amp input
RETLW $83      ; amp input
RETLW $81      ; amp left
RETLW $82      ; amp slope down
RETLW $83      ; amp output
RETLW $86      ; cap top
RETLW $83      ; amp output
RETLW $8B      ; word IN
```

The normal size letters shown on the screen are created using the l.c.d.'s own internal text generator. The letters required are specified in a table (TABLE1) and called in order, with the l.c.d. screen address to which they are written being changed when needed.

The address setting and table calling routines (WORDS and SHWTXT) are similar to those used for sending the circuit diagram symbols to the screen and not shown here. Part of the text-holding TABLE1 called is shown in Listing 18.

Listing 18. First part of TABLE1.

```
RETLW 'G'
RETLW 'R'
RETLW 'A'
RETLW 'P'
RETLW 'H'
RETLW 'I'
RETLW 'C'
RETLW ' '
```

In routine SHWTXT, after TABLE1 has been called, 224 is added to the returned value. This is the equivalent of subtracting 32 from the ASCII value held in the table, so converting it to the Toshiba code value (as discussed earlier).

Exercise 1.1.

Experiment with changing the text content sent to the screen, and its positioning.

Exercise 1.2

Do the same with the graphics display, perhaps even completely creating your own replacement drawing.

DEMO 2
Bit setting and clearing

Pressing the switch now starts the second demo, which illustrates how individual pixel bits on the screen can be set or cleared (see Photo 4).

It uses the same illustration as in Demo 1 but to the right of it now draws a square and then clears it, followed by drawing it again, indefinitely. At the centre of the square a single pixel is shown constantly set.

The action uses a delay loop between the setting or clearing of each pixel so that it is in semi-slow motion.

For the first time in any of the demos so far, the Graphics screen itself is used for this action, superimposed on the circuit diagram, which you will recall makes use of the Text screen.

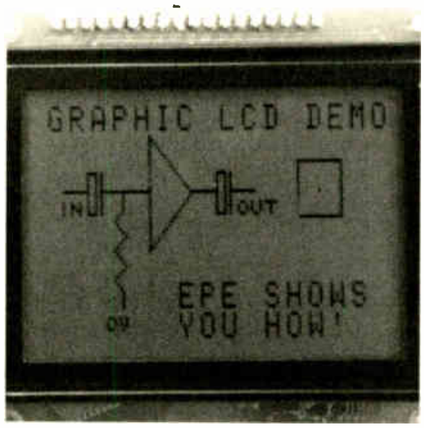


Photo 4. The square being drawn in Demo 2.

The first part of the demo routine is shown in Listing 19.

On entry to Demo 2, the first commands ensure that the display is placed on screen page 1 (more on this later). Both Text and Graphics screens are then activated by the commands:

```
MOVLW %10011100   ; text & graphic
                    on, cursor & blink off
CALL SENDCMD      ; send command
```

Until the display mode is changed, anything written to the Text or Graphic screens will be shown. Hence you continue to see the text-generated characters on the Text screen, plus the graphics-generated square data being drawn on the Graphics screen.

The Graphics screen is made up of 64 horizontal lines (raster lines) each of which contains the same number of columns as previously set during the initialisation. The address of any byte on screen is in relation to the line number and the column number. The pixel to be manipulated is one of the eight bits within the selected byte.

Table 5. Pixel bit setting codes

Code	*Function*
11110XXX	Bit Reset
11111XXX	Bit Set
1111X000	Bit 0 (LSB)
1111X001	Bit 1
1111X010	Bit 2
1111X011	Bit 3
1111X100	Bit 4
1111X101	Bit 5
1111X110	Bit 6
1111X111	Bit 7 (MSB)

To set a screen address, subroutine GLINE (graphics line – not shown) is told which column is required and on which line. It then calculates the address. For example, shortly after entry to Demo 2, column 12 line 23 is the required address. As shown in Listing 19, the column value (12) is loaded into the address LSB and W is then loaded with the line value (23). GLINE is then called.

GLINE performs a rudimentary multiplication routine, multiplying the line number by the number of columns specified in the initialisation. The actual column number required is then added to the total.

The selected pixel is turned on or off in relation to the value of bit 3 of a command byte (BITVAL) which is sent via a specific bit writing routine, BITWRITE. Bit 3 = 0 causes the screen pixel bit to be reset (cleared), and bit 3 = 1 sets the bit (turns it on). The bit itself is specified by the 3–bit code in bits 0 to 2.

Table 5 illustrates the logic. Listing 19 shows part of the routine, performing the setting of the square's single central bit.

In subroutine BITWRITE, the screen address is set from the calculated address value, and then the BITVAL byte is written to the screen, but as a command rather than actual screen data. See Listing 20.

In the square drawing routines, manipulation of the pixel-controlling bit within the byte at the selected address is done by an 8-value (0 to 7) incrementing counter (STORE1). The bit to be set or cleared is stated by the counter value.

Listing 19. First part of DEMO2 bit setting/clearing routine.

```
                        ; set single centre bit
MOVLW 12                ; set column number
MOVWF ADRLSB
MOVLW 23                ; set graph line
CALL GLINE              ; multiply by line length to get address
MOVLW %11111000         ; set bit 0
CALL BITWRITE
MOVLW %11111000         ; bits 0–2 indicate bit affected
MOVWF STORE1            ; bit 3 high = set, low = clear
```

Listing 20. BITWRITE – write single bit routine.

```
MOVWF BITVAL        ; temp store val brought in on W
CALL SCREENADR      ; set screen write address
MOVF BITVAL,W
CALL SENDCMD        ; send BITVAL command
RETURN
```

Listing 21. DEMO3 – fill selected graphics area with reverse attribute value, first section, for top line.

```
DEMO3:
MOVLW 2             ; set graphic address ($02xx)
MOVWF ADRMSB
MOVLW 0             ; set column
CALL LINE0          ; set cell number for line stated
MOVLW 16            ; character quantity to be affected
MOVWF LOOPC
MOVLW %00000101     ; attribute reverse
MOVWF ATTRIB
CALL SETATTR
```

There are several sub-routines within the square drawing demo (not shown here), which respectively cause the apparent movement of the square's perimeter.

During upwards or downwards drawing, the selected bit value remains constant. It is the address of the line/column which is changed, adding or subtracting the column width value depending on the direction of "travel".

In the full source code, note how bit 3 is toggled high or low at the end of each drawing of the square, so alternating between bit setting and bit clearing.

Exercise 2.1.
Set the display mode so that only the square being drawn is displayed.

Exercise 2.2.
Change the screen address at which the square is drawn, together with the centre active pixel.

Exercise 2.3.
Rewrite the square drawing program so that the drawing appears to take place in an anticlockwise fashion, instead of moving clockwise.

Exercise 2.4.
Is your logical thinking up to drawing a circle instead of a square?

Having finished Exercises 2.1 to 2.4, reinstate the Display Mode so that the circuit diagram and bit setting displays are both seen (text and graphics on).

Pressing the switch starts Demo 3.

DEMO 3
Text highlighting

Demo 3 illustrates text highlighting and flashing (see Photo 5). Part of the controlling routine is shown in Listing 21.

The action taken in Demo 3 is to highlight the words at the top of the screen (GRAPHIC LCD DEMO) by inverting them, causing clear letters to be shown on a dark background. Similarly with the other captions (EPE SHOWS YOU HOW), but with them flashing on and off within their dark background.

The control bytes which are responsible for these actions are written to the graphics screen area, consequently any graphics within the graphics screen at the affected locations are overwritten.

Referring to Table 6, the commands for inverting text characters against the background are:

```
MOVLW %00000101     ; attribute reverse
                      command
MOVWF ATTRIB        ; store it
CALL SETATTR        ; call set attribute
                      routine
```

The chosen command (%00000101 in this instance) is written to a temporary variable, ATTRIB, and then subroutine SETATTR is called. The routine is closely similar to other screen writing routines and is not listed here.

Table 6. Screen attribute codes

Code	*Function*
XXXX0000	Normal display
XXXX0101	Reverse display
XXXX0011	Inhibit display
XXXX1000	Blink of normal display
XXXX1101	Blink of reverse display
XXXX1011	Blink of inhibit display

Autowrite mode is used in SETATTR. The required address is first set, Autowrite is turned on and then a loop repeatedly sends the value held in ATTRIB to the required graphics screen area.

Any text character superimposed on that area via the text screen is affected by the ATTRIB value "beneath" it, in this case inverting it.

The blink-reverse command is %00001101, and is sent to the graphics screen area in the same way, having specified the required address and number of bytes involved:

```
MOVLW %00001101     ; blink reverse
MOVWF ATTRIB
CALL SETATTR
```

When all the attribute values have been sent to the required locations, the text has to be set for Attribute Mode, as is performed in Listing 22. The essential commands are:

```
MOVLW %10000100     ; text attribute
                      mode
CALL SENDCMD        ; send command
```

The following commands are also sent to ensure that the correct screen mode is set following any changes you may have made in the previous exercises:

```
MOVLW %10011100     ; text & graphic
                      on, cursor &
                      blink off
CALL SENDCMD        ; send command
```

Exercise 3.1.
Referring to the Attribute table (Table 6), experiment with using the other highlight options available. Also try putting the commands at other places on screen and observe what effect is produced.

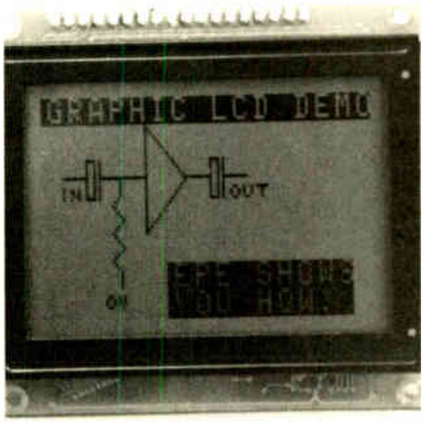


Photo 5. Screen as seen during part of Demo 3.

DEMO 4
Cursor Setting

Demo 4 illustrates how the cursor can be used. The basic routine is in Listing 23.

First it is necessary to specify the screen address at which the cursor is to be positioned, and issue the commands generated in subroutine CSRADR (see Listing 24):

```
CALL CMDADR         ; send command
                      address
MOVLW CSRPOS        ; cursor position
                      command
CALL SENDCMD        ; send command
```

Unlike other address setting calls, the cursor position is specified by the actual display screen line and column position. Thus to set the cursor for line 3 column 15, it is these two values which are sent as the address, rather than having the position calculated in relation to the first screen byte location and the column width set (as you saw occurring for placing text on screen).

Thus, for this line 3 column 15 example, the column position (15) is placed into the address LSB, and the line number (3)

Listing 22. Final section of attribute setting routine, setting for Text Attribute mode.

```
MOVLW %10000100     ; text attribute mode
CALL SENDCMD        ; send command
MOVLW %10011100     ; text & graphic on, cursor & blink off
CALL SENDCMD        ; send command
RETURN
```

Listing 23. DEMO4 – Cursor setting.

```
DEMO4:
MOVLW %10010111     ; text on, graphic off, cursor & blink on
CALL SENDCMD        ; send command
                    ; set cursor position + type
MOVLW 15            ; set column
MOVWF ADRLSB
MOVLW 3             ; set line
MOVWF ADRMSB
CALL CSRADR
CALL CSRTYP         ; set type (specified in sub-routine)
RETURN              ; (from 1 to 8 lines high)
```

Listing 24. CSRADR – Cursor position (address) setting.

```
CSR:
CALL CMDADR         ; send command address
MOVLW CSRPOS        ; cursor position command
CALL SENDCMD        ; send command
RETURN
```

Listing 25. CSRTYPE – set cursor type. See also flow chart Fig.16.

```
CSRTYP:
MOVLW %10100111     ; 8–line
CALL SENDCMD        ; send command
RETURN
```

placed into the MSB, following which the call to routine CSRADR is made, where the address is actioned:

```
MOVLW 15            ; set column
MOVWF ADRLSB
MOVLW 3             ; set line
MOVWF ADRMSB
CALL CSRADR
```

Cursors having eight different heights can be created, as illustrated in Fig.16. Listing 25 shows the command (%10100111) which generated the full 8-line cursor, "line" in this instance meaning a graphics line (of which there are 64, as stated earlier).

The cursor type command is issued in routine CSRTYP (Listing 25), which on this occasion is for an 8-line cursor.

As you will see from Fig.16, the cursor type is selected logically, with bits 0 to 2 holding the binary number whose decimal equivalent is the cursor line-count (height) value.

STATIC CURSOR

It is important to note that the cursor position remains in the same screen position to which it has been allocated. There is no facility for it be automatically incremented in position when writing text to the screen, unlike with standard alphanumeric l.c.d.s, where the cursor can be set to be "actively mobile".

You will also see from Demo 5, where switching between screen pages is performed, that the cursor position is always related to the actual location on the *visible* screen, rather than to the screen memory locations previously discussed.

When changing the cursor position on screen, it is only necessary to specify the address at which it is to be placed. Once the cursor type has been specified and actioned (via CSRTYP), it is not necessary to specify it again, unless you wish to change the type.

Note that the cursor can be set to flash or to remain static. The Display option controls its action (see Table 4).

On entry to Demo 4, the display mode is set for text on, graphic off, cursor and blink on, using the commands:

```
MOVLW %10010111     ; text on, graphic
                      off, cursor &
                      blink on
CALL SENDCMD        ; send command
```

Note that with the graphic screen now turned off, the attribute commands behind the top text line no longer cause the text to be inverted. However, the blinking text line continues to blink because the text attribute mode has not been cancelled.

Exercise 4.1.
Experiment with different addresses for the cursor to be placed, and also with the cursor type.

Exercise 4.2.
How would you stop the flashing of the bottom text lines, returning them to normal text display mode?

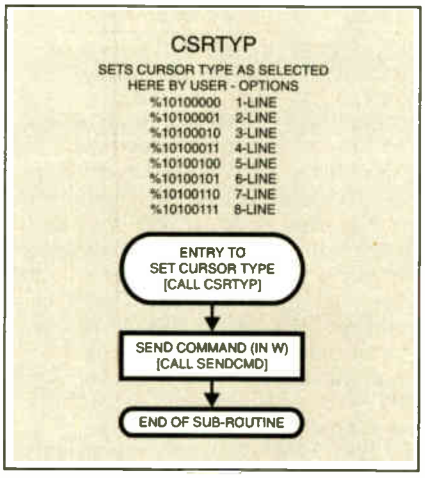


Fig.16. Flow chart for cursor type setting routine plus the cursor codes.

DEMO 5
Panning between pages

In Demo 5 panning between screen pages is illustrated. The principle of l.c.d. pages was discussed when describing how the column width setting determined how data was written to the display screen.

You would not have been aware of it at the time, but when writing text to the screen in Demo 1, text was also written into the region which we can call Page 2. That text simply says "THIS IS PAGE 2".

Panning occurs between the main page (page 1) and page 2. It has been slowed by the inclusion of a delay routine, but this can be omitted (or extended) if preferred in other applications. See the full source code for program details. It is based upon the TEXTHOME routine in Listing 5.

The Text Home address is initially set for page 1, line 1 column 1. A loop is then entered in which the address is repeatedly incremented, causing the display to shift by one column each time from right to left, each shift followed by a short pause.

As the display shifts left, so page 2 will gradually become revealed, with the progressive disappearance of page 1.

At the end of the preset loop count, the shifting is reversed so that it shifts from left to right, to again reveal page 1, with the disappearance of page 2.

The process repeats until such time that you press the switch to enter Demo 6.

If at the end of Demo 4 you had left the cursor and lower text lines flashing, you will see that the cursor does not shift in position while the panning occurs. Nor will the screen area which contains the instructions for text flashing. As the screen pans, the text beneath the flashing commands will shift away from those commands and cease to flash in the positions beyond them.

Note that the l.c.d.'s nature dictates that changes to the screen images do not instantly take effect. There is a short time that it takes for the display's liquid crystals to realign themselves following any change. This results in a brief "ghost" image of the display as it was prior to being shifted. The effect is especially noticeable in situations such as panning or switching between pages.

Exercise 5.1.
Experiment with changing the rate at which the screen pans.

Exercise 5.2.
Increase the column width setting and write text of your own invention to the area which can be regarded as page 3. Then set the panning loop lengths so that page 3 is revealed following page 2.

Exercise 5.3.
How many pages can you create, write to and pan through?

Exercise 5.4.
What happens if you cause the graphic screen to pan rather than the text screen?

Exercise 5.5.
What happens if you pan *both* screens?
Restore the original column width and panning loops to the original values before progressing to Demo 6.

DEMO 6
Switching between pages

Demo 6 is a variant of the action performed in Demo 5. Here the pages are switched between, rather than panned.

Exercise 6.1.
Perform the same experiments as in the exercises for Demo 5. Again ensure that the originally settings exist before you enter Demo 7.

DEMO 7
AND, OR, XOR

In Demo 7 (listing not shown), the AND, OR and XOR modes (Table 4) are demonstrated. Press the switch to enter the demo.

On entry, a return is made to page 1 with both Text and Graphics screens active. The previous text characters will be seen, plus probably the residual state of the square drawing demo on the graphics screen. The Text Attribute mode is also cleared. Initially, the OR display mode is active. These actions take place in the first few subroutines of Demo 7.

In the principal demo routine, an area of the graphics screen has a pattern written to it, the area of which spans part of the "circuit diagram". The process is similar to that in flow chart SENDLOOP.

The pattern is created by writing the binary value 10101010 to alternate lines within the area, and 01010101 to the other alternate lines.

This pattern is written as an Attribute, moving it into the variable ATTRIB and then writing this to the l.c.d. via the SETATTR routine which was demonstrated earlier. The key lines are as follows:

```
MOVLW %10101010 ; fill graphic with
                  val shown
BTFSS LOOPD,0
MOVLW %01010101 ; fill graphic with
                  val shown
MOVWF ATTRIB
CALL SETATTR    ; send value
```

When the pattern has been written to the designated area, the choice of whether it is ANDed, ORed or XORed with the text is available. As set, XOR mode is chosen. The choice of mode is actioned by sending that value as a command to the l.c.d. via the SENDCMD routine.

Following the sending of the selected command, the choice of which text and graphics screens are active is offered (refer back to Table 7). In the demo, the Text and Graphics On mode is selected, and the chosen value sent as a command via the SENDCMD routine.

Exercise 7.1

Experiment with choosing different options from the modes offered and note the results.

DEMO 8
Quackery!

Now we come to a complex example of creating a moving picture via the Graphics screen. Press the switch to enter Demo 8, and observe a bit of quackery (see Photo 6)!

You will see two creatures which might just be confused by some as being ducks! On the assumption that they might be, one of them opens its beak periodically and the word QUACK appears briefly on screen.

The ducks are also seen to be very sedately swimming slowly to the right. As the rightmost exits the screen area, another duck begins to appear on the left. A pattern of water is placed at the bottom of the screen, and a text message is at the top.

The water and text are created and displayed by the program in the manner discussed in previous routines. The water is a

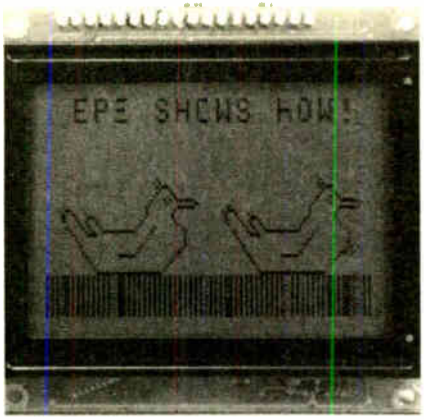


Photo 6. The birds sedately "swim" across the screen in Demo 8.

pattern created by writing a series of 01010101 bytes to the graphics screen. The text is held in a table.

What is interesting, though, is that the data for the ducks themselves is not actually programmed into the source code, but has been programmed into the PIC's EEPROM data memory from a pattern held in a separate text file on disk (DUCK08.MSG).

This is the data you were asked to send to the PIC as part of its programming for the author's demos. Other data could be written instead and similarly downloaded to the EEPROM. The .MSG file can be read (and amended) through a normal text editor.

SIMPLE IN PRINCIPLE

A really complex set of programming commands is involved in creating this screen, and there is insufficient room to show it. The principles are simple, though:

First the water is displayed, plus the top line text. The ducks are identical and the pattern for just one is held in the EEPROM, where it is stored as a set of values for writing to the character generator (user-defined) RAM. The pattern is retrieved and written to the CG RAM. Detail of part of the bird's beak is also retrieved and stored as a separate CG RAM byte.

The data, except for the extra beak detail, is then written twice to the graphics screen, so that two ducks are shown.

The Graphics screen itself is now repeatedly read, line by line within the "Duck zone", and the bytes within each line are shifted (rotated) right, so that the LS bit of one byte shifts into the Carry register, which is then shifted into the next byte as the MS bit, and so on for all 16 bytes of each line.

The final shift right causes the final LS bit to be shifted into a holding register, from where in the next cycle it is shifted into the first byte of the line as the MS bit.

The same is performed for each of the 28 graphics lines involved. The effect is that of a line of ducks slowly swimming across the screen.

On every eighth cycle of shifting lines to the right, the separate beak section is called into action and placed so that one bird appears to have its beak open. Coincident with this, the word QUACK is written to the screen. A short pause follows in which no shifting occurs. Then the extra beak section is removed, and blanks written in place of QUACK.

Various experimental routines were written to see which method could create the fastest swimming effect. To be honest, the author was a bit disappointed that he could not get the ducks moving faster, but he still finds the display amusing!

It was decided, incidentally, not to use the panning technique illustrated earlier. This only shifts the screen by complete bytes. The ducks, though, are shifted by individual pixels, creating a smoother effect.

SCREEN READING

Whilst the full program cannot be included on these pages, it is pertinent to describe some of it in greater detail.

Each screen byte is read, shifted right to bring in the previous Carry from the left as the MS bit and to shift out the current LS bit into the Carry. The byte is then restored back on screen.

This occurs one line at a time, with a final "overflow" byte holding the Carry status of each line concluded, and which is shifted in from the left at the start of the reading procedure for the same line on the next batch round.

The routines involved, with two exceptions, are variants on those already discussed. The first exception is the EEPROM data read routine. There is nothing special about this that is worthy of discussion now. It was described in principle in the author's *PIC Tutorial* of March–May '98, again in the *PICTutor* CD ROM, and then expanded upon as a modification to suit PIC16F87x use, in *EPE* Oct '99 (*Mini PIC Tutorial*).

The other exception that is appropriate here, is the reading from the screen routine, DATAREAD, as shown in Flow Chart Fig.17.

In the full source code the command that instructs the l.c.d. to make a screen read is defined in PEEK, and it is this value which is written as the operative command.

Two sets of status checking are required for screen reads. CHECK6 is the first in which a wait occurs until status bit 6 is *low* – not *high* as in other status checks.

Then follows a CHECK3 status check, as has previously been discussed. However, in order to make the reading routine more efficient, neither check is made by calling the labelled subroutines. It is made *in-situ* within the read routine itself.

On conclusion of the CHECK3 equivalent, CD is taken low, and the byte presented by the l.c.d. to PORTD is read. It is this value which the l.c.d. has read from the addressed screen byte. The byte is temporarily stored in RDBYTE, the routine ended, and a return made to the calling routine. Now RDBYTE can be suitably dealt with as required.

There are no exercises suggested for Demo 8 (or the remainder yet to come). Think up something for yourself!

When you feel you are on the verge of "quacking-up" watching those darned ducks interminably crossing the screen (no, there's no shooting gallery program offered!), press the switch to enter Demo 9.

DEMO 9
Text Character Set

All that Demo 9 does is to display the full in-built text character set in order across the screen (see Fig.4 earlier).

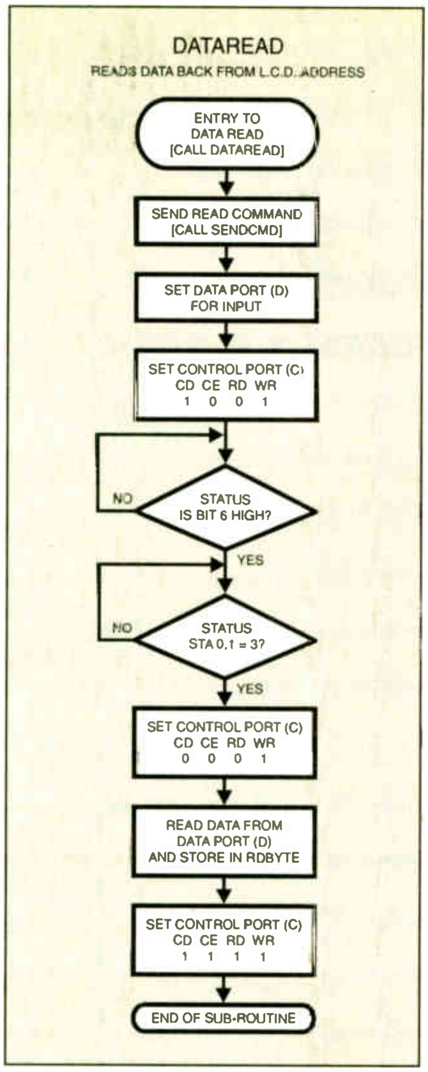


Fig.17. Flow chart for DATAREAD routine.

DEMO 10
Graphics Set Used

Pressing the switch again enters Demo 10. This displays all the user-defined symbols that have been created and stored in the CG RAM. It includes those from the circuit diagram (those on the first line) and downloaded from the EEPROM as the duck detail.

Imagination is needed to interpret which symbol is which part of the demos. The beak, perhaps, is obvious as the penultimate symbol. So too are small sub-captions from the circuit diagram.

DEMO 11
Waveform (1)

Pressing the switch again to enter Demo 11 shows the results of the author's preparatory experiments with drawing waveforms on screen, with an ultimate view to designing the forthcoming *PIC G-Scope*.

In this example, the waveform is drawn horizontally and is seen shifting from top to bottom.

Note how the text is placed on the screen with the waveform shifting beneath it. A delay routine is included in the program and you can change the rate of shift. The number of waveforms seen can also be changed (determined by the rate of incrementing variable COUNT).

The routine shows another instance of writing individual bits to the screen, making use of a look-up table.

Whilst it is a complex program, ensuring that the waveform is not only created, but also erased on the next cycle, there is nothing special about its routines in terms of using the l.c.d.

DEMO 12
Waveform (2)

Demo 12 is similar to Demo 11, except that the waveform is created vertically in the traditional scope style, shifting horizontally (see Photo 6). It too was an experiment prior to designing the *PIC G-Scope*. Do as you like with it.

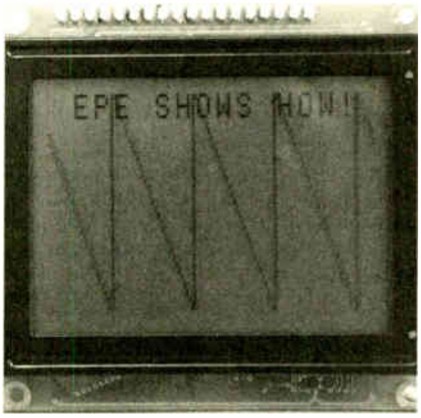


Photo 6. Waveform generated in Demo 12.

REPETITION

Pressing the switch again returns you to Demo 1.

When experimenting with the exercise suggestions, it is probably best if you remout the calls to those demos you do not need to see at that time, placing a semicolon in front of the respective CALL commands.

For each change that you make to the program, it must be reassembled from the source code to a format suitable for downloading (sending) to the PIC. The program is written in TASM, which requires it to be assembled as a .OBJ file for sending to the PIC via a programming tool such as *PIC Toolkit Mk2*.

If you prefer to work with the MPASM dialect, *Toolkit* can translate from TASM to MPASM. In which case any re–assembly would need to be to a .HEX file if you are then using an MPASM-type programmer.

When writing your own future programs you will find that many of the author's routines are ideally suited to use as library routines. You will also spot many ways in which you can deviate from the exactness of the routines while still retaining their essence.

Additionally, you will find that some routines can be "tightened–up" to become more efficient – changing bits, for example, instead of complete bytes. The LINE and GLINE commands, as another example, deserve attention to make them more efficiently programmed.

WINDING UP

Without the guidance of Toshiba's demo program, the author would have found it extremely difficult to get to know the operation of the T6963C l.c.d. controller.

It has to be said, though, that it would have been appreciated had Toshiba's examples gone further. There is much that was left to be discovered by logical deduction and by trial and error. Much of it has been achieved, as the author's demos illustrate. Nonetheless, there are still some questions unanswered, possibly more than are immediately apparent.

Should readers investigate beyond the regions explored through the author's demos, they might care to share their findings with others, submitting them for possible inclusion in *Readout*. You might even design a circuit based on a graphics l.c.d. that you would like to submit for possible inclusion as an *EPE* constructional project.

Give Editor Mike Kenward a call if you have an idea which you think might interest us and other readers.

DOWNLOAD SITES

The Toshiba T6963C data sheet was downloaded from **www.toshiba.com/taec/components/Datasheet/T6963CDS.PDF**. Note that the device is designed to control many different l.c.d. formats and some of the data is not relevant to the PG12864.

The Powertip data sheet is not available for download except by authorised Powertip agents (besides which, the author found it to be unhelpful and in some cases grossly inaccurate). Powertip's site is at **www.powertip.com.tw**.

The RS data sheet (RS 298.4613), which is also available from Electromail, was also found to be unhelpful (and of little relevance to the Powertip PG12864 as a separate entity).

Another graphics l.c.d. site is at **www.varitronix.com**. Some of their l.c.d.s are also controlled by the Toshiba T6963C, but adequate data sheets could not be located.

Kent Displays Inc of the USA have a site at **www.kentdisplays.com** which is interesting for its l.c.d.s that retain their image even after power has been switched off. They do not use the T6963C controller, however.

Microchip's site, from where a PIC16F877 data sheet can be downloaded, is at **www.microchip.com**.

The *EPE* web site, from where the software for this demo can be downloaded (and where lots of other matters of interest exist!), is at **www.epemag.wimborne.co.uk**.

Finally, if you are interested in Partridges (see earlier!) try doing a search on **Perdix**, via **www.google.com**. Google is an excellent search engine anyway and is well worth adding to your list of favourite sites. Thanks to friend Alan Winstanley for having told us about it! □

READOUT

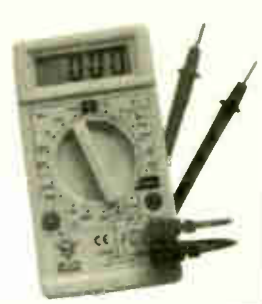
E-mail: editorial@epemag.wimborne.co.uk

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 ★

MIRRORS AND SMOKE

Dear EPE,

I just would like to share my experiences that prove, beyond all doubt, that PICs work with mirrors and smoke.

Having built the wonderful *PIC Icebreaker* board (Mar '00) and got the old l.e.d. flashing, the time had come to move onto more adventurous projects. As I enjoy playing with PCs as well, the COMMS port seemed a good place to go to. After studying all the data books and writing a simple loop to send a set of letters out of the PIC's USART, I dumped the program into the 16F877. Feeling very bold, the baud rate was set to 19.2Kb, HyperTerminal was fired up, only to display a whole bunch of gobbledegook.

Then I remembered that your *8-Channel Data Logger* (Aug/Sep '99) also sends data to the PC. Checking its circuit I found that signal polarities were the same as mine! A lot of scratching on the Internet revealed that "on an RS232 port, a digital High is represented by a Low voltage", which is upside-down.

Then it also strikes me! The data book is printed in the Northern hemisphere and the *Data Logger* was also designed up North, and here I am sitting in the Southern hemisphere! So all I have to do now is turn the Data Book upside-down and everything should work fine. No go! Now the levels are right, but I am sending the Stop Bit first, then the MSB, followed by all the other bits and then the Start Bit!

But hang on, if I turn the book right way up again and put a mirror there . . . Aaaah, now it looks better and I can push up the baud rate to 115Kb and it all hums along merrily with "The Quick Brown Fox . . .". So it seems that we "Southerners" definitely need a mirror to make the USART work properly!

Now comes the proof that they also need smoke to work. I accidentally let some smoke out of a PIC the other day using 20V and it stopped working. Unfortunately, it dispersed before I could catch it all so that I could not put it back to make the PIC work again. Anyone out there got a PIC re-smoker for me?

Seriously though, nowhere in documentation that I have seen does it state that an inversion is required to get from a PIC into RS232. With a simple transistor inverter she works like a dream.

Thanks a lot to *EPE* for giving me the tools to get started with PICs. The articles and circuits were very helpful.

Mike Von Der Heyden, Kimberley, South Africa

Thought provoking comments Mike! The world of serial is full of wonders and little documentation. In my Data Logger *I used interrupts in machine code with an inversion.*

However, we thought that all constructors were familiar with the concept that some electronics components should only be used the "right way round" and so guess that digital Highs and Lows might be equally polarity (and thus hemispherically) conscious! (Only joking, I must reassure the novices amongst you – our projects are globally compatible without reorientation, with the possible exception of my Musical Sundial, *Jun '99!)*

And, er, yes, you've got to keep the smoke in any electronics component. Once it gets out, the component's demise is usually assured. Perhaps there might be a way, though, that I can incorporate a PIC re-smoker with the new PIC Toolkit for Windows *that I'm working on! Any of you ingenious readers have suggestions on this point?*

BLANKET WEED CONTROL

Dear EPE,

I've been looking to buy a commercially available electronic blanket weed controller for my pond, but am astounded at the prices being asked for what appear to be relatively simple devices. I know of several people also keen to get one, but not at the prices quoted. This would seem to be an ideal project for you to feature.

It would appear that these devices use a variable low frequency transmitter (1kHz to 7kHz) with two wires wrapped around the outflow pipes, each wire in opposing directions. The exact detail of how it all works is vague. It seems that calcium carbonate is an important part of cell wall chemistry in the weed. If the mineral is modified (polarised? ionically modified?) the weed can't absorb it so well and growth is retarded. Or so I've read.

The problem is, very mixed feedback on results. Many purchasers are impatient or have other water problems which hinder the function of the unit. Interest is huge – but who will risk spending lots of dosh if it might not work?!

For some idea on the level of interest, try a quick net search for "electronic blanket weed" via **www.google.com**, it yields over 2000 sites!

Brendan Cunningham, via the Net

It seems that the technique might be similar to water pipe descaling, a subject that we have covered constructionally in the Experimental Electronic Pipe Descaler *(Aug '93) and* PIC Pipe Descaler *(Oct '97). Both units used variable frequency, the latter unit using a PIC to control it.*

Following publication in '97, a great deal of Readout *correspondence resulted, and which seemed to (by-and-large) confirm the effectiveness of the device. As to whether it might work as you require, I cannot speculate. Do any readers know?*

VB AND PORTS

Dear EPE,

How do you access a PC's ports when using Visual Basic? What are the equivalents of the QBasic INP and OUT instructions? I've just started playing with VB5 (cheap because a generation behind!) and without the ability to access those ports the whole point of a computer disappears. Maybe the Pro version has them. Any ideas?

Alan S. Raistrick, via the Net

Well, Alan, I'm using VB6 and accessing the parallel printer port using the Freeware INPOUT32.DLL as introduced to us by Robert Penfold in his Interface *series. It is available for free download from our web site (in the* Interface *folder) and is also on EPE Disk 3. It is extremely easy to use.*

It seems crazy, though, that VB does not allow direct access to the ports. Such a facility is an imperative for the type of software that I write for a PC.

Incidentally, although Chat Zone *readers have given me advice on using VB and the comms (serial) ports, I have not yet achieved fully satisfactory interfacing with them. Can any readers point me (and others) to a freeware/shareware serial interface program that is as easy to use as INPOUT32?*

VB FOR FREE!

Dear EPE,

I'm glad to see that you are supporting Visual Basic. I have a lot of experience with it and always look forward to your PIC/VB projects. May I recommend to the readers who may not be able to afford any of the VB suites, that there is a free version available for download at :

