THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY PRACTICAL ELECTRONICS

JANUARY 2001

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UFO DETECTOR/ RECORDER

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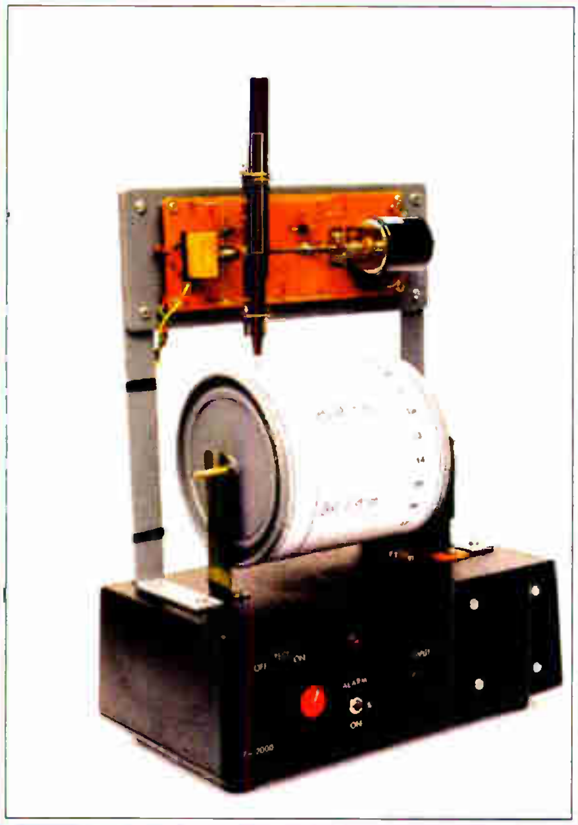