http://support.microsoft.com/support/VBasic/VB5CCE/default.asp.

This is the VB5 Control Creation Edition, and will be of use for most Visual Basic projects.

Paul Finnerty, via the Net

Thanks Paul. I'm finding VB6 superb to work with. Wish I'd got to know how to use VB years ago – my Teach-In 2000 *series would have benefitted and allowed even more facilities, and fewer programming commands! Upgrading from VB5 to VB6 is not greatly expensive (neither is buying VB6 directly).*

Coincidentally, another reader has recently sent the following as well:

Readers may wish to try the Control Creation Edition, available via **http://msdn.microsoft.com/vbasic/downloads/cce/**. This is intended to be used for creation of ActiveX controls but it can be used for standard EXE based applications with the limitation that the project cannot be compiled to an EXE file. It is functional in all other respects.

Mark Jiggins, Hersham, Surrey, via the Net

Thanks Mark, it seems like readers are spoilt for VB choice!

PIC PORTS

Dear EPE,

Can PICs store data on their ports?

Peter Mayhew, via the Net

Yes, Peter, as I discussed and showed in my PIC Tutorial *of Mar-May '98. Any data written to a PIC's port will remain there until intentionally changed. It can also be manipulated while remaining on the port, rotated, ANDed, ORed, inverted, etc.*

PROGRAMMING HISTORY

Dear EPE,

I was interested in Peter Kelly's *Letter of the Month* (Dec '00), and especially his frustration with the common programming construct **FOR A = I to K**. Most programmers actually use I, J, K, L, M for loop counters, and not because "I" might stand for Index. Their use (and I don't condone it) is largely historical.

Fortran IV (blimey that seems a long time ago) defined these variable names as *Integers*. So they were used as loop counters. It seems to have stuck, even if some programmers don't know why.

We have come a long way in language development, many of us will remember programming languages (particularly the many forms of BASIC) where the variable name was limited to two characters. Indeed in my early programming days using DEC's BASIC+ under RSTS/E this is what we were limited to. Somehow we managed to turn out really quite sophisticated applications. So there's a bit (ouch) of programming history for the archives. Thanks for a great magazine.

Godric Goodrich (G4NLA), via the Net

Ah, now "I" know – thanks Godric! When I was teaching myself how to program (late 1970's) I too was limited to two characters for variables. It's amazing how one coped. I was also limited to only 32K of memory in which to contain my programs, and to 1MHz at which to run them (Commodore PET). (It was also when I learnt to hate "I" as a variable name!)

What such limitations taught, though, was the ability to condense and refine one's code to the absolute minimum. These days there is so much memory and speed available that code compactness often "goes out the window (Windows?!)" – sadly, this can encourage programmers to become sloppy in their code writing, using far more program lines than are really needed, and which could be achieved with a bit more thought (although with more time spent at it, it has to be admitted).

I also recall using cassette recorders as the storage medium. These took ages to read and write. At times I could power up the PET and have time to make coffee before it had loaded a program! It was not until the early 80's that disk drives became available for the PET (storing about 360K of data per disk).

At the time of writing, Dell Computers have just advised me that they now have PCs with Pentium 4 processors running at 1·5GHz (1500MHz), and having disk drives storing 40 gigabytes, all for around £1600 (about half of what the PET system cost me in total 20-odd years ago)!

WHAT PROGRAMMER?

Dear EPE,

I have just started thinking about programming my own PICs, having previously bought only programmed ones. After reading different advertising extracts, I am now totally confused about which to buy? Which is the best all rounder for the newcomer and which will program the widest range of chips?

Mark Cowley, via the Net

As you seem to have found, Mark, there are many commercial PIC programmers on the market. Indeed Microchip appear to encourage people to design their own programmer and provide rudimentary information about doing so in their data books etc.

We are not familiar with the programmers available from our advertisers and cannot comment on their merits. However, I can make two observations.

First, it seems likely that the programming facilities available from Microchip (e.g. MPLab, MPSim, MPASM) will cover the entire range of their PIC and other products. This would seem to be a route you should investigate as you want "the widest range". However, my own (brief) experience with MPASM was that it seemed slow to access when developing program code.

Another choice open to you is my PIC Toolkit Mk2, *originally published in May-Jun '98, with additional software enhancements since then, the latest (V2.4) having been published with the Dec '00 issue. As a frequent writer of programs for PICs, I placed a very heavy emphasis on the speed and ease of use of* Toolkit.

*I am currently working on Mk3 (*Toolkit for Windows*) which has even more facilities.* Toolkit, *though, is principally designed for use with the PIC16x84 and PIC16F87x EEPROM-based devices (although there are some other PICs that it can also program).*

TEACH-IN 2000 CD

Dear EPE,

I found out about your *Teach-In 2000* electronics series (Nov '99 – Oct '00) in recent magazines. This is just what I've been looking for as a practical introduction to electronics. I have little electronics experience and no equipment.

I was wondering if there is a resources pack available for this series, or do you recommend a particular component supplier? Are the articles available as a stand-alone package, or do I have to purchase the back issues of the magazine?

Andrew Fielden, via the Net

There are two choices now available, Andrew. Back-issues of the magazine in printed paper format can be bought as stated on the Back Issues *pages in any edition of* EPE. *The software that accompanies that format is available on a 3.5-in disk, as stated on the* PCB Service *page or free from our ftp site.*

Alternatively, you can now buy the recently introduced Teach-In 2000 *CD-ROM which includes the full series in PDF format (which can be viewed under Acrobat), and also the software. The CD-ROM version also includes Alan Winstanley's* Basic Soldering Guide *as a bonus article!*

At the time that the series commenced, the following companies advised us that they were supplying some or all of the components: ESR Electronic Components, Magenta Electronics, FML Electronics, N.R. Bardwell – see their adverts for contact details.

MPSIM TUTORIAL

Dear EPE,

Over the past couple of years your *PIC Toolkit, PIC16F87x* and *PIC Tutorial* articles have been most informative and interesting and must have given many of your readers a much better understanding into the operation and uses for these devices.

I believe that, as a sequel to these articles, a brief tutorial on the Microchip simulator MPSIM would be of great help, not only to the more experienced programmer, but particularly to those just starting. This simulator software (freely available), not only allows the program to be executed one step at a time, but also allows the contents of any of the registers to be displayed in either binary, decimal or hexadecimal or all three, so that the effects of each step can be watched.

This feature is particularly useful when studying the Status register flags after an instruction. This software also has the advantage of not requiring any extra hardware.

Walter Scanes, Stroud, via the Net

Personally, I am quite content to develop code in "real-time" by running it directly on a PIC. There are many easy techniques available for being able to examine register values when you want, including temporary attachment of l.e.d.s, alphanumeric l.c.d.s or direct interface to a PC.

However, I recognise that MPSIM offers an important programming development facility, and one which I believe many readers find to be invaluable. We will give thought to your helpful suggestion Walter.

WHY NOT USE C?

Dear EPE,

Regarding the *Readout* discussion on a replacement for QBasic, Visual Basic and Delphi are unique to PCs so I wondered if some of your readers (especially students) might consider learning C. This language is useful for programming microcontrollers and PCs. C is defined by an ANSI standard and hence it is possible to write portable code that will work on many machines with a few or no changes. It is a compiled language and is thus fast (Visual Basic is partially interpreted). A free DOS ANSI C Compiler is available from Borlands website, go to **www.borland.com** and click Community, Login and Downloads.

Even if you don't use a compiler, C is a very useful basis for writing pseudocode for your assembly language programmes. This is because it was designed to be able to do almost anything assembly language could do. And, because its designers didn't like typing, C will save you writer's cramp!

Also, C is useful for employment as it is replacing assembly language for programming microcontrollers. C is a subset of the new language ANSI C++, while Borland C++ Builder is the C++ equivalent of Visual Basic.

I found the best C book to be *The C Programming Language* (second edition) by Brian W. Kernighan and Dennis M. Ritchie (known as K&R2) which describes the C89 ANSI standard. K&R2 is sort of the official book on C and has the advantage of being short.

Alan Bradley, via the Net

Thanks for your comments Alan. Knowing a bit about C, I appreciate your sentiments. However, we do not think that the majority of our readers have an interest in the language and so do not feel that we should "take it on on-board". What do others think?

HOT OFFER

Dear EPE,

I recently built the *Temperature Interface* of Oct '00. As I use Linux and not MS Windows I wrote a small C program to control it. This is a command line program with only a text output at present. If I get time to learn a bit more I will add a pretty GUI front end.

In the meantime, I thought I would let you know there is life outside MS Windows. If anyone wants a copy of my program they can E-mail me at **n.elliott@ntlworld.com**

Norman Elliot, via the Net

Thanks Norman. Now, Linux, there's a name we have not had mentioned in Readout *so far as I recall (will we see it again, eh, readers?).*

ZAPPING PICS

Dear EPE,

Can static electrical damage to a PIC cause partial changes to its stored programme/performance, or would it always cause a total failure?

Alex Cunningham, via the Net

It seems highly likely that program code could be disrupted under some conditions of static electrical exposure. Whilst one might normally expect total fatality from static discharge, it is possible that the discharge intensity might decay as it travels through the structure of the PIC (or other semiconductor device). This would cause damage to some parts but not others.

Always discharge static electricity from yourself by touching a grounded (earthed) conductor before handling such devices, even though most modern devices are far more robust than they used to be some years ago. Also, always ensure that your soldering iron is earthed to prevent electrical charge building up on its body as well.

If the integrity of a PIC is suspect it is always worthwhile trying to reconfigure and reprogram it.

Special Constructional Feature

USING THE LM3914-6 L.E.D. BARGRAPH DRIVERS

RAYMOND HAIGH

Getting to grips with this versatile family of l.e.d. and bargraph driver i.c.s couldn't be easier. We include practical circuits and a multi-purpose p.c.b. set that will turn ten l.e.d.s into a robust, easily read, voltage display – and more!

WHEN something more robust, or more easily read, than a moving coil meter is needed, one of the LM3914-6 family of dot- or bargraph drivers and an l.e.d. display will usually provide a solution.

Manufactured by National Semiconductors, this "family" of chips (three) is extremely versatile. A single resistor and ten l.e.d.s are the only extra components required to produce a basic voltmeter or signal-strength meter. Two or three more resistors enable sensitivity to be adjusted, or the range expanded until a small, but critical, voltage change fills the entire display.

INTERNAL STRUCTURE

The internal arrangement of the LM3914 i.c. is shown in Fig.1.

The Comparators

At the heart of the device is a chain of ten resistors which set the bias on ten comparators so that l.e.d.s are switched on sequentially as the input voltage rises. The LM3914, 5 and 6 are identical apart from the values of the resistors in the voltage divider chain.

In the LM3914 the resistors have equal values to produce the *linear* response required for voltmeter applications. The resistors in the LM3915 are scaled *logarithmically*, and span 0dB to 30dB in ten 3dB steps, making this version suitable for signal-strength and power meters. The resistors in the LM3916 are related in a *semi-log* fashion to simulate a VU meter.

Input Buffer

A high input impedance buffer stage minimises loading on the circuit under measurement. The stage is protected against reverse polarity inputs by a shunt connected diode, and up to 35V can be applied to input pin 5 before any damage occurs.

This can be increased to 100V by placing a 39 kilohms resistor in series with the input. Pin 5 *must* be connected to the 0V rail via a resistor of not more than 100 kilohms ohms or l.e.d. 10 will lock on.

Reference Voltage

Although the ends of the resistor chain can be connected to external reference voltages, it is generally more convenient to use the reference produced within the i.c. Typically 1·25V (it can vary from 1·2V to 1·34V), it is brought out at pins 7 and 8.

The voltage at pin 7 (Reference Out) can be increased to a maximum of 12V by connecting pin 8 (Ref. Adj.) to the 0V rail via

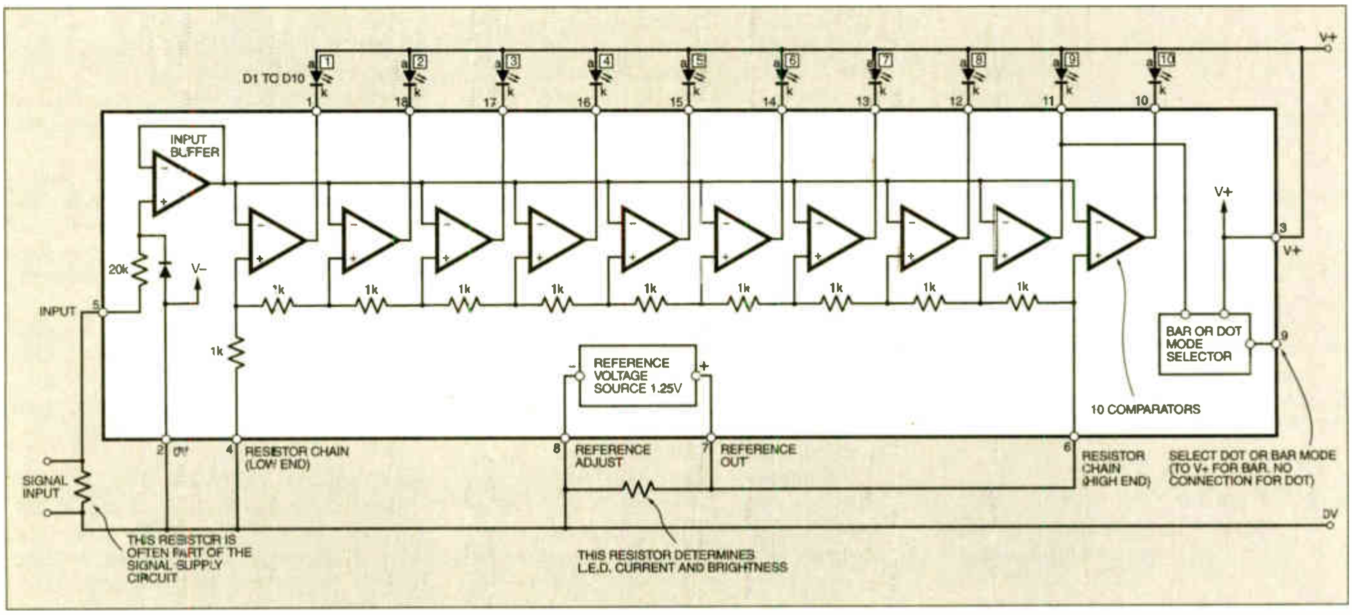


Fig.1. Block schematic diagram for the LM3914 l.e.d. bargraph driver showing the simplest external circuit. The LM3915 and LM3916 are identical except for the values of the internal resistors which determine the switching of the comparators.

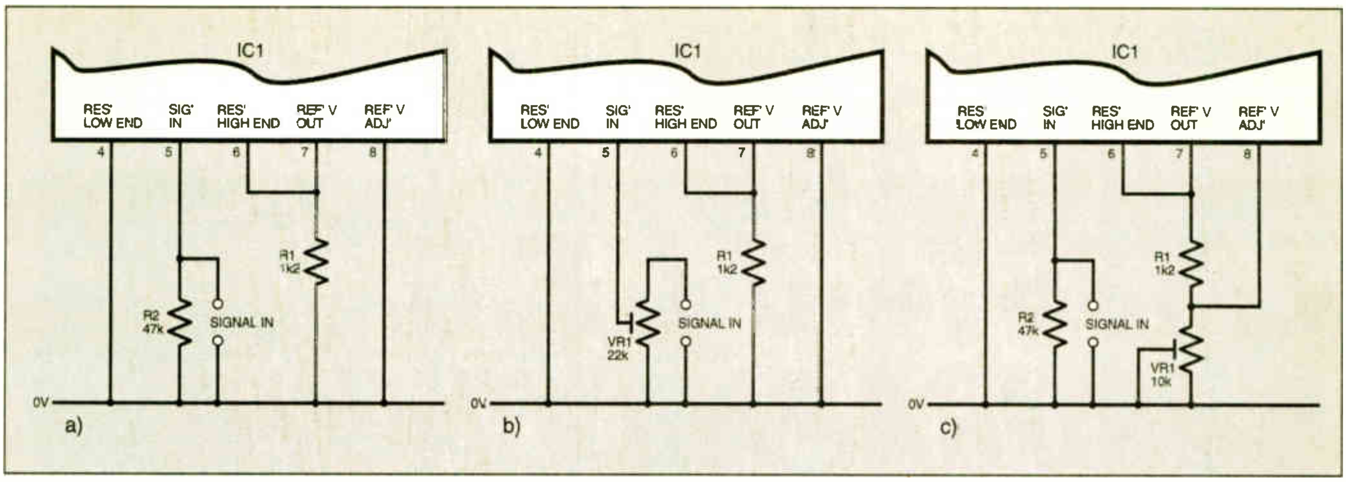


Fig.2a. Basic Sensitivity. Connecting the internal resistor chain directly across the 1·25V reference gives an input sensitivity, to l.e.d. D10 on, of 1·25V. Fig.2b. Reducing Sensitivity (Method One). Connecting the input to pin 5 via a preset potentiometer is the simplest way of reducing sensitivity. Fig.2c. Reducing Sensitivity (Method Two). Grounding pin 8 (Reference Adjust) via potentiometer VR1 increases the voltage across the internal resistor chain. This increases the input voltage required to turn l.e.d. D10 on. With a value of 10k for VR1, the sensitivity can be varied from 1·25V to more than 10V.

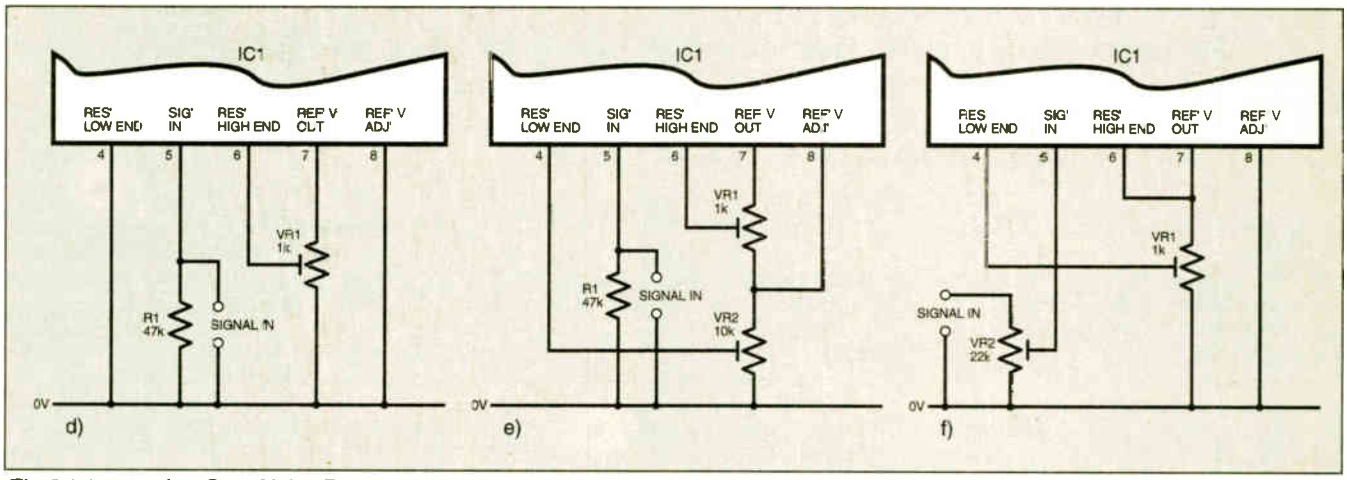


Fig.2d. Increasing Sensitivity. By connecting the "high" end of the internal resistor chain to the slider of potentiometer VR1, the input voltage to turn l.e.d. D10 on can be reduced to 0·1V or less. Fig.2e. Expanded Range (Method One). Connecting the ends of the internal resistor chain to the sliders of potentiometers VR1 and VR2 enables l.e.d. D1 and l.e.d. D10 "on" voltages to be adjusted. In this way a small, but critical, voltage change can be expanded to fill the entire display. Fig.2f. Expanded Range (Method Two). Connecting the "low" end of the internal resistor chain to the slider of VR1 enables range minimum (the input voltage required to turn l.e.d. D1 on) to be set between one tenth of range maximum and close to range maximum. Range maximum (the input voltage required to turn l.e.d. D10 on) is set by potentiometer VR2.

a resistor. The ability to increase the internal reference in this way makes it easier to set sensitivity over wider limits.

Bar or Dot Mode

A Bar or Dot mode selector is brought out to pin 9. Leaving pin 9 unconnected results in a dot display. Connecting pin 9 to pin 3 produces a bargraph.

Supply Voltage and Current

The supply voltage to the chip can be as low as 3V. It must, however, always be at least 1·5V more than the reference voltage applied to the "high" end of the internal resistor chain. The absolute maximum supply voltage is 25V.

Standby current (all l.e.d.s off) varies from around 3mA with a 5V supply to 10mA with a 20V power supply rail.

FIXING L.E.D. CURRENT

Current flow through ***each individual l.e.d.*** is ten times the current drain on the internal reference. L.E.D current can, therefore, be programmed by a resistor connected between pin 7 and pin 8 (see Fig.1).

If the internal resistor chain is connected across the reference source (it usually is) the current through it must be added to the current through the programming resistor. When the LM3914 is used, the total resistance of the chain is nominally 10 kilohms, and l.e.d. current can be calculated from the following formula:

$$\text{L.E.D. current} = 10\left(\frac{1{\cdot}25}{R} + \frac{1{\cdot}25}{10\text{k}}\right)$$

when R is the value of the programming resistor.

With a 1·2k programming resistor, individual l.e.d. current is:

$$10\left(\frac{1{\cdot}25}{1200} + \frac{1{\cdot}25}{10000}\right) = 11{\cdot}6\text{mA}$$

and the current in bargraph mode with all l.e.d.s on would, of course, rise to 116mA.

The reference voltage and value of the resistor chain can vary significantly between samples of the i.c., and some departure from the calculated current can be expected. The resistor chains in the LM3915 and LM3916 exceed 20 kilohms, and their contribution to l.e.d. current can usually be ignored.

SENSITIVITY AND RANGE

The input voltage required to turn l.e.d. 10 (D10) on is equal to the reference voltage applied to the "high" end of the resistor chain. Similarly, the input required to turn l.e.d. one (D1) on is determined by the voltage applied to the "low" end.

There are limitations. The "low" end of the chain cannot be taken below the 0V rail, and the potential on the "high" end cannot exceed 1·5V below the power supply voltage. The internal reference can be set no higher than 12V.

The various ways in which the sensitivity and measurement range can be adjusted are illustrated in Fig.2a to Fig.2f. A brief description of the various methods of adjusting the input sensitivity follows:

Basic Sensitivity (Fig.2a)

Connecting pin 6 to pin 7 applies the internal reference to the "high" end of the resistor chain and the input voltage required to turn l.e.d. 10 (D10) on is, therefore, fixed at 1·25V.

The "low" end of the chain, pin 4, is connected to the negative terminal of the reference, pin 8, via the 0V rail. The input voltage required to turn l.e.d. one (D1) on is, therefore, one-tenth of 1·25V or 125mV, and each increment of 125mV turns another l.e.d. on.

L.E.D. current is programmed by resistor R1 which is, in effect, connected across the internal reference source.

Reducing Sensitivity (Fig.2b):
Method One

Applying the input signal via potentiometer, VR1, enables the voltage for l.e.d. 10 on to be set at any level above the 1·25V internal reference. Inputs much in excess of 50V should be connected via a fixed resistor of suitable value to avoid the power rating of the potentiometer being exceeded.

Reducing Sensitivity (Fig.2c):
Method Two

The reference voltage at pin 7 can be increased by connecting pin 8 to the 0V rail via a resistor. In Fig.2c, the current flowing in resistor R1 is grounded via preset potentiometer VR1 (wired as a variable resistor), thereby increasing the voltage at pin 7 and pin 8. Applying this increased reference voltage to the "high" end of the internal resistor chain increases the voltage required to turn l.e.d. 10 on.

The formula relating resistor values to reference voltage is:

Reference voltage =

$$1{\cdot}25\left(1 + \frac{VR1}{R1}\right) + VR1 \times \frac{80}{10^6}$$

(The above formula allows for an $80\mu A$ current flowing out of pin 8 to ground via VR1.)

By making the resistor between pin 8 and ground (0V) a 10 kilohms preset potentiometer, the reference voltage can be varied from 1·25V (VR1 at zero resistance) to 12V (VR1 near maximum).

Increasing Sensitivity (Fig.2d)

The basic sensitivity of 1·25V can be low for some applications. If preset VR1 is connected across the reference voltage and its slider (moving contact) taken to the "high" end (pin 6) of the internal resistor chain, the input to turn l.e.d. 10 on can be varied from 1·25V down to 100mV.

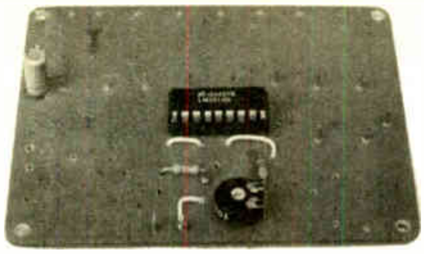
Expanding the Range (Fig.2e):
Method One

Sometimes it is desirable to expand a small, but critical, voltage range to fill the entire display. Battery condition checkers often rely on circuits of this kind.

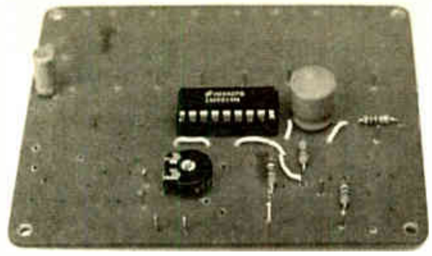
Range maximum is set just above the fully charged or "fresh" voltage, and range minimum is set a little below the voltage at which the working of the equipment would be impaired. Different coloured l.e.d.s representing "good", "acceptable" and "dubious" ensure an easily read display, and a resistor to simulate the normal load should be wired across the cell under test.

In Fig.2e, preset potentiometer VR2 increases the reference voltage at pin 7. The "low" end of the internal resistor chain (pin 4) is connected to its slider enabling range minimum to be shifted over wide limits.

Adjustment of range maximum is facilitated by connecting the "high" end of the chain (pin 6) to the slider of VR1.

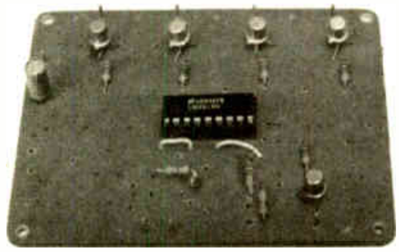


Voltmeter with adjustable input sensitivity (1·25V to 10V) circuit board. See Fig.2c for circuit and Fig.10a for p.c.b. details.



Bargraph display with "warning" flasher. Sensitivity adjustable from 1·25V upwards. See Fig.4 for circuit and Fig.10c for board details.

Signal-Strength Meter (dot-mode) with amplified and rectified input. See Fig.2a for sensivity fixing, Fig.5 for input circuit and Fig.10e for p.c.b. details.



Remote Relay Driver circuit board. See Fig.7 for circuit diagram and Fig.10f for board details. It is possible to control up to 10 relays, using the control board of Fig.9.

The resistance of VR2 should chosen to increase the voltage on pin 7 to a level just above range maximum. If necessary, connect fixed and variable resistors in series to produce the desired value.

Expanding the Range (Fig.2f):
Method Two

A more versatile method of expanding the range is shown in Fig.2f, where the circuit is configured for a basic sensitivity of 1·25V. Connecting the slider of preset VR1 to the "low" end of the resistor chain enables range minimum to be set anywhere between one-tenth of range maximum and close to range maximum.

Range maximum is set at any level above 1·25V by potentiometer VR2.

ACCURACY

Accuracy is partially dependant on the switching precision of the comparators, and their performance improves as the voltage across the internal chain of resistors approaches its maximum value. For this reason, the sensitivity adjusting circuits given in Fig.2c and 2e are to be preferred when accuracy is paramount. The circuits in 2b and 2f will, however, function with power supply voltages down to 3V.

Temperature variations, over a 0°C to 70°C range, have a negligible effect, especially if the voltage across the internal resistor chain is kept high.

When considering the question of accuracy, it should always be remembered that this method of displaying voltage lacks the precision of a digital or large moving-coil meter. The l.e.d.s are switched in a series of one-tenth steps and, to avoid display ambiguity, one l.e.d. fades out whilst the next is switching on.

Unless, therefore, there is considerable expansion, the display inevitably represents an approximation of the voltage being measured.

DISSIPATION

The manufacturers of the devices quote an absolute maximum power dissipation of 1365mW, and this figure has to be de-rated if the ambient temperature is higher than normal. When the display is configured in the bar mode, it is prudent, therefore, to check that total dissipation does not exceed, say, 600mW when *all* l.e.d.s are on.

Voltage drop across the l.e.d.s is determined by colour. It is near enough 2V for red, yellow and green l.e.d.s, and around 3·6V for white and blue.

To calculate dissipation, deduct the l.e.d. voltage drop from the supply voltage to give the voltage across the i.c., and multiply this by the total l.e.d. current plus, say, 10mA for device standing current.

With red l.e.d.s working at 10mA, and with a supply voltage of 12V:

Voltage across i.c. = 12 – 2 = 10V.
Maximum current = 10 + (10 × 10) = 110mA
Maximum dissipation = 10 × 110 = 1100mW, which is too high for safety.

Adopting dot instead of bar mode will bring dissipation within safe limits, and l.e.d. current can be reduced by increasing the value of the resistor between pin 7 and pin 8. However, for many applications using standard l.e.d.s, a current of 10mA is required to produce a bright enough display.

Dissipation can, of course, be reduced by reducing the supply voltage to the i.c., but it must always be 1·5V or more above the voltage applied to the internal resistor chain. When the supply to the i.c. has to be high for this reason, dissipation can be reduced by using a separate power supply of 3V or 5V for the l.e.d.s.

If separate supplies are inconvenient, dissipation can be kept within safe limits by placing a 470 ohm resistor in series with *each* l.e.d.. The manufacturers suggest a single resistor placed in series with the l.e.d.'s common anode lead (the l.e.d. end of this resistor should be bypassed to the 0V rail by a $10\mu F$ electrolytic capacitor). With this method there may be a perceptible reduction in brightness as the bargraph extends.

STABILITY

The circuit may become unstable if the l.e.d. connecting leads are longer than 150mm. A 10μF electrolytic capacitor connected across the power supply rails, and mounted reasonably close to pins 2 and 3, avoids this possibility.

Instability can also arise if the internal resistor chain is connected to independent reference voltages of high impedance. Bypassing pin 6 to ground via a 100nF capacitor will eliminate any problems.

L.E.D.S

The efficiency of l.e.d.s (light emitting diodes) in terms of light output for a given current varies considerably. The so-called "high brightness" l.e.d.s certainly produce a vivid display, but this is usually achieved by adopting current levels of 20mA or more.

If current economy is important, either to contain dissipation or to extend battery life, low current l.e.d.s, which are very luminous at 2mA, represent an ideal solution. The 3mm types seem brighter than their 5mm counterparts, no doubt because the light source is not obscured by so much plastic.

By using low current l.e.d.s in the dot mode with a 3V supply, and increasing the l.e.d. current programming resistor to 10 kilohms (R1 in Fig.2a), a very economical voltage display can be produced.

BARGRAPH DISPLAYS

Rectangular l.e.d.s are more appropriate for bar graphs, and separate diodes can be combined into a ten l.e.d. display. A method of doing this is illustrated in Fig.3.

The provision of a bezel avoids the difficulty of cutting a neat rectangular slot in the instrument case, and l.e.d.s of different colour can be combined. The meeting faces of the l.e.d.s must be coated with dark paint before being glued together, or light spread will be a problem.

Ten segment displays can be purchased for little more than the cost of separate l.e.d.s. This does, however, deny the constructor the opportunity to mix l.e.d.s of different colours.

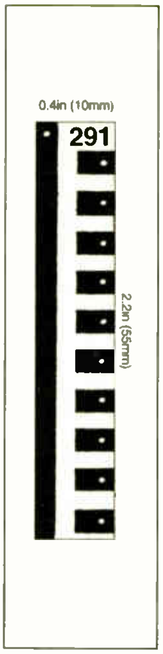


Fig.3b. Full-size L.E.D. Display foil master.

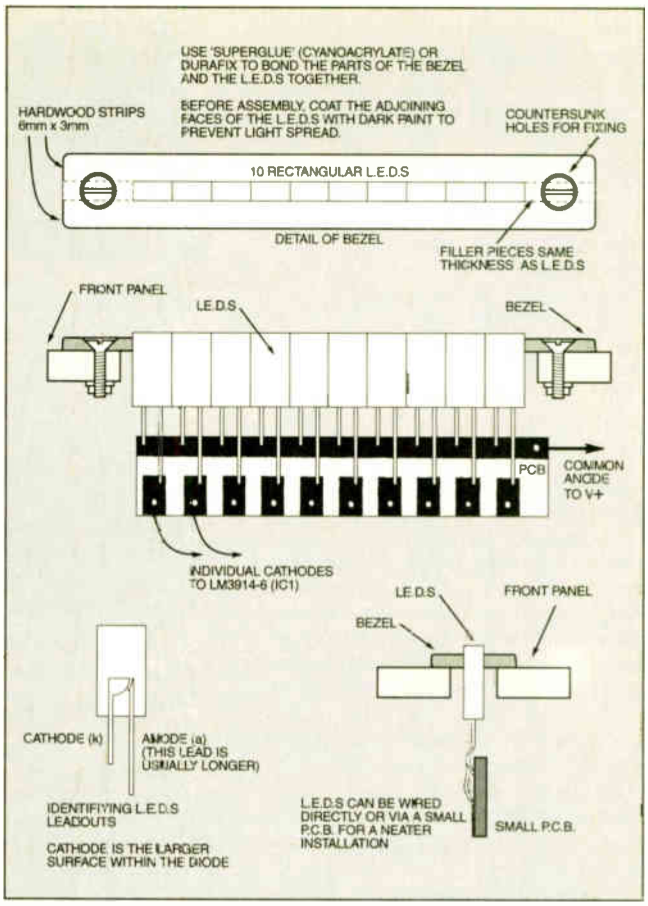


Fig.3a. Assembly details for making the l.e.d. bargraph.

"Homebrewed" bargraph display using separate l.e.d.s.

FLASHING DISPLAYS

How the entire display can be made to flash when a critical voltage level has been reached is shown in Fig.4. Bargraph mode (pin 9 to pin 3) must be adopted with this arrangement.

The display can be made to start flashing from l.e.d. 2 onwards. Simply connect resistor R2 in series with the anode (a), and take the junction of resistor R3 and capacitor C2 to the cathode (k), of the l.e.d. where flashing is to start.

SIGNAL STRENGTH METERS

Bargraph drivers are commonly used for signal strength and power meters. The LM3915, with its logarithmic response, is the natural choice for applications of this kind.

The simplest system involves the direct connection of the signal to pin 5. Remember to include a blocking capacitor if d.c. is present: a 220nF ceramic or polystyrene component is suitable.

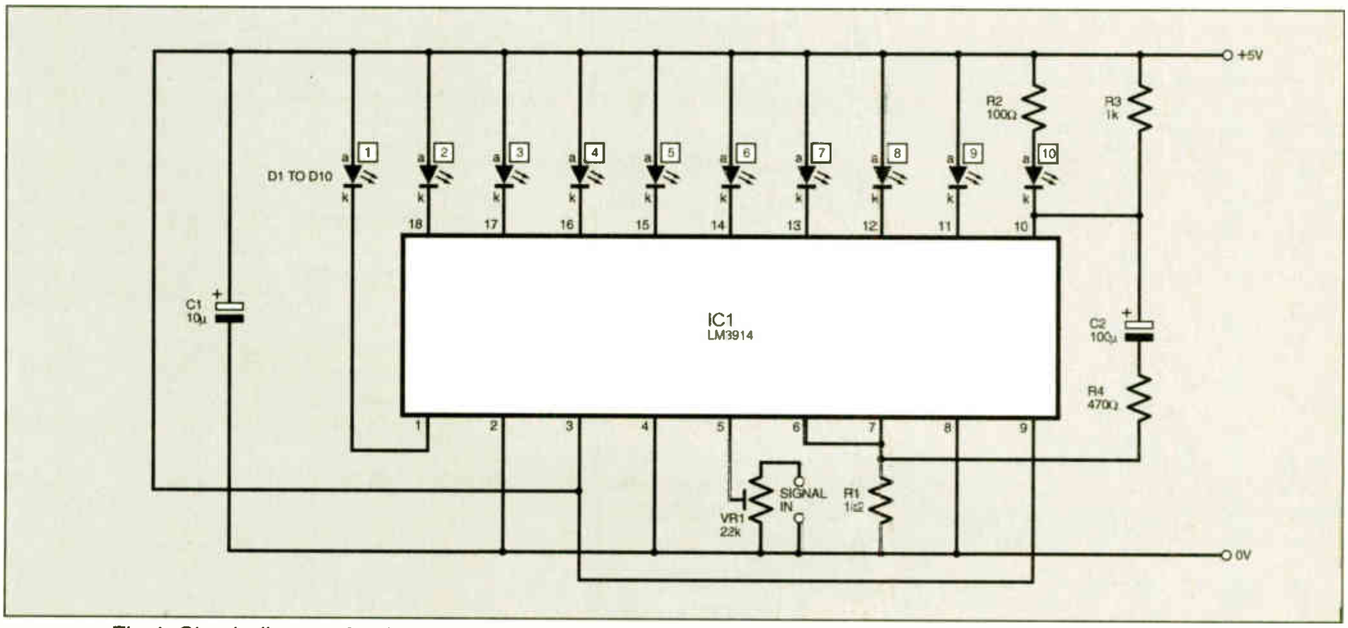


Fig.4. Circuit diagram for the Bargraph display, with alarm flasher. When D10 is activated it begins to flash.

The manufacturers recommend dot mode and a 30mA l.e.d. current when this method is adopted. If, however, the display seems patchy at high signal levels, try the bar mode and a lower l.e.d. current.

When a sensitivity greater than the basic 1·25V is required, use the circuit given in Fig.2d.

RECTIFIERS

Better results can be obtained by rectifying the signal and applying d.c. to the bargraph driver. A suitable circuit is given in Fig.5.

Transistor TR1 amplifies the signal to ensure that diodes D1 and D2 are working in their conductive region. The diodes are arranged in a voltage doubling circuit, and preset potentiometer VR1 should be set just short of signal clipping in TR1 to ensure that they are driven hard. Potentiometer VR2 is then set to deliver the required input to the i.c.

The high input impedance of the field-effect transistor, TR1, minimises loading on the signal circuit, and reservoir capacitor C5 sharpens the l.e.d. display. The amplifier and rectifier circuit can be teamed with the basic i.c. arrangement illustrated in Fig.2a. and a 12V power supply is required.

If the bargraph mode is chosen, take one or other of the measures outlined earlier to ensure that dissipation is not excessive. The stabilising capacitor across the power supply, C1, should be increased to 47μF when this circuit is used.

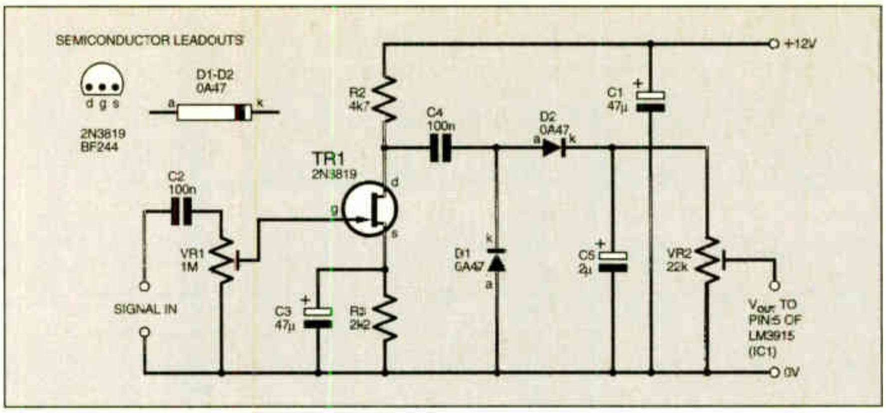
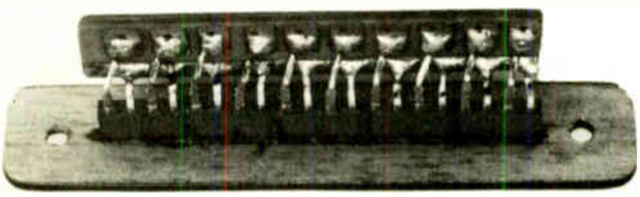


Fig.5. Amplifier and rectifier stages for the Signal Strength Meter. R1 is the l.e.d. brightness resistor, not shown here – see Fig.2a. VR2 acts as the input (pin 5) grounding resistor (R2 in Fig.2a).



POWER METERS

Signal strength meters can be adjusted to indicate power levels. The load is known (the speaker impedance quoted by the manufacturers), and the power delivered is, of course, proportional to the voltage developed across it.

How a dummy load, test meter and the bargraph driver are connected during the setting up process is shown in the circuit of Fig.6. Simply inject a signal into the amplifier, increasing it until the test meter indicates that the maximum power level has been reached, then set preset VR1 to light l.e.d. 10.

The formula relating power to voltage and load impedance is also given in Fig.6: e.g., with a 4 ohm speaker, 10 watts is being supplied when 6·3V is developed across the dummy load, 50 watts when the voltage is 14V, and 100 watts when the voltage is 20V.

The setting up signal should be below 1kHz because the accuracy of most test meters reduces at frequencies much higher than this. Provided the response of the amplifier is wide enough, 50Hz from a low voltage transformer can be applied if a signal generator is not available.

Test meters indicate the r.m.s. values of a.c. voltages, and the power meter will, therefore, display r.m.s. power levels. If peak power is to be displayed, set VR1 so that l.e.d. 10 (D10) lights when the voltage reading on the test meter is 0·707 times the value indicated by the formula in Fig.6.

REMOTE RELAY DRIVER

If switching transistors and relays are substituted for the l.e.d.s, the LM3914 can be used to control up to ten functions via a two-wire link.

The circuit diagram for a Relay Driver set-up using the LM3914 is given in Fig.7. When one of the comparators draws current, the voltage developed across base/emitter resistor, R4 to R8, makes the relevant transistor collector (c) conduct and the asssociated relay coil is energised. Diodes D1 to D5 shunt the high voltage developed across the relay coil when the transistor turns off.

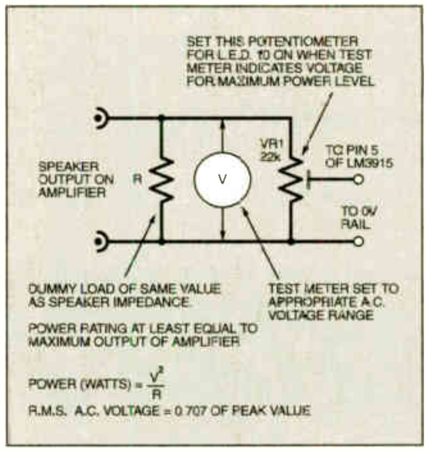


Fig.6. Setting up bargraph drivers to display peak r.m.s. power.

The combination of resistors R1 and R2 fixes the voltage across the resistor chain at 9V. This ensures a good difference between trigger levels and adjustment of the control voltages is less critical. Only

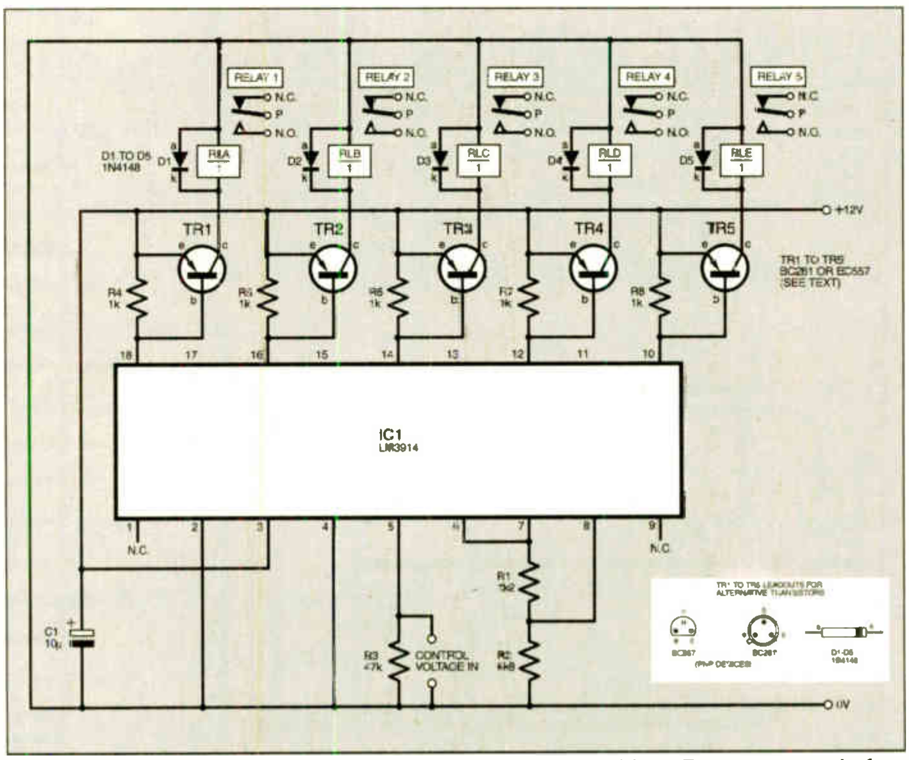


Fig.7. Circuit diagram for using the LM3914 as a relay driver. Remote control of up to ten relays, via two wires, is possible.

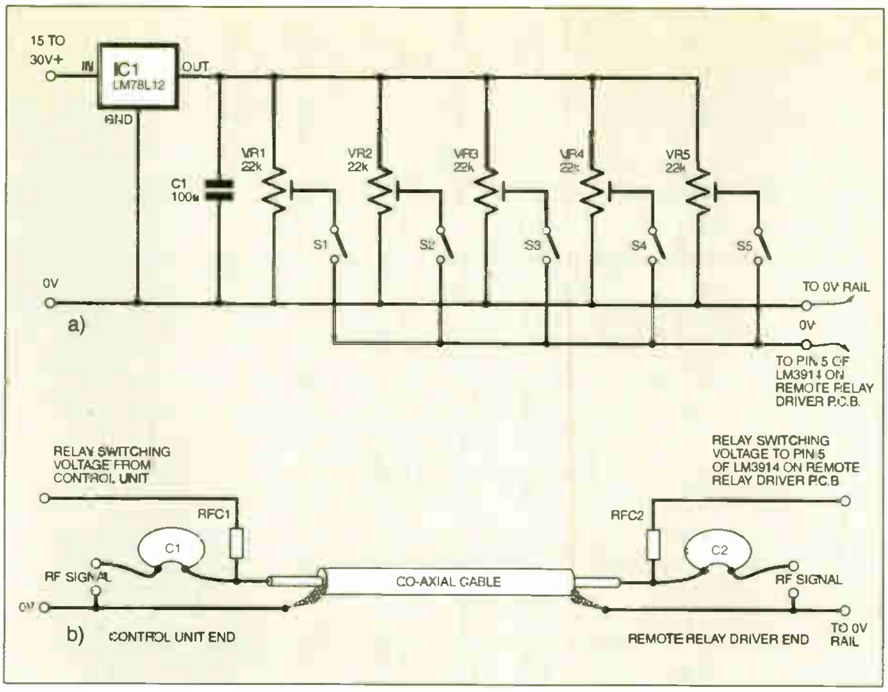
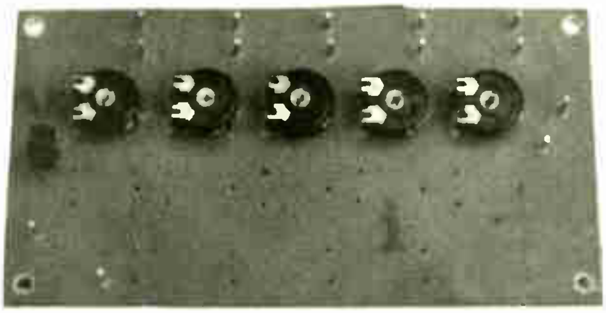


Fig.8. Control Unit and applying switching voltages via an r.f. signal cable. (a) circuit diagram and (b) cable interlink details.



Relay Control board (for 5 relays).

five relay circuits are shown, but all ten outputs from the i.c. can be used if desired.

A relay control board circuit diagram is given in Fig.8a. Control voltages are set by potentiometers VR1 to VR5 and selected by switches S1 to S5. Voltage regulator IC1 ensures that the correct voltage levels are maintained. Broad band r.f. noise developed by the i.c. is bypassed by capacitor C1.

This avoids problems when the control voltages are carried by an r.f. signal cable in the manner illustrated in Fig.8b. Here, r.f. chokes, RFC1 and RFC2, isolate the signals from the control circuitry, and blocking capacitors C1 and C2 prevent the flow of d.c. into the signal circuits.

Select the inductance of the chokes to suit the signal frequencies: e.g., 4·7mH for low and medium frequencies, and 1mH for medium and high frequencies. The capacitors can be 100nF ceramic type.

Alternatively, three-core cable can be used: one wire supplying low voltage power for the LM3914 and, say, drive motors, another the control voltages, and the third a common 0V rail.

The only disadvantage to the system is that only one relay can be activated at any one time. However, with up to ten circuits available, this is no great drawback.

CIRCUIT ASSEMBLY

The full-size foil and component sides of a p.c.b. for the Relay Driver Control Board are shown in Fig.9. Although five circuits are shown, provision is made on both p.c.b.s for all ten to be installed should this be required

The components for the various circuits are best assembled on a small printed circuit board (p.c.b.). The full-size, copper foil side of a multi-purpose board, which can accommodate all of the circuits discussed, is shown in Fig.11. The various topside component layouts are illustrated in Fig.10a to Fig.10f, also see the photographs. The board (one only) is part of a set which is available from the *EPE PCB Service*, codes 289/290/291.

It is a good idea to use a holder for the LM3914/6, and solder pins, inserted at the lead out points, ease the task of off-board wiring. Use a small crocodile clip as a heat-shunt when soldering the f.e.t. (TR1) and germanium diodes (D1, D2) for the "rectified" version of the Signal Strength Meter in Fig.5. Remember to include the wire links, and always check the orientation of electrolytics and semiconductors before applying power to the board. □

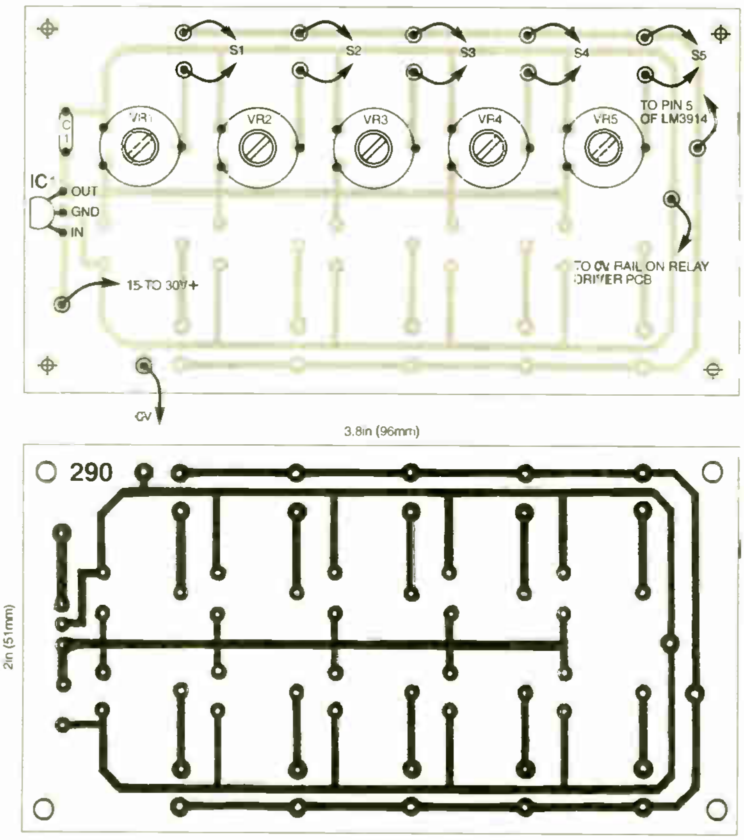
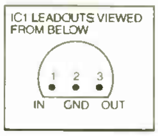


Fig 9. Relay Control p.c.b. component layout and foil master.



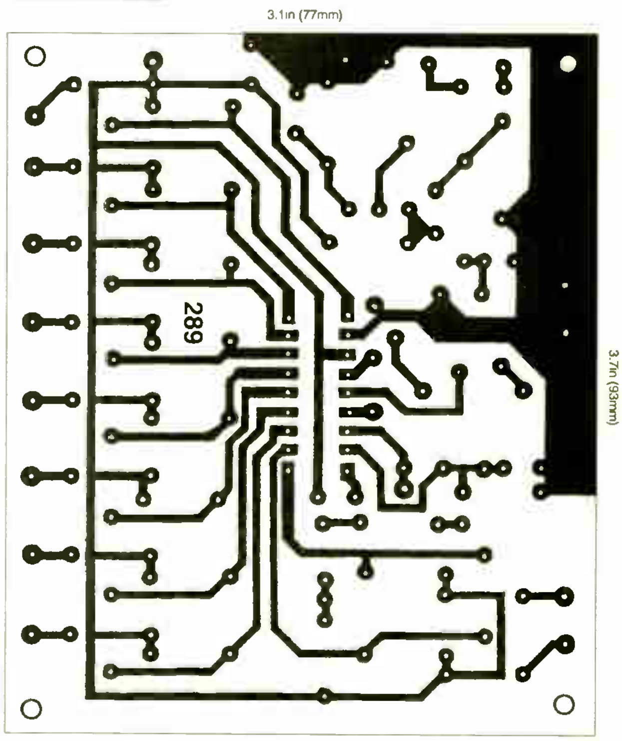


Fig.11. Full-size Multi-purpose L.E.D. Driver foil master.

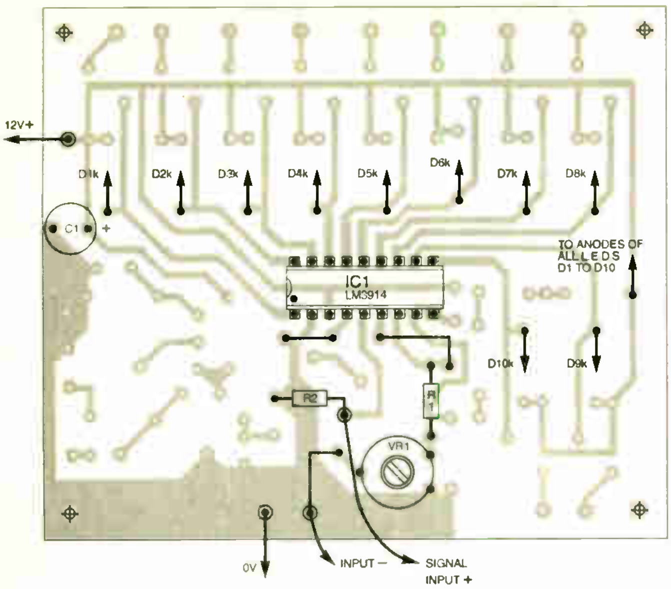


Fig.10a. Component layout for Voltmeter with adjustable input sensitivity (1·25V-10V). See Fig.2c for input circuit. C1 is a 10µF capacitor connected across the supply rails.

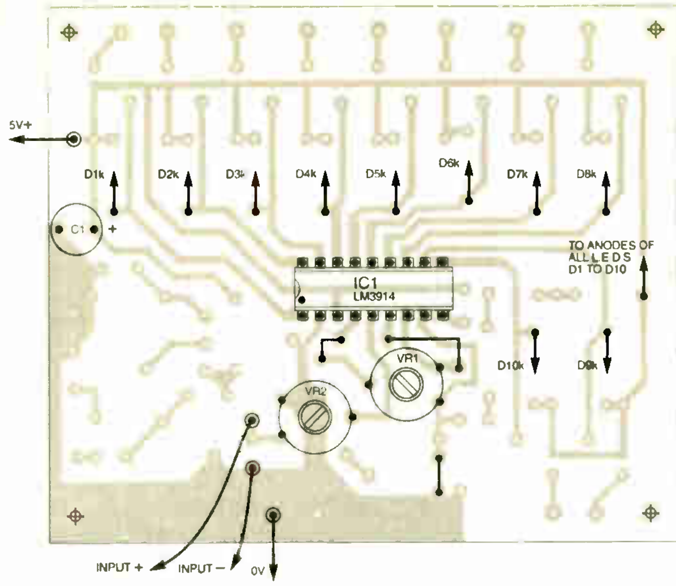


Fig.10b. Component layout for expanded range dot mode voltmeter. See Fig.2f for circuit.

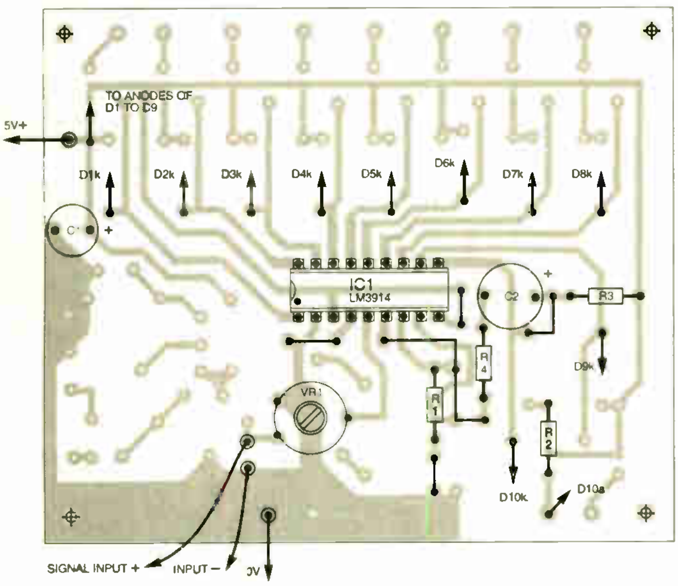


Fig.10c. Component layout for Bargraph display, with alarm flasher. Sensitivity adjustable from 1·25V upwards. See Fig.4 for circuit.

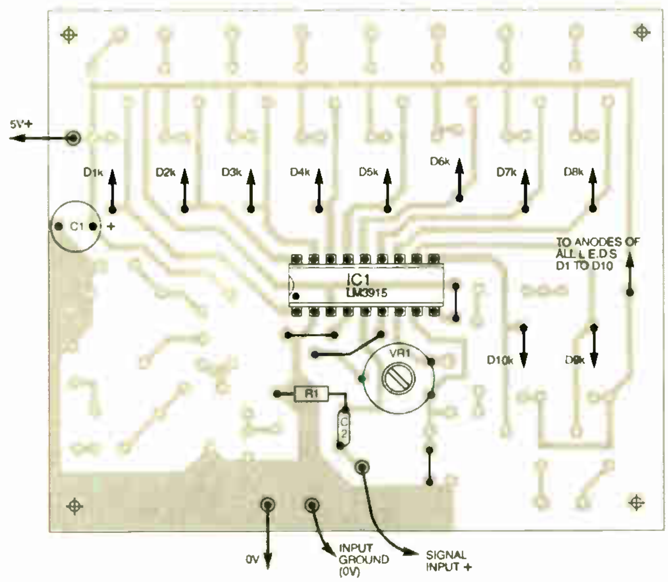


Fig.10d. Component layout for basic bar-mode Signal-Strength Meter. Input sensitivity adjustable over a 100mV to 1·25V range. See Fig.2d for circuit. C2 is a 220nF d.c. blocking capacitor at the input.

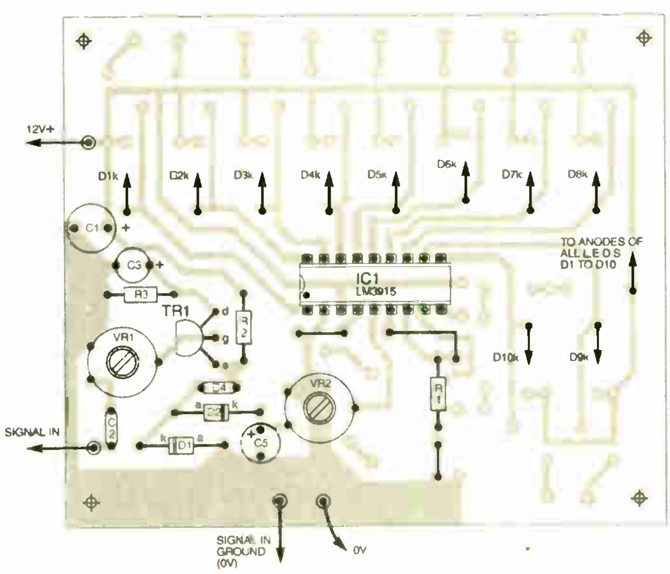


Fig.10e. Component layout for Signal-Strength Meter (dot-mode), with amplified and rectified input. See Fig.5 for input circuit. See Fig.2a for i.c. sensitivity fixing circuit.

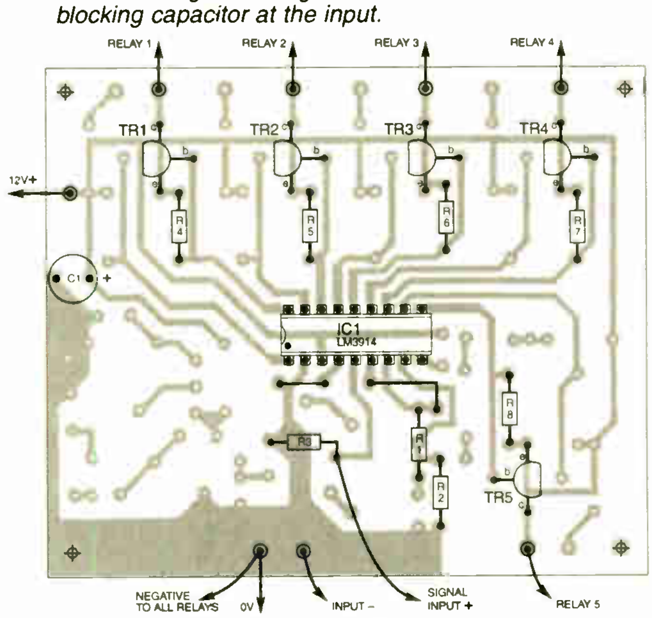


Fig.10f. Component layout for Remote Relay Driver. See Fig.7 for circuit diagram. Up to ten relays can be controlled.

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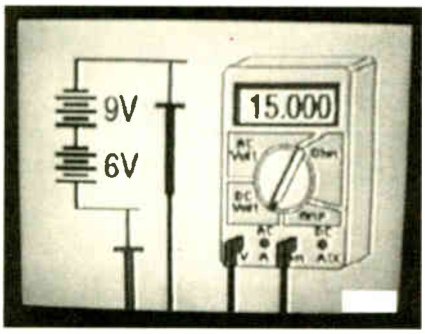

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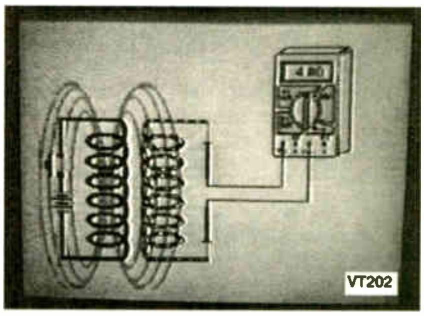

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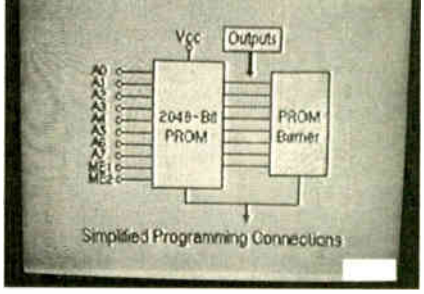

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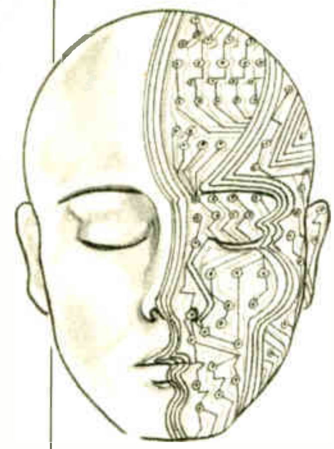

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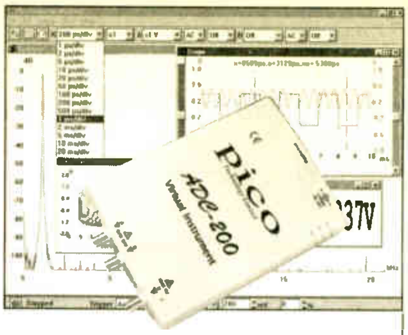

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Garden Lighting Controller – Delayed Action

THE circuit diagram shown in Fig.1 provides on/off pushbutton control for a Garden Lighting System. In addition, there is a 1½ hour timeout facility, as well as remote control inputs at CMOS levels for external control use if desired.