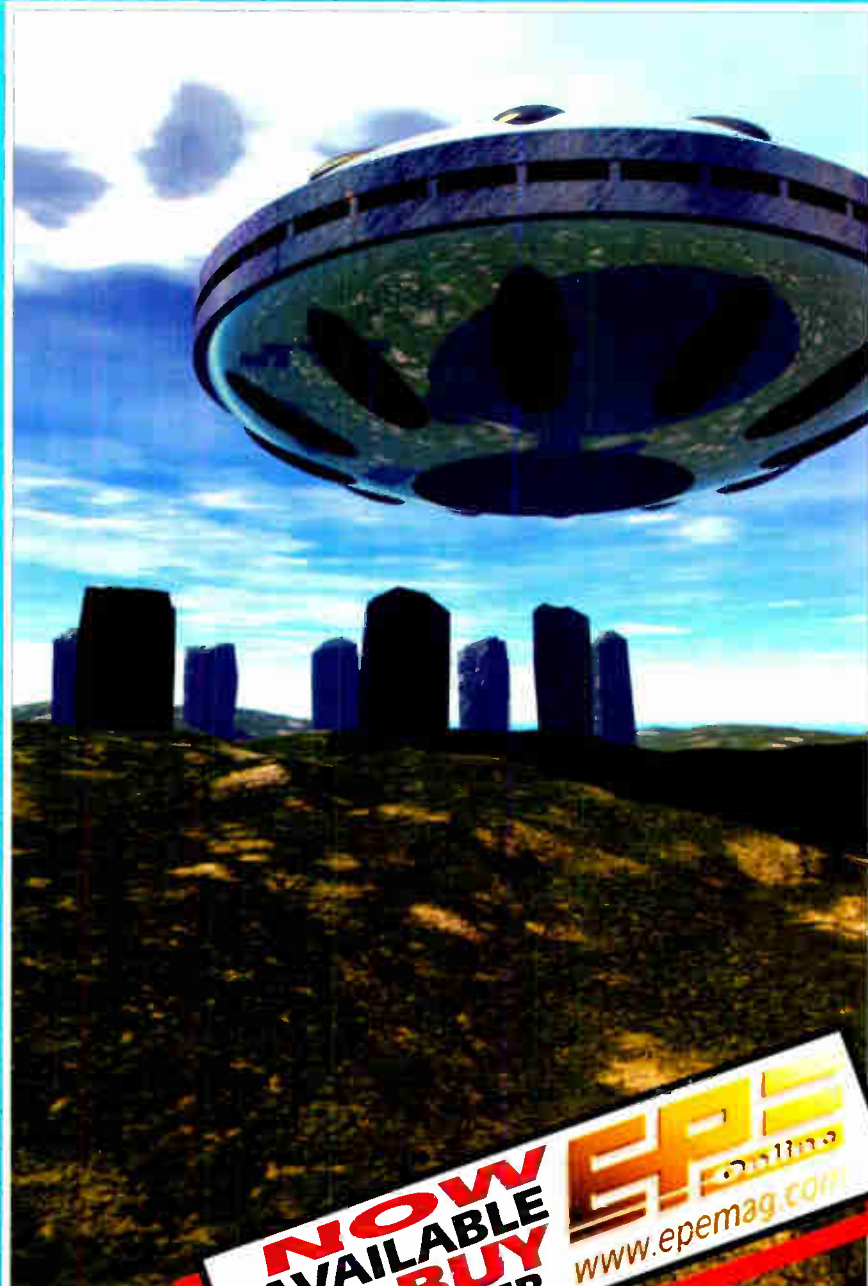

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12v 18Ah SEALED LEAD ACID BATTERIES, new and boxed, unused pack of 4 £39.95 ref CYC7 or £15 each ref CYC6

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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 torrodial 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 £5 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 sufficient 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 2x 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 ±40% (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 560 grms Operating Temperature Range -30deg C to +60 degC 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 2x 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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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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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. 1 JANUARY 2001
Cover illustration by Jonathan Robertson

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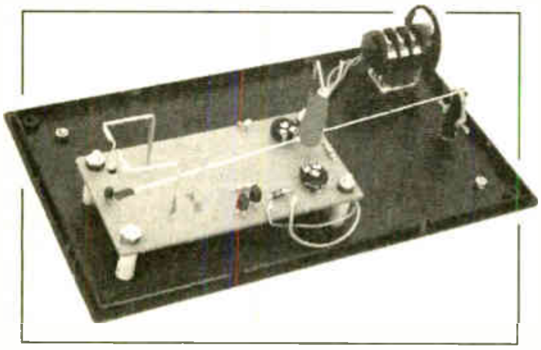
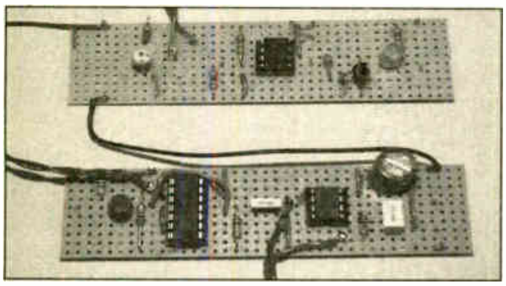
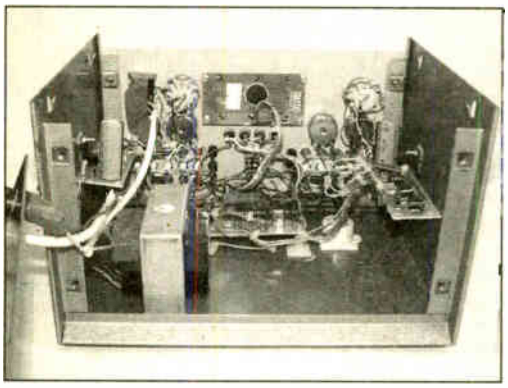






THE SEASON'S GREETINGS
TO ALL OUR READERS
May we wish you a peaceful
and prosperous 2001

Our February 2001 issue will be published on Thursday, 11 January 2001. See page 3 for details