In these days of "PICS with everything" this is an example of good old-fashioned logic. Assuming the lighting is off (IC2a at reset), IC3 is held at reset via OR gate IC1d.

Pressing switch S2 sets IC2a via OR gate IC1c, taking pin 13 high. This energises the relay RLA which switches on the lighting, via the relay contacts. Since pin 12 of IC2a is now low, IC3 is allowed to count.

Once the Q14 output, pin 3 of IC3, goes high, flip-flop IC2a is reset via IC1a and IC1b, removing the drive to transistor TR1. Further presses of switch S2 during the timing interval will reset the timer via IC1c and IC1d, so causing the time interval to start again. Pressing switch S1 at any time resets the flip-flop and the timer via IC1b, IC2, and IC1d.

The 14-stage ripple counter IC3 contains a multivibrator clock, the frequency of which is set by C1, R6, and R7 to around 1.5Hz. After 8,192 cycles Q14 output will go high (*and low again after a further 8,192 cycles, making* 2^{14} *in all – ARW*), which equates to a delay of 1·52 hours.

The contact arrangement of RLA1 is not shown as it depends on your application. The author used a d.p.d.t. relay, with its normally open contacts in parallel, switching the mains side of the lighting transformer. Ensure adequate fusing is provided and that you take care to ***ensure full isolation*** between the low voltage and mains parts of the circuit, if applicable.

Remote Control

The remote control inputs provided were intended for a system based on the Holtek HT12 series of encoders/decoders. Overall the system will then provide multipoint control, with the knowledge that if the lights are left on, they will turn off automatically, preserving the life of the lamps in the outside fittings. Note that the HT12D decoder chips have latching outputs and that if used in conjunction with this circuit, steps must be taken to ensure a momentary pulse is supplied.

As a final tip, I originally had a Hozelock 24V a.c. lighting set. Most systems are now 12V, so in order to use the original transformer I placed a 1N4001 diode in series with 12V 4W lamps. By arranging an equal number of fittings to operate on each half cycle (reversing the orientation of the diode), the transformer sees a balanced load and the 12V lamps will not burn out.

David Geary, Blackheath, London.

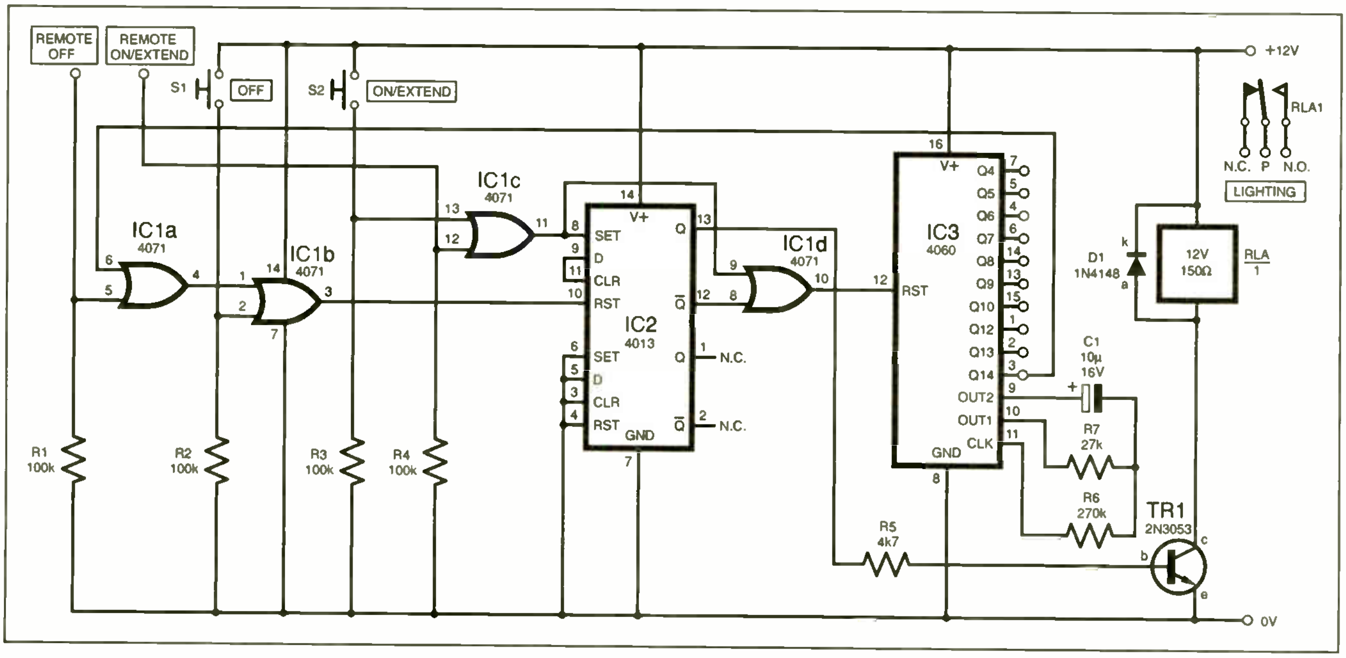

Fig.1. Circuit diagram for a Garden Lighting Controller, with timeout and remote control features.

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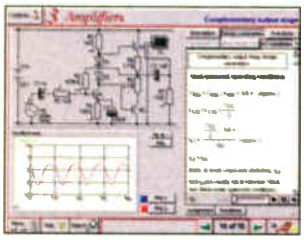
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

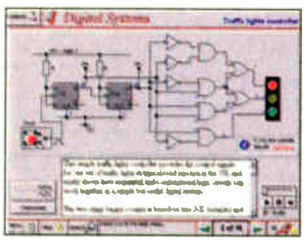
ANALOGUE ELECTRONICS



Complimentary output stage

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

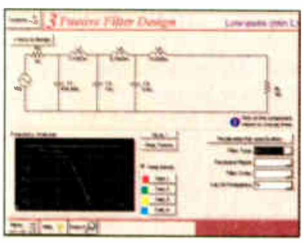
DIGITAL ELECTRONICS



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.

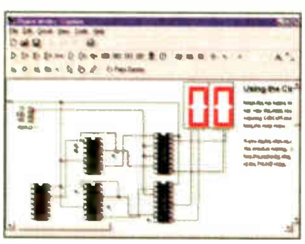
FILTERS



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



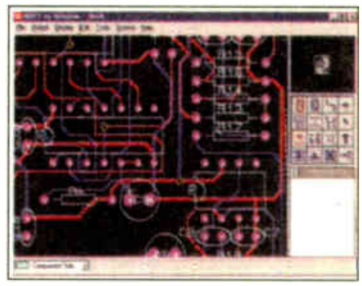
Counter project

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.

- Software for simulating digital logic circuits
- Create your own macros – highly scalable
- Create your own circuits, components, and i.c.s
- Easy-to-use digital interface
- Animation brings circuits to life
- Vast library of logic macros and 74 series i.c.s with data sheets
- Powerful tool for designing and learning

ELECTRONICS CAD PACK

NEW



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

NEW

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.

PRICES

Prices for each of the CD-ROMs above are:

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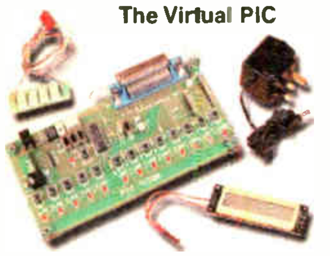
Interested in programming PIC microcontrollers? Learn with PICtutor by John Becker

The Virtual PIC



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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ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details). Also contains a **FREE** 30-day evaluation of Paint Shop Pro 6 – Paint Shop Pro image editing tips and on-line help included!

Price **£19.95** inc. VAT

ELECTRONIC CIRCUITS & COMPONENTS + THE PARTS GALLERY

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits*** . ***Active Circuits***

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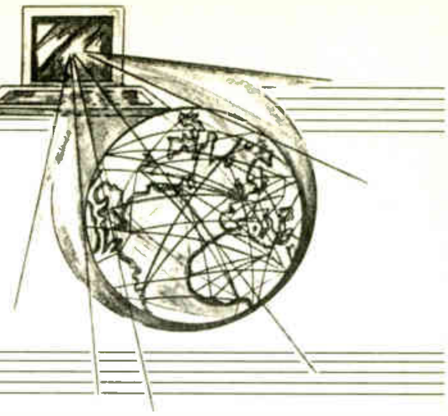


NET WORK

ALAN WINSTANLEY

A Tasty Dish

A RECENT TV programme followed the progress of a number of trainee chefs as they passed through a training school. The tutor demonstrated how to turn out a certain dish which the students had to re-create as accurately as possible in the allotted time. If it didn't quite look as they intended, they were told, it didn't matter too much because the customer would never know what the "proper" dish was supposed to look like anyway!

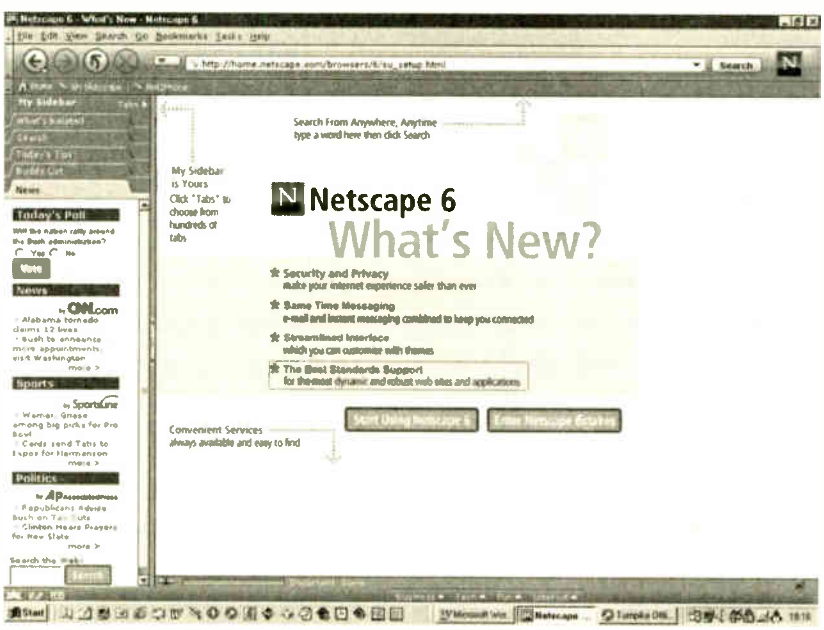
I thought that this principle could apply to web design. Each web browser has its own peculiarities in the way it can handle cascading style sheets, tables, text, Javascript and more besides. A web site optimised for one browser can look a mess in another, or on another system. It is possible to use browser-sniffing scripts to detect the type of browser being used, and direct the user to a suitable version of the site developed for his web browser, but running several versions of a site just adds to the cost of its design and development.

A more realistic approach is to make the site look reasonably "accurate" when viewed in any of the popular browsers on popular platforms, and also try to design for a certain screen resolution, also being mindful of any functionality needed (cookies, secure ordering, Javascript and so on). If a web site designer aims for a middle ground, then there is a good chance that most of the users looking in will see an acceptable version of the "dish", especially as they will probably never know what the dish was supposed to look like anyway.

I sometimes check the web site statistics of my client sites, and I can say that anything from 65 per cent up to 95 per cent of people use Microsoft Internet Explorer 5. The rest use Netscape Navigator, Opera or a small number of specialist text-based browsers.

Netscape 6.0

Netscape's latest incarnation of its web browser is now available for download from their website at **www.netscape.com** Navigator 6 has been completely rebuilt from the ground up, and uses Netscape's "Gecko" engine, so by rights it's a Version One browser, rather than a Version Six upgrade. It has been coded on an open-source basis. *"Netscape 6 is the most standards-compliant browser ever released. It is the first browser to deliver the robust, consistent, cross-platform web standards support that developers have been demanding. It supports more web standards, more deeply, more consistently across platforms than any other browser, and it's being released simultaneously on Windows, Macintosh, and Linux"* says Netscape's web site.



This standards compliance will come as a novelty to many designers, who, like myself, have become accustomed to adapting, scrapping and rewriting code to make it work properly in all the popular browsers. In practice, the striving for compliance is a double-edged sword though.

Not every web user will want to persevere with a download in excess of 20MB from Netscape's site: the first stage downloads a small installer program after which various options can be selected to customise the download. You can also choose the more sensible option of downloading the re-installation files themselves, rather than letting Netscape try to upgrade your system "on the fly".

Installation Snags Overcome

I downloaded the 23MB needed to install Navigator 6. The file transfer went flawlessly but worryingly, it wanted to de-install my existing version of Netscape Navigator first, until I realised it actually referred to my beta version of Netscape 6 and not my older Navigator 4.6. Then the installation routine stalled completely, forcing me to reboot. Nevertheless the installation process was completed properly afterwards, and soon I was pointing Netscape's new browser towards various web sites.

The first thing I noticed was that it was somewhat slow to launch, but before long I was greeted with a stylish window and a multitude of navigation bars. Version 6 has configurable "skins" or themes to adapt the appearance, or you can revert to the classic Navigator style instead. A neat draggable sidebar can be selected to fill with your choice of channels when you go online, and it has a built-in Buddy List to keep track of friends when on-line, and links to enable Net2Phone to be downloaded. Furthermore, it imports Internet Explorer Favorites immediately, a welcome feature. Many other features are available in the configurable sidebar.

More problematic for designers, though, is that some current web pages were broken up when viewed in Navigator 6. Some Javascripted functions failed to function properly and "sliced" images – which are arranged in tables – were sometimes broken up; furthermore the new browser doesn't support certain functions whatsoever.

If the pages have been coded to obey the rules, then in theory there shouldn't be a problem, yet until now designers have had to work with web browsers that have not been entirely compliant: now having made web sites compatible with older browsers, we must agonise over the more strict rules-obedience of Navigator 6 instead.

The challenge now is to code all pages precisely in accordance with published HTML standards, and also make everything backwards-compatible for the older generations of web browsers as well. The hope is that ultimately we can eventually dump our legacy web browsers and move onto something which is stable, predictable and compliant, and in this respect Netscape 6 is a welcome move in the right direction. If only it had happened five years ago.

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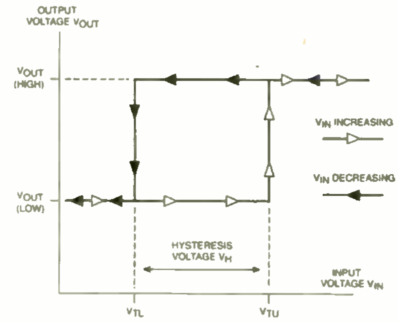
Special Series

THE SCHMITT TRIGGER



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Part 4

In this short series, we investigate the Schmitt trigger's operation; explore the various ways of implementing its special characteristics and also look at how we can use it to create oscillators and pulse width modulators.

Astable, PWM, Triangle Waveforms, Transducer Interface

LAST month, in Part Three of this series, we saw how the Schmitt trigger can be used as the central element in monostable and bistable multivibrator circuits. This month, we'll look at the third member of the multivibrator family, the ***astable*** multivibrator, and we'll see how it can be adapted to form a pulse width modulator. We'll also examine the use of hysteresis in generating triangle waves, and we'll investigate the Schmitt's important role as an interface for sensor devices.

TIME FOR SOME RELAXATION . . .

Both the monostable and bistable multivibrators examined last month have at least one stable state, i.e., they remain in a constant, stable state until "triggered" by an external signal. The *astable* multi-vibrator, on the other hand, has no stable state: the circuit alternates from one state to another, and continues to *oscillate* without need of any external trigger signals.

The astable falls into a class of oscillators known as *relaxation* oscillators, circuits in which the voltages or currents change suddenly at least once during each cycle. The circuit diagram of a simple, dual-rail astable, using the LF351 op.amp as a comparator, is shown in Fig.4.1a. Note how the circuit has both positive feedback (essential to the Schmitt trigger function), and negative feedback applied via resistor R3. We can understand how the astable works by referring to the circuit waveforms in Fig.4.1b.

Assume that IC1's output voltage, V_{OUT}, is at its positive saturation level, V_{SAT+}. The potential V+ at the non-inverting input (pin 3) will sit at a positive level defined by V_{SAT+}, resistor R1 and R2. This is the *upper threshold* voltage, V_{TU}. During the period T1, the voltage V_{C1} on timing capacitor C1 will increase, exponentially, in a positive direction as C1 is charged via timing resistor R3.

. . . AND REGENERATION

Eventually, when V_{C1} just exceeds V_{TU}, the comparator "trips" and V_{OUT} starts to go negative. The positive feedback provided by resistor R2 provides the familiar *regenerative* action which ensures that V_{OUT} rapidly traverses from positive saturation to negative saturation, denoted V_{SAT-}.

During period T2, V_{C1} starts to decrease as capacitor C1's electric field begins to "relax" and the energy stored in it starts to dissipate. However, the process does not stop when the voltage on capacitor C1 reaches zero; instead, V_{C1} becomes increasingly negative as C1 charges toward V_{SAT-}.

During this time, the non-inverting input voltage, V+ , sits at a negative level, V_{TL}, the *lower threshold* voltage. When the *negative* voltage on C1 just exceeds V_{TL}, the comparator trips again and V_{OUT} rapidly returns to its positive saturation level, V_{SAT+} . The process now repeats, and V_{OUT} alternates between its two, *unstable* states at a frequency determined by capacitor C1 and resistor R3.

Essentially, the circuit is simply a dual-rail, inverting Schmitt trigger with thresholds set by resistors R1 and R2 as described in Part Two of this series:

$$V_{TU} = \frac{R1 \times V_{SAT+}}{R1 + R2} \text{ (volts)}, \qquad \text{and:} \qquad V_{TL} = \frac{R1 \times V_{SAT-}}{R1 + R2} \text{ (volts)}$$

However, the circuit effectively provides its own input in the form of the exponentially varying voltage on C1. The "mark" and "space" time periods, T1 and T2, are given by:

$$T1 = \tau \ \ln \left\{ \frac{V_{SAT+} - V_{TL}}{V_{SAT+} - V_{TU}} \right\} \text{ (seconds)},$$

$$\text{and: } T2 = \tau \ \ln \left\{ \frac{V_{SAT-} - V_{TU}}{V_{SAT-} - V_{TL}} \right\} \text{ (seconds)},$$

where the *time constant* τ = (C1 × R3) (seconds), and ln represents the natural logarithm.

ASYMMETRICAL OUTPUT LEVELS

The circuit was built using the component values as shown in Fig.4.1a. With the supply rails set to $+V_S$ = +5V and $-V_S$ = –5V, the output saturation levels were found to be V_{SAT+} = +4·20V and V_{SAT-} = 3·65V. Using the equations given above, the thresholds should be V_{TU} = +0·979V and V_{TL} = –0·850V. The actual values, measured by observing the voltage levels at the non-inverting input (pin 3), were V_{TU} = +0·98V and V_{TL} = –0·86V.

With C1 = 3·3nF and R3 = 100kΩ, τ = 0·33ms. Therefore, using the measured values for V_{SAT+}, V_{SAT-}, V_{TU} and V_{TL}, the equations for periods T1 and T2 yield values of 149µs and 167µs, respectively.

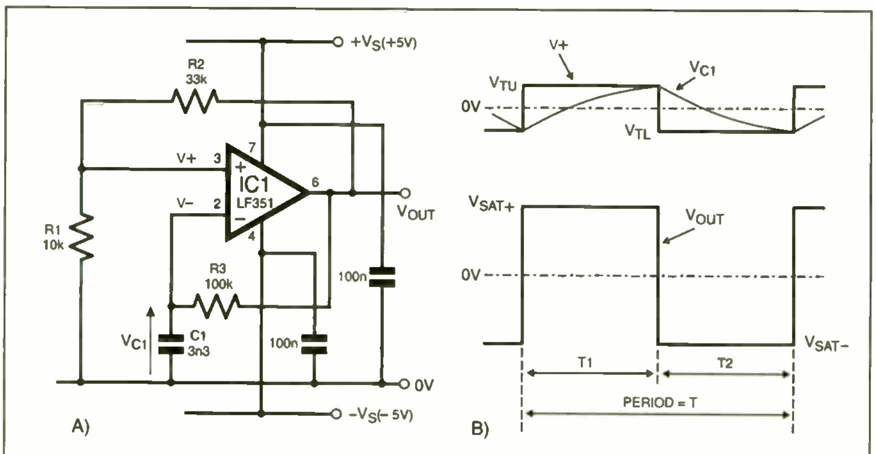


Fig.4.1(a). Astable multivibrator based on a Schmitt trigger and (b) circuit waveforms.

The measured values were T1 = 144µs and T2 = 160µs. The fact that T1 does not equal T2 is due to the asymmetry in the output saturation levels, which also results in the magnitude of the thresholds being unequal. Whether or not this unequal *mark-space ratio* is a problem depends entirely on the application.

DUTY CYCLE

The mark-space ratio of a rectangular waveform is more properly expressed in terms of *duty cycle*, where:

$$\text{Duty Cycle} = \frac{T1}{T1 + T2} \times 100\%$$

In the above case, we see that the output duty cycle is 144µs/(144µs + 160µs) = 47·4%. If we can adapt the circuit such that $V_{SAT+} = -V_{SAT-}$, and hence $V_{TU} = -V_{TL}$, we find that:

$$T1 = T2 = \tau \ \ln \left\{ \frac{V_{SAT+} + V_{TU}}{V_{SAT+} - V_{TU}} \right\} \text{ (seconds)}$$

resulting in a 50% duty cycle.

One way to achieve this is to use an op.amp with "rail-to-rail" output swing, whereby V_{OUT} swings to within a few millivolts of each supply rail. Provided IC1's output is lightly loaded and the magnitudes of the supply rails are equal, this approach ensures that $|V_{SAT+}| = |V_{SAT-}|$. If a rail-to-rail op.amp is not available, consider the use of output "clamping" using back-to-back Zener diodes or a diode bridge arrangement, both of which were described in Part Two.

The astable's oscillation frequency is given by

$$\text{Frequency, } f = 1/T$$

where T is the period of the output cycle. Since T = T1 + T2, it follows that when T1 = T2, the frequency is simply $f = 1/(2 \times T1)$, and can be found from:

$$\text{Frequency, } f = \frac{1}{2\tau \ln \left\{ \frac{V_{SAT+} + V_{TU}}{V_{SAT+} - V_{TU}} \right\}} \text{ (Hz)}$$

Clearly, the frequency can be increased either by reducing τ, or by decreasing the size of the threshold voltages. More about this later.

CHOICE OF OP.AMP

The LF351 is a good choice of op.amp for use in multivibrators like the one in Fig.4.1. Although it does not provide "rail-to-rail" performance, it is a reasonably fast device with good slew rate (typically 13V/µs), and its j.f.e.t. input stage results in very low input bias currents.

With capacitor C1 = 3·3nF and resistor R3 = 100kΩ, the circuit produced a well-shaped rectangular output at just over 3kHz. Reducing R3 to 10kΩ increased the frequency to just under 30kHz, and although the output shape was still good, the measured values of T1 and T2 were somewhat different from the calculated values due to changes in the thresholds resulting from the effects of finite bandwidth.

Reducing C1 to 330pF increased the frequency to 150kHz, although the edges of the output waveform were noticeably sloped. With C1 = 100pF the frequency was just over 300kHz, but the output waveshape was now "trapezoidal". Although the LF351 has a *unity-gain* bandwidth of around 4MHz, its ability to generate "sharp" square waves at frequencies above 100kHz is limited by the effects of finite slew-rate.

LOW FREQUENCIES

Generating low frequency waveforms requires a large time constant. To some degree, this can be achieved by maximising capacitor C1, although for a *bipolar* astable like the one in Fig.4.1, where V_{C1} swings both positive and negative, C1 must be a non-polarised type, which limits the maximum capacitance available. (Although large-value, non-polarised electrolytic capacitors are available, they often have relatively large leakage currents which can affect the circuit's operation quite considerably).

At first sight, selecting a large value for resistor R3 would appear to be the simplest way of maximising τ, especially as resistance values up to 10MΩ are readily available. However, the effects of input bias current, I_B, flowing into (or out of) the inverting input should not be ignored, especially where accurate control of frequency and duty cycle are required.

For example, let's say we built the astable using an op.amp with an input bias current of around 200nA (not uncommon for devices like the LM358 or 741). When R3 is small (<100kΩ), the bias current has negligible effect on the charging and discharging of C1. However, when R3 is in the region of 1MΩ or more, the input bias current becomes relatively large compared to the current flowing through R3, and effectively "unbalances" the charging action. (The capacitor leakage currents mentioned above can have a similar effect). Although this will not stop the astable oscillating, it can have a marked effect on duty cycle and frequency.

Fortunately, the LF351's very low input bias current (typically just 50pA at room temperature) permits the use of large values for resistor R3 with little effect on performance. For instance, with C1 = 1µF (non-polarised) and R3 = 1MΩ, the circuit of Fig.4.1 produced a square wave with period T = 0·954s and pulse width T1 = 0·449s. At 47%, the duty cycle was just short of the 50% needed for a perfectly "symmetrical" square wave, but this was due to the unequal magnitudes of V_{SAT+} and V_{SAT-}, not to the effects of input bias current.

COMMON MODE INPUT RANGE

The LF351 is just one of many op.amps available with low input bias currents. Other devices with low I_B are the Harris/Intersil CA3140 (single; I_B = 10pA typ.); the National Semiconductor LMC662 (dual; I_B = 0·002pA typ.); the Motorola MC33182 (dual; I_B = 30pA typ.); and the Texas Instruments TLC27L2 (dual; I_B = 0·7pA typ.). There are many others to choose from.

Another important input parameter that should not be overlooked when designing any op.amp or comparator circuit is the *common mode input voltage range*. As we saw in Part Two, the common mode input voltage range defines the allowable input voltage that can be tolerated by the device without malfunction.

When operating on ±5V supplies, the LF351's common mode range is typically +5V, –2V. Therefore, resistors R1 and R2 (Fig.4.1) should be selected to ensure that the voltage, V+, at the non-inverting input (pin 3) terminal (and, hence, at the inverting input (pin 2)) cannot go outside this range, otherwise the op.amp might not function properly. With R1 = 10kΩ and R2 = 33kΩ, V+ will not exceed ±1·2V even if V_{OUT} swings as much as ±5V.

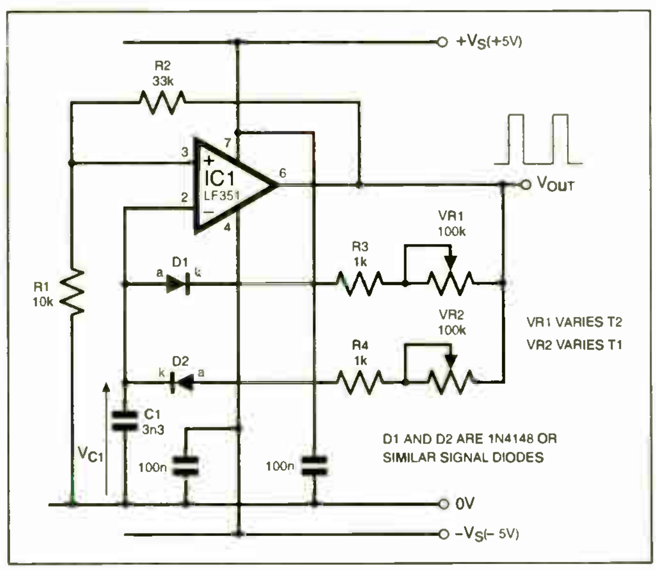


Fig.4.2. Circuit modifications to the astable results in a Variable Width Pulse Generator.

VARIABLE PULSE GENERATOR

The simple astable of Fig.4.1 can easily be adapted to produce a rectangular output with widely variable duty cycle. The required modifications are shown in the circuit diagram Fig.4.2, where R3 has been replaced by the diode/resistor network comprising D1, D2, R3, R4, VR1 and VR2.

The presence of the diodes allows capacitor C1 to be charged and discharged at different rates. For example, when V_{OUT} is high (at V_{SAT+}), C1 charges via D2, R4 and potentiometer VR2. Diode D1 is reverse biased, so only R4 and VR2 control the charging current flowing into C1, and hence determine the width of the time period T1.

When V_{OUT} goes low (to V_{SAT-}), D2 becomes reverse biased and C1 discharges via D1, R3 and VR1. Consequently, R3 and VR1 now dictate the rate of discharge, and hence control the width of T2.

Typical waveforms generated by the Variable Width Pulse Generator circuit are shown in Fig.4.3, obtained with C1 = 3·3nF, R3 plus VR1 = 30kΩ, and R4 plus VR2 = 10kΩ. The exponential waveform, V_{C1}, shows how capacitor C1 charges rapidly and then discharges relatively slowly, resulting in T1 = 18·8µs and T2 = 59·2µs.

Potentiometers VR1 and VR2 provide *independent* control of T1 and T2, and with the values shown allow the duty cycle to be varied from around 1·5% to 98·5%. By switching in different values of C1, say in decade ranges from 1nF to 10µF, the circuit is capable of producing pulse widths ranging from around 1µs to over half a second.

SINGLE RAIL ASTABLE

A single rail version of the astable multivibrator is shown in Fig.4.4. Using an op.amp like the TS902 having rail-to-rail input and output swings simplifies the design procedure. Provided the output is not heavily loaded, V_{OUT} will swing from 0V to $+V_S$, removing any ambiguity about the values of V_{SAT-} and V_{SAT+}. Furthermore, there is no need to worry about the input signals, V+ and V–, straying outside the common mode input voltage range.

Since V_{OUT} swings rail-to-rail, we can assume that V_{SAT-} = 0V and $V_{SAT+} = +V_S$, and making these substitutions in the equations for T1 and T2 quoted previously for the dual-rail astable, we find that:

$$T1 = \tau \ \ln \left\{ \frac{+V_S - V_{TL}}{+V_S - V_{TU}} \right\} \quad \text{(seconds)}$$

$$\text{and: } T2 = \tau \ \ln \left\{ \frac{V_{TU}}{V_{TL}} \right\} \quad \text{(seconds)}$$

where the time constant τ = (C1 × R3) (seconds).

Since the circuit is basically an adaptation of the single rail Schmitt trigger described in Part Two, the threshold voltages, V_{TU} and V_{TL} are given by:

$$\text{Upper Threshold Voltage, } V_{TU} = \frac{(V_{REF} \times R2) + (+V_S \times R_{TH})}{R_{TH} + R2} \quad \text{(volts)}$$

$$\text{and: Lower Threshold Voltage, } V_{TL} = \frac{(V_{REF} \times R2)}{R_{TH} + R2} \quad \text{(volts)}$$

where R_{TH} is the Thévenin equivalent resistance of the R1a-R1b potential divider:

$$R_{TH} = \frac{R1a \times R1b}{R1a + R1b} \quad \text{(ohms)}$$

and V_{REF} is the reference voltage generated by the potential divider R1a-R1b and the positive supply:

$$V_{REF} = \frac{+V_S \times R1b}{R1a + R1b} \quad \text{(volts)}$$

Introducing R_{TH} and V_{REF} allows us to represent the single rail astable with its *equivalent circuit* shown in Fig.4.5a. We will consider the equivalent circuit in more detail, shortly. First, we'll examine the performance of the Single Rail Astable with voltage follower circuit – shown in Fig.4.4.

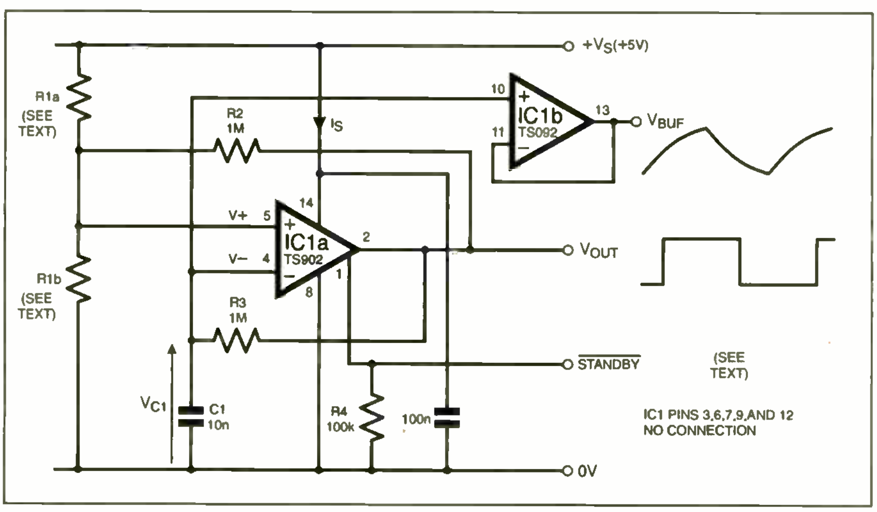


Fig.4.4. Circuit diagram for a Single-Rail Astable with voltage follower.

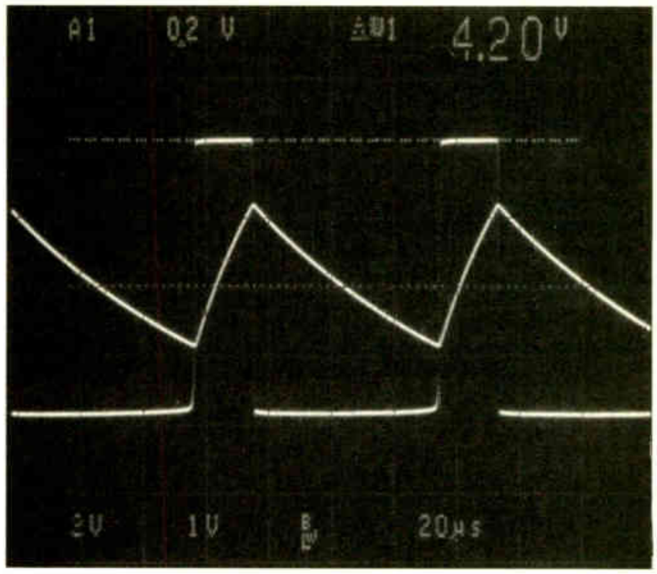


Fig.4.3. Pulse Generator Waveforms. Pulse waveform is V_{OUT} (2V/div.). Exponential waveform is timing capacitor voltage, V_{C1} (1V/div.). Timebase: 20µs/div.

POWER SAVING

Although not exceptionally fast (the slew rate is typically 0·8V/µs), the STMicroelectronics TS902 has very low input bias current (I_B = 1pA typ.) which, as we have seen, is important when using large resistance values. It also features a "standby" function, whereby its current consumption can be reduced to a minimal level to save power. More about this later.

Since the resistance values in Fig.4.4 are large, it is important not to "load" the circuit nodes when probing the waveforms. Even using a 'scope probe with a 10MΩ input impedance would significantly load the op.amp inputs and would affect the astable's operation.

This can be avoided by connecting the second half of the dual TS902 as a voltage follower (IC1b) which "buffers" the sensitive nodes. By connecting the follower to either of IC1a's inputs, the threshold levels and exponential waveform can be observed by connecting the 'scope probe to IC1b's low-impedance output. Note, however, that the signals will be "shifted" by IC1b's input offset voltage, which can be as much as ±10mV.

CIRCUIT PERFORMANCE

Initially, the Single Rail Astable (Fig.4.4) circuit was built with R1a = R1b = 200kΩ. With C1 = 10nF and R3 = 1MΩ, the time constant τ = 10ms. With $+V_S$ = +5V, the *theoretical* values of T1 and T2 calculated using the equations earlier are T1 = 1·82ms and T2 = 1·82ms. The actual, *measured* values were T1 = 1·90ms and T2 = 1·91ms, equivalent to a duty cycle of 49·9%.

Next, with R1a = 150kΩ and R1b = 300kΩ, the measured values were T1 = 2·75ms and T2 = 1·47ms, corresponding to a duty cycle of 65·2%. The calculated values are T1 = 2·63ms and T2 = 1·40ms.

Finally, with R1a = 300kΩ and R1b = 150kΩ, the measured values were T1 = 1·45ms and T2 = 2·75ms, corresponding to a duty cycle of 34·5%. The calculated values are T1 = 1·40ms and T2 = 2·63ms.

Clearly, the measured results are in close agreement with the theoretical values. However, it is the variation in duty cycle which is most interesting. For the case where resistors R1a and R1b have equal values of 200kΩ, the equivalent value of V_{REF} was 2·5V, i.e., 50% of $+V_S$, and the duty cycle was 49·9%.

When R1a = 150kΩ and R1b = 300kΩ, the equivalent value of V_{REF} was 3·333V, i.e., 66·7% of $+V_S$, and the duty cycle was 65·2%. Lastly, when R1a = 300kΩ and R1b = 150kΩ, the equivalent value of V_{REF} was 1·667V, i.e., 33·3% of $+V_S$, and the duty cycle was 34·5%.

Notice that for each case the duty cycle varies linearly with V_{RH} and is almost directly proportional to V_{REF} as a percentage of $+V_S$. Furthermore, the value of R_{TH} is 100kΩ for each case, i.e., only V_{REF} varies from one case to another, all other values remain constant.

Clearly, V_{REF} is controlling the duty cycle, an important finding that we'll investigate shortly.

SUPPLY CURRENT AND FREQUENCY

With resistors R1a and R1b at 200kΩ, R3 at 1MΩ and capacitor C1's value changed to 100nF, Fig.4.4's circuit produced an output frequency of 27·5Hz. Decreasing C1 by two decades to 1nF increased the output frequency to 2275Hz, roughly a hundred-fold increase. The upper limit is about 15kHz: at higher frequencies, the output waveform takes on a "trapezoidal" shape because the TS902 does not have the slew rate necessary to produce rectangular waveforms beyond 20kHz.

It is a fact of life that all circuits, whether linear or digital, tend to consume more power at higher operating frequencies; consequently, the supply current is also greater. The predominant reason for this increase is that capacitances, either external to the active device (like C1), or internal (such as junction capacitances), must be charged and discharged every cycle.

Excessive supply current can be a major problem, especially in battery-powered systems where battery life is inversely proportional to power consumption. Clearly, one way to reduce current drain is to use smaller capacitances wherever possible.

For instance, with C1 shorted out to make V_{OUT} continually high, the average current taken by Fig.4.4's circuit was 222µA. This is the "static" or "quiescent" operating current. Then, with C1 = 1nF and R3 = 1MΩ, such that τ = 1ms, the astable oscillated at 2275Hz and the average supply current was 332µA, an increase of 110µA on the static value.

However, with C1 = 100nF and R3 = 10kΩ (τ = 1ms), the astable again oscillated at 2275Hz but the supply current was 426µA, an increase of 204µA on the static value. Clearly, the *increase* in current has almost doubled compared to the case above, even though the time constant, and hence the operating frequency, remain the same.

A DISABLING FEATURE

Another way to reduce the circuit current drain is to switch off any sections that aren't required. In a notebook computer, for example, the processor can "power down" the internal modem when not in use, thereby conserving battery energy. Even in relatively small circuits, switching off any sub-circuit that is not needed will reduce the average power consumption.

The TS902 dual op.amp provides a "standby" feature which makes it easy to reduce current drain. When the $\overline{\text{STANDBY}}$ terminal (pin 1) is high (connected to $+V_S$), the op.amps function normally. However, if $\overline{\text{STANDBY}}$ is pulled low (to 0V), both op.amps in the package are "disabled" and the outputs go to a high impedance state.

The effect on the astable's current consumption is quite dramatic. For instance, with C1 = 100nF and R3 = 10kΩ, and with $\overline{\text{STANDBY}}$ high (circuit oscillating at 2275Hz), the op.amp supply current, I_S, was 420µA. However, with $\overline{\text{STANDBY}}$ pulled low, the circuit stopped oscillating and I_S fell to just 13µA.

FREQUENCY STABILITY

For precision applications demanding high frequency stability, a crystal-controlled oscillator would be a better choice than the astable of Fig.4.4. Nevertheless, when an op.amp or comparator with rail-to-rail output swing is used, the astable's operating frequency and duty cycle remain remarkably constant with changes in supply voltage.

For example, using one half of the rail-to-rail LMC6762 dual comparator for IC1a, and with C1 = 10nF and R3 = 100kΩ, the circuit's frequency and duty cycle were measured as 2539Hz and 49·94% with $+V_S$ at +5V. With $+V_S$ increased to +15V, the values were 2549Hz and 50·27%. The fact that the frequency and duty cycle changed by less than one per cent is due to a "balancing" effect between the switching thresholds and charging current.

As the supply voltage increases, V_{OUT}, and hence the charging current into C1, also increase, and so C1 charges and discharges more quickly. However, the increase in $+V_S$ causes a corresponding increase in hysteresis voltage (the difference between V_{TU} and V_{TL}), such that C1 has "further" to charge and discharge. The net effect is that T1 and T2 remain fairly constant with changes in $+V_S$.

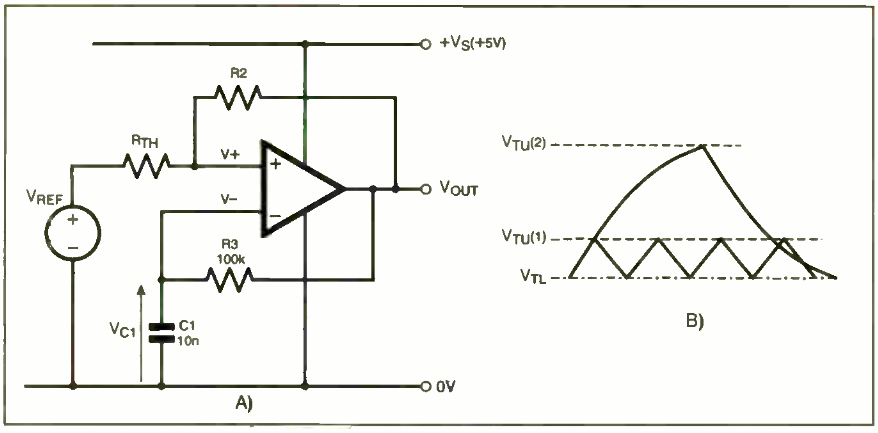


Fig.4.5(a). Equivalent circuit of the single rail astable, and (b) graph showing capacitor charging and discharging between different thresholds.

PULSE WIDTH MODULATION

We saw how changing the relative values of resistors R1a and R1b effectively varies the value of V_{REF} and causes a corresponding change in output duty cycle. If we dispense with R1a and R1b and use a voltage source for V_{REF} as shown in Fig.4.5a, V_{REF} can then be used to *modulate* the width of the output pulses.

Waveforms in Fig.4.5b shows C1's voltage, V_{C1}, when the capacitor charges and discharges between different thresholds. For the case where V_{C1} starts from V_{TL} and charges to the relatively large threshold voltage $V_{TU}(2)$, the waveform takes on the familiar "exponential" shape. However, if the same capacitor is charged and discharged with the same current over a relatively narrow range from V_{TL} to $V_{TU}(1)$, the waveform is much more "linear" and appears almost triangular.

A circuit that can be built to experiment with the pulse width modulator, where R1 and R2 set the thresholds, and C1 and R3 determine the time constant, is illustrated in Fig.4.6. This part of the circuit is basically the same as that in Fig.4.5a, but with the equivalent resistance R_{TH} replaced by a real resistor, R1, and with equivalent voltage V_{REF} replaced by the modulating voltage V_{MOD}.

Since the difference between V_{TU} and V_{TL} is the hysteresis voltage, V_H, we can ensure that capacitor C1 charges over a narrow range by making resistor R2 much larger than R1 such that V_H is very small compared to V_{OUT}. This also results in the average voltage, V+, at the non-inverting input being approximately equal to V_{MOD}, that is: $V+ \approx V_{MOD}$. Similarly, since V_{C1} charges between the thresholds established at the non-inverting input, the average voltage, V−, at the inverting input will also be approximately equal to V_{MOD}, that is: $V- \approx V_{MOD}$.

Therefore, during T1 when V_{OUT} is at V_{SAT+}, and C1 is charging via R3, the charging current is simply: $I_{CHARGE} = (V_{OUT} - V-)/R3$, or $I_{CHARGE} = (V_{SAT+} - V_{MOD})/R3$. Similarly, during T2 when V_{OUT} is at V_{SAT-}, and C1 is discharging via R3, the discharging current is simply: $I_{DISCHARGE} = (V_{SAT-} - V_{MOD})/R3$. If IC1b has a rail-to-rail output swing, such that $V_{SAT+} = +V_S$ and $V_{SAT-} = 0$, then

$$I_{CHARGE} = (+V_S - V_{MOD})/R3 \text{ and } I_{DISCHARGE} = (-V_{MOD})/R3.$$

Now, the rate of change of voltage on a capacitor is given by: $\Delta V_C/\Delta t = I/C$, where ΔV_C is the change in voltage, Δt is the time period, I is the current and C is the capacitance. During T1, the voltage on C1 rises from V_{TL} to V_{TU}, and so $\Delta V_C = V_{TU} - V_{TL} = V_H$. Therefore, $V_H/T1 = I_{CHARGE}/C1$. Rearranging and substituting for I_{CHARGE} we find that:

$$T1 = \frac{V_H \times C1 \times R3}{+V_S - V_{MOD}} \quad \text{(seconds).}$$

Similarly, during T2, the voltage on C1 falls from V_{TU} to V_{TL}, and so $\Delta V_C = V_{TL} - V_{TU} = -V_H$. Therefore, $-V_H/T2 = I_{DISCHARGE}/C1$. Rearranging and substituting for $I_{DISCHARGE}$ we find that:

$$T2 = \frac{V_H \times C1 \times R3}{V_{MOD}} \quad \text{(seconds).}$$

Now, we saw earlier that

$$\text{Duty Cycle} = \frac{T1}{T1 + T2} \times 100\%,$$

and by substituting for T1 and T2, we find that:

$$\text{Duty Cycle} = \frac{V_{MOD}}{+V_S} \times 100\%.$$

Clearly, the duty cycle is directly proportional to the modulating voltage, V_{MOD}. The circuit diagram of Fig.4.6 works well with most dual, rail-to-rail op.amps having low input bias current; the STMicroelectronics TS912 and National Semiconductor LMC6482 are good examples. In this circuit, a voltage follower, IC1a, buffers the voltage on VR1's wiper. The buffer is essential to ensure that resistor R1 is driven from a low impedance voltage source. (If a good quality, external d.c. voltage source is available, IC1a can be omitted). IC1b could, of course, be a rail-to-rail comparator, but this would require a separate op.amp to form the voltage follower.

Careful layout and proper decoupling are good practice when "breadboarding" any of the circuits in this series. However, with resistor R1 = 10kΩ and R2 = 1MΩ, the hysteresis voltage in Fig.4.6 is only 50mV, and so the slightest noise or interference can introduce significant "jitter" to the output waveform. To minimise these problems, make sure a good quality, "clean" d.c. power supply is used to generate $+V_S$. Resistor R4 combined with capacitor C2 form a low-pass filter which removes any mains pickup on potentiometer VR1 wiper, and capacitor C3 (which should be as close as possible to IC1) provides decoupling for the op.amps. A large-value electrolytic capacitor, say 100µF, in parallel with C3 can also help.

LINEAR RELATIONSHIP

Pulse width modulators can be grouped into two categories: those whose frequency remains constant as duty cycle is varied, and those – like the circuit in Fig.4.6 – where both the duty cycle *and* output frequency vary with V_{MOD}.

The graphical results obtained using the TS912 dual op.amp for IC1 are shown in Fig.4.7. Notice how the output frequency varies considerably, peaking when $V_{MOD} = +V_S/2$, when T1 and T2 are both at a minimum.

It is possible to use op.amps whose input and output voltage swing extends from 0V to some voltage less than $+V_S$. For example, tests using the dual LM358 op.amp revealed an output swing from 0V to 3·7V. Therefore, V_{MOD} would be limited to a maximum of 3·7V, although in practice the limit would be 3·5V since this is the common mode input limit for a supply voltage of +5V. There is still a linear relationship between duty cycle and V_{MOD}, although duty cycle is now proportional to V_{MOD} as a fraction of V_{SAT+} (the positive output saturation voltage), not $+V_S$.

Pulse Width Modulation (PWM) is a versatile and widely used function in electronic systems, and finds uses in areas such as motor control, switched mode power supplies and data transmission.

TRIANGULAR WAVES