Projects and Circuits

Series and Features

Regulars and Services

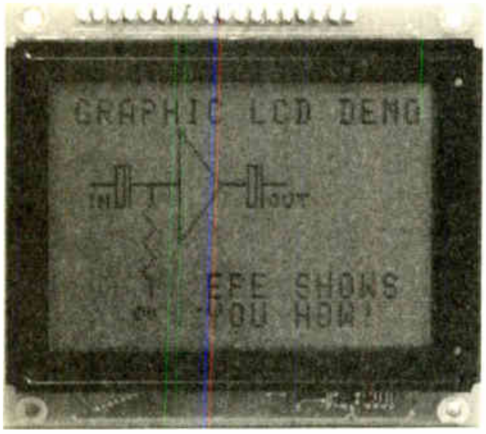
NEXT MONTH

SPECIAL SUPPLEMENT

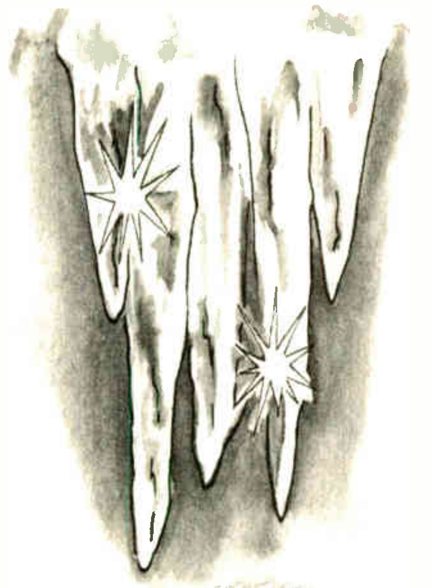
HOW TO USE GRAPHICS LIQUID CRYSTAL DISPLAYS

Graphics liquid crystal displays have been available for several years. It would appear, though, that EPE *readers have not successfully explored them. 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 such 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.



Eventually he succeeded (after a fair bit of hassle!), and set about getting to know how to use the family of displays based on the Toshiba T6963C l.c.d. controller. He describes in extensive detail how PIC microcontrollers can be programmed to use these versatile displays, with many interactive demo examples of the program codes required. They are easy to use once their mysteries are revealed!



ICE ALERT

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.

PC AUDIO POWER METER

This project is the latest in the occasional series of PC-based test equipment. This device is based on an analogue-to-digital converter, 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 eight-ohm 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. The eight-ohm dummy load can handle a little over 100 watts r.m.s.

The circuit connects to the printer port of the host PC, and the port does not need to be a bi-directional type. The power meter program is written in VisualBASIC 6, and it requires Windows 95, 98 or ME to run.

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**

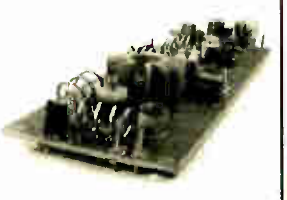
SPEED CONTROLLER for any common DC motor up to 100V/5A. Pulse width modulation gives maximum torque at all speeds. 5-15VDC. Box provided. **3067KT £12.95**

- **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

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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**
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- **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.**
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Order Ref	Description	Inc. VAT ea
ABCMINISP	ABC MINI Starter Pack	£64.95
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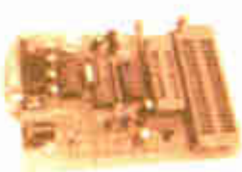

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Order Ref	Description	Inc. VAT ea
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AS3023	Assembled 3023	£39.95

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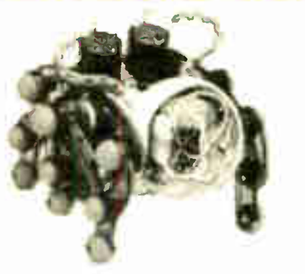

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AS3117	Assembled 'PICALL' PIC Programmer	£69.95
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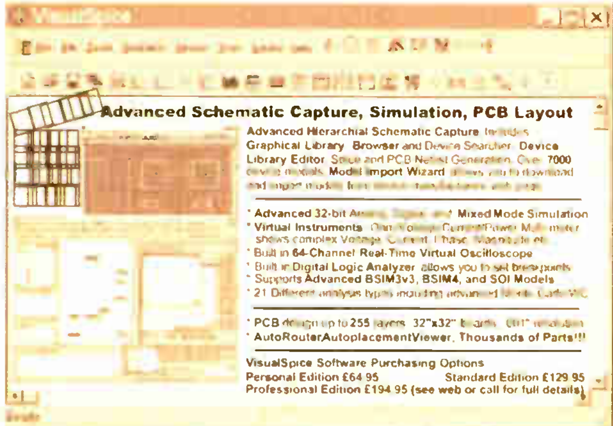

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Order Ref	Description	Inc. VAT ea
3108KT	Serial Port Isolated I/O Controller Kit	£54.95
AS3108	Assembled Serial Port Isolated I/O Controller	£69.95

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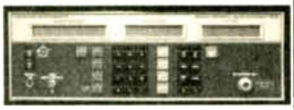

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EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 30 No. 1 JANUARY 2001

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A2. Please look through the back issues and indexes on the website before asking.