Throughout this series we've seen how a *triangular* waveform can be useful when testing the thresholds of a Schmitt trigger, so it's appropriate to describe how a Schmitt trigger can be used as part of a triangle wave generator.

We saw in Fig.4.5b how the exponential voltage waveshape on a capacitor can be made to appear triangular by limiting the range over which the capacitor charges and discharges. This could be achieved using the circuit in Fig.4.4 by making resistor R2 much larger than the parallel combination of resistors R1a and R1b, such that the hysteresis is very small compared to $+V_S$. Then, by connecting IC1b as an amplifier rather than as a follower, the small amplitude "pseudo-triangle" on C1 could be increased to a useful magnitude.

The disadvantage of this approach is that the large gain required (in the region of 50 to 100) would lead to problems with noise and offsets, and in any event the output waveshape would never be truly triangular.

FUNCTION GENERATOR

A more effective approach is shown in Fig.4.8, where a dual op.amp is used to form a non-inverting Schmitt trigger and an *integrator*. These two circuit elements are connected in a closed feedback loop known as a *function generator* where the Schmitt trigger generates a square wave output, $V_{OUT(SQ)}$, which forms the input to the integrator, and the integrator generates a triangular output, $V_{OUT(TRI)}$, which is fed back to the input of the Schmitt.

Assume that the output of IC1a is in positive saturation, that is: $V_{OUT(SQ)} = V_{SAT+}$. This voltage forces a positive current to flow into resistor R3, and since no current flows into IC1b's inverting input (we can ignore the negligible input bias current), all of this current must flow into capacitor C1.

Op.amp IC1b has negative feedback applied via C1; this means that its output will go to whatever voltage is necessary to maintain its inverting input, V–, at the same potential as its non-inverting input, V+. Since V+ is at 0V, this means V– is forced to equal 0V, also. Therefore, a *constant* current equal to V_{SAT+}/R3 flows into R3 and then into C1.

Now, we saw earlier that when a capacitor is charged by a constant current, its voltage varies *linearly*. Consequently, as the voltage on C1 increases linearly, IC1b's output, $V_{OUT(TRI)}$, must ramp linearly in a *negative* direction to maintain V+ equal to V–.

Eventually, when $V_{OUT(TRI)}$ crosses the Schmitt's lower threshold voltage, IC1a's output goes from positive to negative saturation, that is $V_{OUT(SQ)} = V_{SAT-}$. This results in a constant, *negative* current equal to V_{SAT-}/R3 flowing into R3 and C1. Consequently, IC1b's output must now ramp linearly in a *positive* direction to maintain V– equal to V+.

When $V_{OUT(TRI)}$ crosses the Schmitt's upper threshold, IC1a's output, $V_{OUT(SQ)}$, goes back into positive saturation, and the process repeats. The resulting waveform at IC1b's output is a triangle wave which ramps between the Schmitt's threshold levels, i.e., the amplitude of $V_{OUT(TRI)}$ equals the hysteresis voltage, V_H.

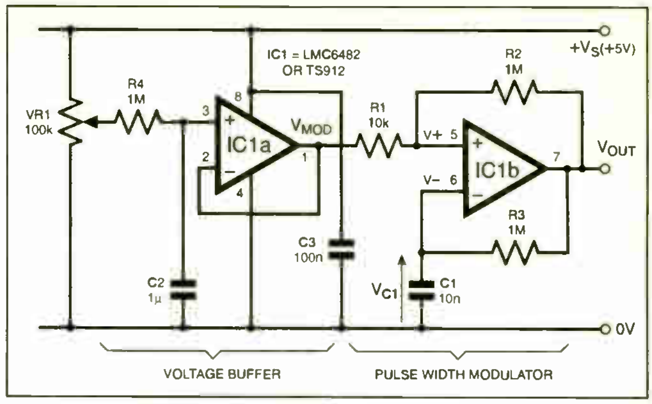


Fig.4.6. Circuit diagram for an experimental Pulse Width Modulator.

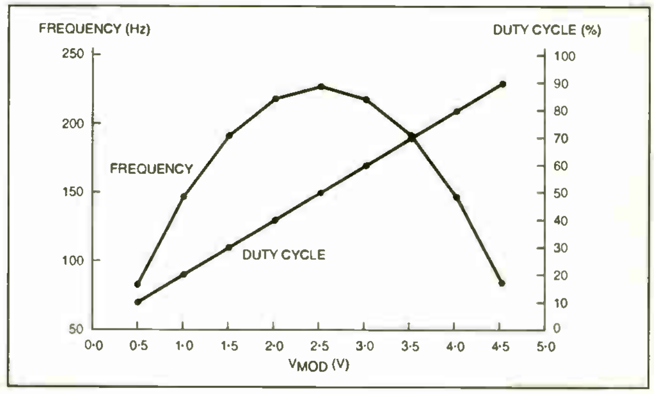


Fig.4.7. Graph showing the output frequency and duty cycle versus modulation voltage for the Pulse Width Modulator circuit using the TS912 op.amp.

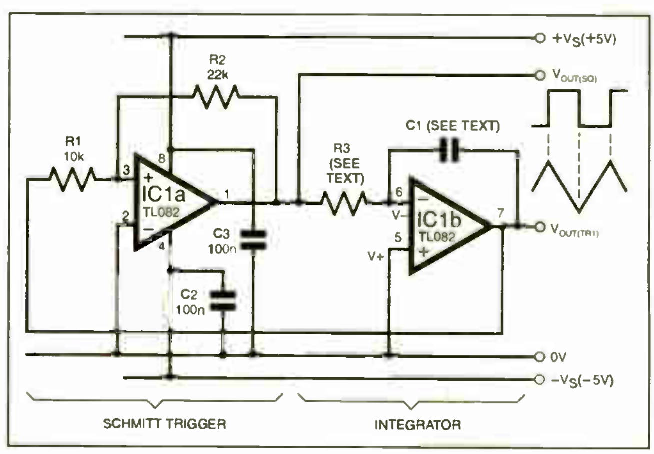


Fig.4.8. Circuit diagram combining a Schmitt trigger and integrator to form a Function Generator.

AMPLITUDE AND FREQUENCY

Since the hysteresis V_H is set by resistors R1 and R2, the magnitude of $V_{OUT(TR1)}$ can be controlled by varying the ratio of these resistors. The time constant τ equals (C1 × R3) which, together with V_H, determines the pulse widths and frequency of operation:

$$T1 = \tau \times \left\{\frac{V_H}{V_{SAT+}}\right\} \text{ (s)};\quad T2 = \tau \times \left\{\frac{V_H}{-V_{SAT-}}\right\} \text{ (s)};$$

$$\text{and Frequency } f = \frac{(V_{SAT+}) \times (-V_{SAT-})}{V_H \times (V_{SAT+} - V_{SAT-}) \times \tau} \text{ (Hz)}$$

If V_H, V_{SAT+} and V_{SAT-} are held constant, the frequency can be continually adjusted by making R3 a variable resistor, and can be varied in decade steps by switching in different values of C1.

With R3 = 20kΩ and C1 = 1nF, the waveforms produced using a TL082 dual op.amp are shown in Fig.4.9. The TL082 has very low input bias current and is specified for operation with supplies up to ±15V. Although reasonably fast, it is not a rail-to-rail device; this can be seen in Fig.4.9, where $V_{OUT(SQ)}$ swings between –3·6V and +4·2V, resulting in a slight asymmetry in the triangle wave timing. Notice how linear the triangle wave is: compare it with the "exponential" waveform shown in Fig.4.3.

When operating on ±5V supply rails, the TL082 produces a well-shaped triangle wave at frequencies up to 60kHz. At higher frequencies, the triangle peaks start to look "rounded" and the square wave edges become "sloped" due to slew rate limitations.

ZERO-CROSSING DETECTOR

In the circuits we have examined so far, the Schmitt trigger has been used in a "self-contained" fashion to generate an output waveform. However, some of the most useful applications for the Schmitt exploit its ability to convert an analogue signal (often slowly changing or poorly shaped) into a digital signal with well-defined amplitude and rapid transition times.

In this capacity, the Schmitt forms an ideal *interface* between sensors and digital systems, two examples of which will be described shortly. First, though, we shall see how the Schmitt is used as a *zero-crossing detector*.

In certain applications, particularly in commercial and industrial power systems, it is necessary to detect when the sinusoidal mains voltage waveform crosses through zero. This "zero-crossing" point can be used to trigger power devices such as thyristors, where it is useful in minimising the electromagnetic interference generated when the devices switch on and off.

There are many ways of detecting the mains zero-crossing point; the circuit in Fig.4.10a is just one incarnation of a zero-crossing detector which uses a transformer, T1, to provide a mains reference signal. In practice, the circuit would probably be arranged differently to allow transformer T1 to provide power to a load. However, as it stands, the circuit can easily be breadboarded for experimental purposes, and provides a good example of *temporal* hysteresis which was introduced in Part Two.

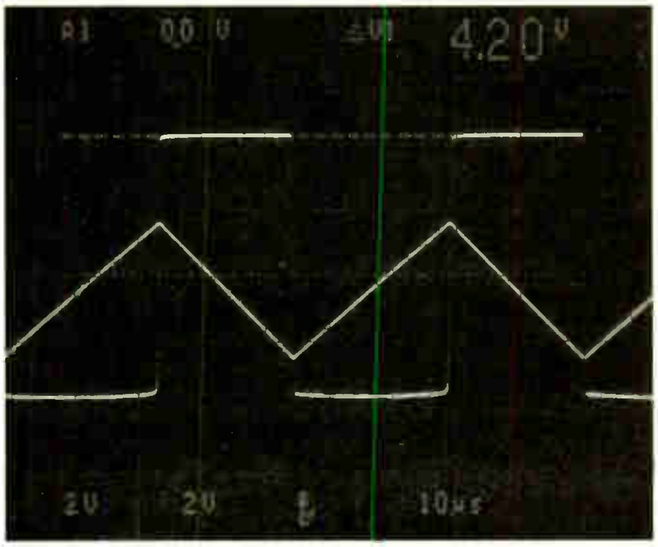


Fig.4.9. Function Generator Waveforms. Pulse waveform is $V_{OUT(SQ)}$ (2V/div.). Triangular waveform is $V_{OUT(TR1)}$ (2V/div.). Timebase: 10µs/div.

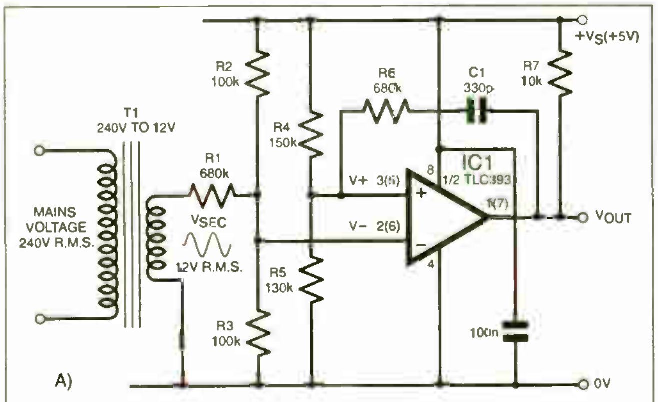
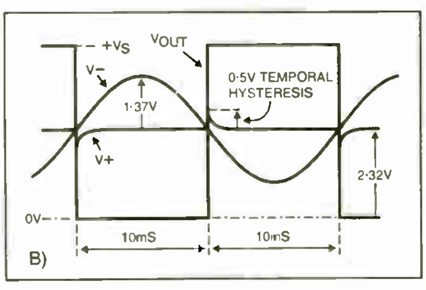


Fig.4.10a. Circuit diagram for a Zero-Crossing Detector using a transformer and an inverting Schmitt trigger.

Fig.4.10b (right). circuit waveforms for the Zero-Crossing Detector.



TRANSFORMER SECONDARY VOLTAGE

Transformer T1 in Fig.4.10a has a root mean square (r.m.s.) secondary voltage of $V_{SEC(RMS)}$ of 12V (transformers with different secondary voltages could be used with appropriate circuit modifications). Therefore, the *peak* secondary voltage is $V_{SEC(PEAK)} = \pm\sqrt{2} \times 12V$, or ±17V. Since T1 is effectively "off load", we must assume that V_{PEAK} could be a maximum of ±20V.

Since comparator IC1 is powered by a single +5V rail, resistors R1, R2 and R3 must be selected to ensure the voltage, V–, at the comparator's inverting input remains within its common mode range, which for the TLC393 is 0V to +4V. Using the *superposition theorem*, the voltage at the inverting input can be found:

Inverting Input Voltage,

$$V- = \frac{V_{SEC} \times (R2//R3)}{R1 + (R2//R3)} + \frac{(+V_S) \times (R1//R3)}{R2 + (R1//R3)} \text{ (volts)}$$

where // means "in parallel with".

Clearly, since $+V_S$ is positive, V– will be a maximum when V_{SEC} is at its maximum positive value, namely +20V. With R1 = 680kΩ, R2 = 100kΩ, and R3 = 100kΩ, we find that:

$$V-(\text{max}) = \frac{20 \times (100k\Omega//100k\Omega)}{680k\Omega + (100k\Omega//100k\Omega)} + \frac{5 \times (680k\Omega//100k\Omega)}{100k\Omega + (680k\Omega//100k\Omega)}$$

$$= 1{\cdot}37 + 2{\cdot}33 = 3{\cdot}7V$$

Therefore, provided $V_{SEC(PEAK)}$ does not exceed 20V and $+V_S$ is regulated to +5V, V– will remain within the 0V to 4V common mode input voltage range.

Now, we require the comparator to trip each time the mains sinusoid crosses the zero point. Provided T1's primary and secondary voltages are in phase, this will coincide with the secondary voltage crossing zero, i.e., when $V_{SEC} = 0$. Substituting this value in the expression for V–, we see that:

$$V- \text{ at zero-crossing point} = 0 + \frac{5 \times (680\Omega//100k\Omega)}{100k\Omega + (680k\Omega//100k\Omega)}$$

$$= 0 + 2{\cdot}33 = 2{\cdot}33V.$$

Therefore, by selecting resistors R4 and R5 to make the non-inverting input voltage, V+, equal to 2·33V also, the comparator will trip each time the mains signal crosses zero. With R4 = 150kΩ and R5 = 130kΩ, the quiescent value of V+ is 2·32V.

Resistor R6 and capacitor C1 provide around 0·5V of temporal hysteresis; this decays to zero after about 1ms as shown by the circuit waveform diagram in Fig.4.10b. The amount of this "transient" hysteresis can be increased by reducing R6 and/or increasing C1 if there is excessive noise on V_{SEC}.

PULL-UP RESISTOR

The TLC393 is a low-power, dual comparator with open drain output, therefore a pull-up resistor, R7, is needed at the output. Resistor R7 can be omitted if a comparator like the TLC3702 having rail-to-rail output swing is used.

Both the TLC393 and TLC3702 have very low input bias currents (typically just 5pA) so large resistance values can be used for R1 to R6. If an alternative device such as the LM393 is used, beware that the bias currents are much larger (250nA maximum), so it may be necessary to scale down the resistor values.

Tests on the Zero-Crossing Detector circuit of Fig.4.10a revealed that the timing error (the time difference between the zero-crossing points and the rising or falling edge of V_{OUT}) was less than 65µs, which is just 0·33% of the 20ms mains period.

Finally, a word of caution. When experimenting with zero-crossing detectors, never be tempted to connect the Schmitt trigger circuitry directly to the mains supply. Not only is this likely to destroy the low voltage components, but it also bypasses the galvanic isolation provided by the transformer, a practice which can be fatal.

TEMPERATURE DETECTOR

Temperature is probably the most commonly measured physical parameter, so it is not surprising that it can be measured with many different types of sensor, such as thermocouples, RTDs (resistance temperature detectors), thermistors, and so on.

The humble bipolar junction transistor (BJT) makes a surprisingly good temperature sensor. For most silicon devices, the base-emitter junction exhibits a reasonably linear temperature coefficient of around –2mV/°C. How an *npn* transistor can be combined with an amplifier and Schmitt trigger to produce an inexpensive temperature detector is shown in Fig.4.11.

Transistor TR1 is the sensor. It is "diode-connected" (its base and collector are connected together), and is biased by resistor R1 which produces a nominal collector current, I_C, of around 100µA. Provided the supply voltage, $+V_S$, is held constant, the only changes in base-emitter voltage, V_{BE}, will be due to changes in TR1's ambient temperature.

Almost any low-power, small-signal, *npn* silicon transistor could be used, but the 2N3904 is well-suited to temperature measurement and is widely used for temperature sensing applications. The combination of resistor R2 and capacitor C1 form a low-pass filter which helps to remove any mains pickup or other low-frequency noise which gets onto the sensor. (If TR1 is located some distance from IC1a, it should be connected to the circuit via a "twisted pair" of wires to minimise pickup on the wires themselves).

Op.amp IC1a should have a wide output swing to accommodate as much gain as possible. With resistor R3 selected at 120kΩ and R4 at 30kΩ, the amplifier has a gain of five, such that $V_A = 5 \times (V_{BE} + \Delta V_{BE})$, where V_{BE} is the quiescent, room temperature base-emitter voltage, and ΔV_{BE} is the change in V_{BE} caused by temperature variations.

THRESHOLD LEVELS

Op.amp IC1b acts as a comparator and forms the Schmitt trigger, with hysteresis set by resistors R7 and R8; trimmer pot VR1 provides a variable reference voltage, V_{REF}, at the inverting input which is used to calibrate the detector. The circuit values have been chosen such that the Schmitt's thresholds correspond to temperature levels of approximately +25°C and +35°C, although it could be adapted to trip at other temperatures if required.

Assuming TR1's temperature coefficient is –2mV/°C, an increase in temperature of 10°C will cause a change in V_{BE} of: ΔV_{BE} = 10°C × (–2mV/°C) = –20mV. The corresponding change in V_A will be: $\Delta V_A = 5 \times \Delta V_{BE} = 5 \times -20\text{mV} = -100\text{mV}$. Therefore, the Schmitt trigger's hysteresis must be set to 100mV; provided V_{OUT} swings from 0V to +5V, this is accomplished by selecting R7 = 2kΩ and R8 = 100kΩ.

The values chosen for R5, VR1 and R6 provide a V_{REF} range of around 2·60V to 3·20V. This allows the circuit to be calibrated to accept any value of V_{BE} at 25°C from 540mV to 640mV. The way this relates to the circuit's behaviour can be understood by following the calibration routine.

CALIBRATING THE DETECTOR

Assuming the particular sample of transistor TR1 in Fig.4.11 has a room temperature (+25°C) value of V_{BE} = 580mV, such that V_A = 5 × 580mV = 2·9V. Starting with V_{REF} at its maximum value such that V_{OUT} is low and the l.e.d. D1 is on, preset VR1 is carefully adjusted until V_{REF} is just slightly less than V_A, at which point the comparator trips, V_{OUT} goes high and the l.e.d. turns off.

If the temperature now increases slightly, the comparator does not trip – the hysteresis prevents it from doing so. However, when the temperature increases to +35°C, the value of V_A will be low enough to take IC1b's non-inverting input voltage below V_{REF}: the comparator trips, V_{OUT} goes low and l.e.d. D1 turns on, signaling that the upper temperature threshold has been reached. Whilst V_{OUT} remains low, the l.e.d. stays on until TR1's temperature has fallen back down to +25°C, at which point the comparator trips again and D1 turns off.

When calibrating the detector, the simplest way to raise TR1's temperature is to apply heat from a soldering iron; it can quickly be cooled down again using "freezer spray", or by touching it with a suitable object (e.g. a screwdriver) which has been left in the freezer for an hour or so!

The circuit's accuracy depends largely on the "quality" of its calibration. *Repeatability* (the degree to which the circuit trips at the same threshold levels over a period of time) depends mainly on the stability of the hysteresis levels, which in turn depend on V_{OUT} and $+V_S$.

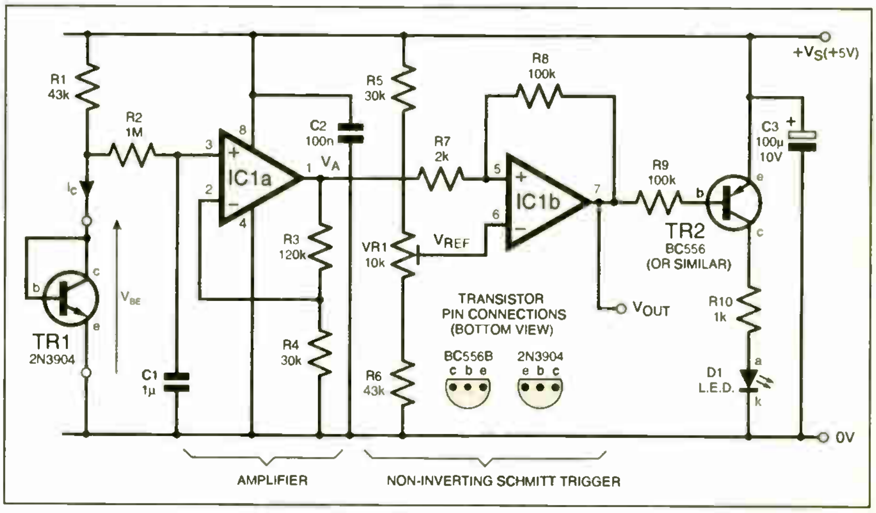


Fig.4.11. Circuit diagram for a transistor-based Temperature Detector.

TRIPPING THE LIGHT FANTASTIC

Like temperature, light is also a commonly measured quantity, and can be sensed using devices like photodiodes, phototransistors and light dependent resistors (l.d.r.s). Usually made from Cadmium Sulphide (CdS), the l.d.r. is strictly a *photoconductive cell* in which the conductivity increases in logarithmic fashion as the light intensity increases.

Light dependent resistors are relatively cheap and make ideal sensors for threshold-type light detectors. An example circuit diagram for a Light Detector with an audio output is shown in Fig.4.12. The l.d.r. sensor (R2) is connected, together with VR1 and R1, in a potential divider network at the input to an inverting Schmitt trigger formed by comparator IC1a. A second comparator, IC1b, is configured as a "gated" astable which drives the piezoelectric sounder WD1.

Preset potentiometer VR1 is used to set the trigger threshold. The values chosen for R1 and VR1 depend on the particular light level that must trip the comparator. For instance, if the circuit is required to detect a range of relatively high light intensities, then resistor R1 and preset VR1 must be small; on the other hand, operation in dull conditions will require higher resistance values.

Tests on three samples of the NORP12 revealed that in bright sunlight the sensor resistance ranged from 40 to 50 ohms. In relatively dark conditions, however, the sensors' resistance was in the hundreds of kilohms range.

Few of us are likely to possess a calibrated light source, so the easiest way to experiment with this circuit is to place the l.d.r. sensor at varying distances from a mains-powered, filament-type 60W light bulb in an otherwise darkened room. Changing the distance between sensor and bulb effectively varies the light intensity falling on the sensor.

For example, at just 3cm from the bulb, the sensor resistance was measured as 104Ω; with the distance increased to 30cm the resistance increased to 552Ω. (Interestingly, the relationship between distance and resistance is fairly linear, suggesting the l.d.r. could be used in conjunction with a light source as a crude "distance meter" – albeit only in the dark!)

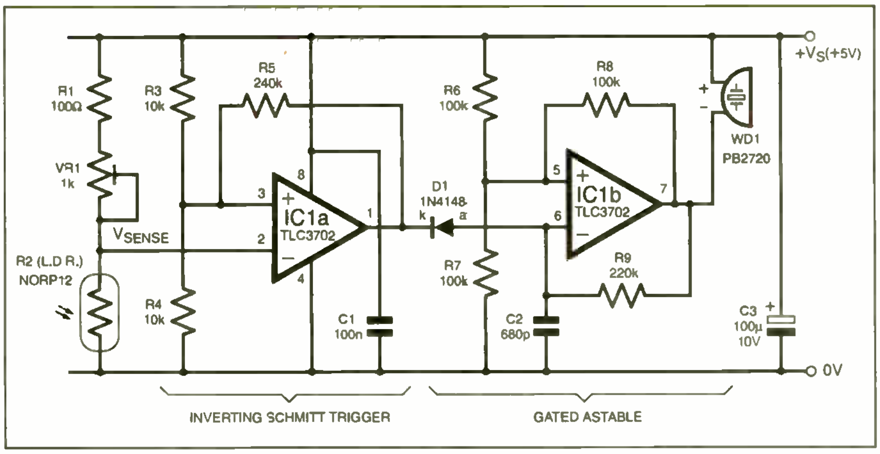


Fig.4.12. Circuit diagram for a Light Detector, with audible output.

MID-HYSTERESIS POINT

With resistors R3 and R4 both equal to 10kΩ, and provided IC1a has a rail-to-rail output swing, the mid-hysteresis point of the Schmitt trigger will be $+V_S/2$, or 2·5V. Therefore, if preset VR1 is adjusted such that R1+VR1 equals the sensor resistance at the required light level, then the voltage, V_{SENSE}, on l.d.r. R2 will also equal 2·5V and the comparator will trip.

In this circuit (Fig.4.12), resistor R5 must be selected to provide adequate hysteresis. The degree of hysteresis required will depend on the operating conditions. One reason for requiring hysteresis is to eliminate the effects of background light fluctuations which could otherwise cause the detector to "oscillate" about the trip point.

However, a more important reason for requiring hysteresis in this kind of experimental set-up is to suppress the effects of mains "ripple" in the light bulb intensity. With the values of R1+VR1 set to 470Ω, and with the sensor (R2) located 3cm from the 60W bulb, the r.m.s. component of V_{SENSE} was measured as 25mV. This a.c. component is caused by the 50Hz mains voltage which effectively "modulates" the light intensity at 100Hz and acts as a kind of "noise". (Why is the modulation frequency *twice* the mains frequency?)

An r.m.s. voltage of 25mV corresponds to a *peak-to-peak* ripple voltage of 71mV. Therefore, resistor R5 must be selected to provide hysteresis of at least 71mV such that the ripple voltage on V_{SENSE} does not upset the trip point. With R5 = 240kΩ, the thresholds are V_{TL} = 2·449V and V_{TU} = 2·551V and the hysteresis is V_H = 102mV. Reducing R5 will increase the hysteresis if more "noise immunity" is required.

GATED OSCILLATOR

When the light intensity is low, the l.d.r. sensor's resistance is large compared to R1+VR1, and so V_{SENSE} is greater than 2·5V, causing IC1a's output to be in negative saturation. Since the TLC3702 dual comparator is capable of rail-to-rail output swings, diode D1's cathode (k) potential will be very near to 0V.

Consequently, D1 is forward biased, effectively "clamping" the voltage on capacitor C2 to around 0·7V. This prevents the astable from oscillating, and forces IC1b's output voltage into positive saturation such that there is no voltage across the piezoelectric sounder WD1.

However, as the l.d.r. sensor (R2) is moved *closer* to the light source, its resistance falls and V_{SENSE} decreases. When the sensor resistance is low enough, the detector trips and IC1a's output goes high, reverse biasing diode D1. The astable is now free to run, and the squarewave voltage at IC1b's output causes WD1 to sound.

RESONANT FREQUENCY

Capacitor C2 and resistor R9 set the astable's time constant. This should be chosen to set the operating frequency as close as possible to the piezoelectric sounder's resonant frequency. With the component values shown in Fig.4.12, the frequency is around 4·4kHz, quite close to WD1's resonant frequency of 4·5kHz. If alternative sounders are used, C2 and R8 should be adjusted, if necessary, to suit the sounder's characteristics.

Calibrating the Detector stage is easy. Start with preset VR1 at its minimum resistance and locate the l.d.r. sensor R2 at the required distance from the light bulb. Then, slowly adjust VR1 until sounder WD1 just begins to sound.

As the sensor is moved either side of the threshold point (the preset distance from the bulb), the sounder should turn on and off "cleanly". However, if resistor R5 is removed from the circuit, such that the comparator no longer has any hysteresis, the sounder will now produce a "squawking" sound when the sensor is moved near the trip point: this is caused by the mains ripple effectively modulating the astable's output frequency.

This dramatic effect is a perfect example of how hysteresis can be used to overcome the problems caused by noise and interference. In this case, the unwanted signal is the ripple voltage on V_{SENSE}. It oscillates at twice the mains frequency simply because the mains sinusoid reaches a peak (one positive, one negative) *twice* each cycle: each peak in the mains voltage causes a slight increase in the bulb's light output, i.e., the light intensity is "modulated" at twice the 50Hz mains frequency.

LOOKING AHEAD

The Light Detector circuit in Fig.4.12 employs not one, but two Schmitt triggers, each performing a different task. There can be little doubt that the Schmitt function is a versatile and essential element in analogue systems built using op.amps and comparators. However, as we shall see in Part Five, the Schmitt trigger finds many applications in digital systems, where specialised Schmitt trigger logic gates are available to simplify the design task.

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The aim of this book is to provide the model railway enthusiast with a number of useful but reasonably simple projects that are easily constructed from readily available components. Stripboard layouts and wiring diagrams are provided for each project. The projects covered include: constant voltage controller; pulsed controller; pushbutton pulsed controller; pulsed controller with simulated inertia, momentum and braking; automatic signals; steam whistle sound effect; two-tone horn sound effect; automatic two-tone horn effect; automatic chuffer.

The final chapter covers the increasingly popular subject of using a computer to control a model railway layout, including circuits for computer-based controllers and signalling systems.

151 pages **Order code BP384** **£4.99**

A PRACTICAL INTRODUCTION TO SURFACE MOUNT DEVICES
Bill Mooney

This book takes you from the simplest possible starting point to a high level of competence in handworking with surface mount devices (SMD's). The wider subject of SM technology is also introduced, so giving a feeling for its depth and fascination.

Subjects such as p.c.b. design, chip control, soldering techniques and specialist tools for SM are fully explained and developed as the book progresses. Some useful constructional projects are also included.

Whilst the book is mainly intended as an introduction it is also an invaluable reference book, and the browser should find it engrossing.

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FAULT-FINDING ELECTRONIC PROJECTS
R. A. Penfold

Starting with mechanical faults such as dry joints, short-circuits etc, coverage includes linear circuits, using a meter to make voltage checks, signal tracing techniques and fault finding on logic circuits. The final chapter covers ways of testing a wide range of electronic components, such as resistors, capacitors, operational amplifiers, diodes, transistors, SCRs and triacs, with the aid of only a limited amount of test equipment.

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TEST EQUIPMENT CONSTRUCTION
R. A. Penfold

This book describes in detail how to construct some simple and inexpensive but extremely useful, pieces of test equipment. Stripboard layouts are provided for all designs, together with wiring diagrams where appropriate, plus notes on construction and use.

The following designs are included:-
AF Generator, Capacitance Meter, Test Bench Amplifier, AF Frequency Meter, Audio Mullivoltmeter, Analogue Probe, High Resistance Voltmeter, CMOS Probe, Transistor Tester, TTL Probe. The designs are suitable for both newcomers and more experienced hobbyists.

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HOW TO DESIGN AND MAKE YOUR OWN P.C.B.s
R. A. Penfold

Deals with the simple methods of copying printed circuit board designs from magazines and books, and covers all aspects of simple p.c.b. construction including photographic methods and designing your own p.c.b.s.

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R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

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RADIO / TV VIDEO

ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

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SETTING UP AN AMATEUR RADIO STATION
I. D. Poole

The aim of this book is to give guidance on the decisions which have to be made when setting up any amateur radio or short wave listening station. Often the experience which is needed is learned by one's mistakes, however, this can be expensive. To help overcome this, guidance is given on many aspects of setting up and running an efficient station. It then proceeds to the steps that need to be taken in gaining a full transmitting licence.

Topics covered include: The equipment that is needed; Setting up the shack; Which aerials to use; Methods of construction; Preparing for the licence.

An essential addition to the library of all those taking their first steps in amateur radio.

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EXPERIMENTAL ANTENNA TOPICS
H. C. Wright

Although nearly a century has passed since Marconi's first demonstration or radio communication, there is still research and experiment to be carried out in the field of antenna design and behaviour.

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Although primarily a practical book with text closely supported by diagrams, some formulae which can be used by straightforward substitution and some simple graphs have also been included.

72 pages **Order code BP278** **£3.50**

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E. M. Noll

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By Clive (call me Max) Maxfield

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The Foreword by Pete Waddell, Editor, *Printed Circuit Design* reads:

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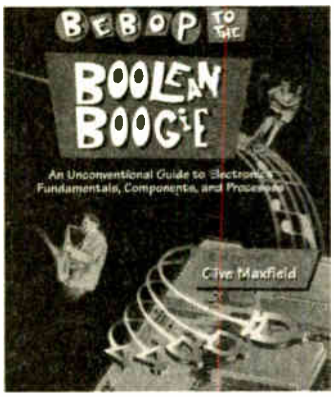

This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!).

Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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Bebop Bytes Back

By Clive "Max" Maxfield and Alvin Brown

ORDER CODE BEB2 **£29.95**

An Unconventional Guide To Computers

Plus **FREE CD-ROM** which includes: Fully Functional Internet-Ready Virtual Computer with Interactive Labs

The Foreword by Lee Felsenstein reads:

"1. The more time you spend with this book and its accompanying CD-ROM, the more you'll get out of it. Skimming through it won't take you where you want to go. Paying serious attention, on the other hand, will teach you more about computers than you can imagine. (You might also see a few beautiful sunrises.)

2. The labs work on two levels: on and under the surface. When you're performing the labs you'll need to look for patterns that build up from individual events.

3. When you're done, you won't look any different. You won't get a trophy or a certificate to hang on your wall. You'll have some knowledge, and some skill, and you'll be ready to find more knowledge and develop more skill. Much of this will be recognisable only to someone who has the same knowledge and skill."

This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers.

If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this one!

Audio and Music

VALVE & TRANSISTOR AUDIO AMPLIFIERS
John Linsley Hood

This is John Linsley Hood's greatest work yet, describing the milestones that have marked the development of audio amplifiers since the earliest days to the latest systems. Including classic amps with valves at their heart and exciting new designs using the latest components, this book is the complete world guide to audio amp design.

Contents: Active components; Valves or vacuum tubes; Solid-state devices; Passive components; Inductors and transformers; Capacitors, Resistors, Switches and electrical contacts; Voltage amplifier stages using valves; Valve audio amplifier layouts; Negative feedback; Valve operated power amplifiers; Solid state voltage amplifiers; Early solid-state audio amplifiers; Contemporary power amplifier designs; Preamplifiers; Power supplies (PSUs); Index.

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AUDIO AMPLIFIER PROJECTS
R. A. Penfold

A wide range of useful audio amplifier projects, each project features a circuit diagram, an explanation of the circuit operation and a stripboard layout diagram. All constructional details are provided along with a shopping list of components, and none of the designs requires the use of any test equipment in order to set up properly. All the projects are designed for straightforward assembly on simple circuit boards.

Circuits include: High impedance mic preamp, Low impedance mic preamp, Crystal mic preamp, Guitar and GP preamplifier, Scratch and rumble filter, RIAA preamplifier, Tape preamplifier, Audio limiter, Bass and treble tone controls, Loudness filter, Loudness control, Simple graphic equaliser, Basic audio mixer, Small (300mW) audio power amp, 6 watt audio power amp, 20/32 watt power amp and power supply, Dynamic noise limiter.

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Ian Waugh

In this practical and clearly written book, Ian Waugh explains all aspects of the subject from digital audio basics to putting together a system to suit your own music requirements. Using the minimum of technical language, the book explains exactly what you need to know about: Sound and digital audio, Basic digital recording principles, Sample rates and resolutions, Consumer sound cards and dedicated digital audio cards.

On a practical level you will learn about: sample editing, digital multi-tracking, digital FX processing, integrating MIDI and digital audio, using sample CDs, mastering to DAT and direct to CD, digital audio and Multimedia.

This book is for every musician who wants to be a part of the most important development in music since the invention of the gramophone. It's affordable, it's flexible, it's powerful and it's here now! It's digital and it's the future of music making.

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Robert Penfold
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The PIC processors have plenty of useful features, but they are still reasonably simple and straightforward to use. This book should contain everything you need to know.
Topics covered include: the PIC register set; numbering systems; bitwise operations and rotation; the PIC instruction set; using interrupts; using the analogue to digital converter; clock circuits; using the real time clock counter (RTCC); using subroutines; driving seven segment displays.
166 pages **Order code BP394** **£5.99**

PRACTICAL OSCILLATOR CIRCUITS
A. Flind
Extensive coverage is given to circuits using capacitors and resistors to control frequency. Designs using CMOS, timer i.c.s and op.amps are all described in detail, with a special chapter on "waveform generator" i.c.s. Reliable "white" and "pink" noise generator circuits are also included.
Various circuits using inductors and capacitors are covered, with emphasis on stable low frequency generation. Some of these are amazingly simple, but are still very useful signal sources.
Crystal oscillators have their own chapter. Many of the circuits shown are readily available special i.c.s for simplicity and reliability, and offer several output frequencies. Finally, complete constructional details are given for an audio sinewave generator.
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PRACTICAL ELECTRONIC CONTROL PROJECTS
Owen Bishop
Explains electronic control theory in simple, non-mathematical terms and is illustrated by 30 practical designs suitable for the student or hobbyist to build. Shows how to use sensors as input to the control system, and how to provide output to lamps, heaters, solenoids, relays and motors.
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198 pages **Order code BP377** **£5.99**

PRACTICAL ELECTRONICS HANDBOOK – Fifth Edition. Ian Sinclair
Contains all of the everyday information that anyone working in electronics will need.
It provides a practical and comprehensive collection of circuits, rules of thumb and design data for professional engineers, students and enthusaists, and therefore enough background to allow the understanding and development of a range of basic circuits.
Contents: Passive components, Active discrete components, Circuits, Linear I.C.s, Energy conversion components, Digital I.C.s, Microprocessors and microprocessor systems, Transferring digital data, Digital-analogue conversions, Computer aids in electronics, Hardware components and practical work, Microcontrollers and PLCs, Digital broadcasting, Electronic security.
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B. B. Babani
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OPTOELECTRONICS CIRCUITS MANUAL
R. M. Marston
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R. A. Penfold
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A BEGINNERS GUIDE TO CMOS DIGITAL ICs
R. A. Penfold
Getting started with logic circuits can be difficult, since many of the fundamental concepts of digital design tend to seem rather abstract, and remote from obviously useful applications. This book covers the basic theory of digital electronics and the use of CMOS integrated circuits, but does not lose sight of the fact that digital electronics has numerous "real world" applications.
The topics covered in this book include: the basic concepts of logic circuits; the functions of gates, inverters and other logic "building blocks"; CMOS logic i.c. characteristics, and their advantages in practical circuit design; oscillators and monostables (timers); flip/flops, binary dividers and binary counters; decade counters and display drivers.
119 pages **Order code BP333** **£4.95**

AUDIO AND MUSIC

INTRODUCTION TO DIGITAL AUDIO
(Second Edition) Ian Sinclair
The compact disc (CD) was the first device to bring digital audio methods into the home.
This development has involved methods and circuits that are totally alien to the technician or keen amateur who has previously worked with audio circuits. The principles and practices of digital audio owe little or nothing to the traditional linear circuits of the past, and are much more comprehensible to today's computer engineer than the older generation of audio engineers.
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J. Chatwin
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Along with the electric guitar, sections are also included relating to acoustic instruments. The function of specialised piezoelectric pickups is explained and there are detailed instructions on how to make your own contact and bridge transducers. The projects range from simple preamps and tone boosters, to complete active controls and equaliser units.
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VALVE AMPLIFIERS
Second Edition. Morgan Jones
This book allows those with a limited knowledge of the field to understand both the theory and practice of valve audio amplifier design, such that they can analyse and modify circuits, and build or restore an amplifier. Design principles and construction techniques are provided so readers can devise and build from scratch, designs that actually work.
The second edition of this popular book builds on its main strength – exploring and illustrating theory with practical applications. Numerous new sections include: output transformer problems; heater regulators; phase splitter analysis; and component technology. In addition to the numerous amplifier and preamplifier circuits, three major new designs are included: a low-noise single-ended LP stage, and a pair of high voltage amplifiers for driving electrostatic transducers directly – one for headphones, one for loudspeakers.
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Chas Miller
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Published on approximately the second Thursday of each month by Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. Printed in England by Apple Web Offset Ltd., Warrington, WA1 4RW. Distributed by COMAG Magazine Marketing, Tavistock Rd., West Drayton, UB7 7QE. **Subscriptions** INLAND: £14.50 (6 months); £27.50 (12 months); £50 (2 years). OVERSEAS: Standard air service, £17.50 (6 months); £33.50 (12 months); £62 (2 years). Express airmail, £27 (6 months); £51 (12 months); £97 (2 years). Payments payable to "Everyday Practical Electronics", Subs Dept, Allen House, East Borough, Wimborne, Dorset BH21 1PF. **E-mail:** subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.