A3. Sorry but we cannot undertake to assist with advice or designs to meet the needs of individual readers.

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Please help us to help you.

Mike Kenward

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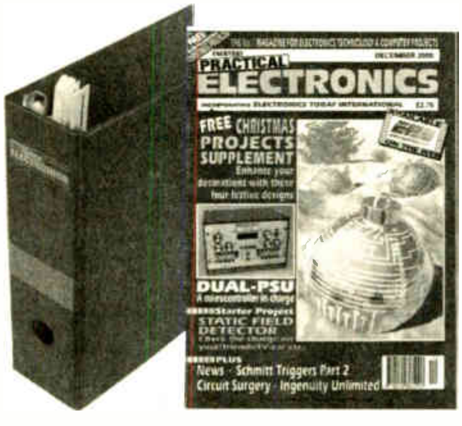

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VERSATILE OPTICAL TRIGGER

OWEN BISHOP

Project 5

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.

THIS is a circuit that is flexible enough to cater for many different applications. In its basic form, the Versatile Optical Trigger switches a load on or off, depending on the amount of light falling on its sensor. It can be set to respond in reasonably bright conditions or in dim light. It can be adapted to work either way round, switching on when the light gets brighter, or when it becomes dimmer.

Applications for the basic circuit include switching on a porch lamp at dusk, briefly sounding a buzzer when someone's shadow falls on the sensor (or when the cat leaves the house by the cat door), or to switch on a lamp in a cupboard when the door is opened. We leave it to the imagination of the reader to find other interesting things to do with this circuit. There is more later about how to adapt it to different uses.

If the load is a relay with contacts suitably rated, the circuit can be used to switch devices powered by a.c., including a.c. mains. ***However, you should NOT attempt to switch mains currents without considerable previous experience.***

FAST RESPONSE

With the addition of a second circuit board, there is an optional extra stage to this project, called the Differentiator. This changes the response of the trigger. Instead of being sensitive to light *level*, it becomes sensitive to the *rate of change* of light level.

With the Differentiator incorporated into the circuit, it is unaffected if light levels change slowly but shows a sharp change in output when the level changes rapidly. For example, in a security system a slowly changing light level, such as might be caused by the arrival of dusk or dawn, or the passing of clouds over the Sun, has no effect. By contrast, the circuit responds to someone walking past and causing the light level at the sensor to change very quickly.

It is able to make a transient response or a permanent one. A permanent response is useful in a security system. Once the intruder has triggered the circuit to sound a siren, the warning carries on until the circuit is reset.

HOW IT WORKS

The basic Trigger circuit diagram is shown in Fig.1 and uses an MEL12 phototransistor, TR1. This is a very sensitive device incorporating an amplifying circuit in the form of a Darlington pair. In the circuit diagram, it is drawn as an *npn* transistor, including a base (b) terminal.

However, we do not make a connection to the base in this trigger circuit because the light energy falling on the phototransistor generates the equivalent of a small base current. This is amplified within the device to produce a collector-emitter current in the region of 3mA in bright light. In darkness, the current is only a few nanoamps.

When the light is shining on the phototransistor the resulting current flows through resistor R1 and Level control VR1 in series. If the current is 2mA, for example, and VR1 is set so that the total resistance of R1 and VR1 is 2·25kΩ, the voltage drop across the two resistors is 4·5V. Then, if the supply voltage is 9V, the voltage at pin 2 of the op.amp is 9 – 4·5 = 4·5V. The voltage at pin 3 is also equal to 4·5V, since resistor R2 equals R3 and the voltage is half way between the power lines. In this state, the op.amp is just at its trigger point and its output is 4·5V (also half way between the power lines).

Now let us see what happens if the light level changes. If the light level increases, the current through phototransistor TR1 increases, the voltage across R1 and VR1 increases and the voltage at pin 2 falls. A fall in voltage at the inverting input (–) of an op.amp produces a rise in voltage at the output. The op.amp is connected as a comparator, with no negative feedback, so its full open loop gain of around 200,000 comes into play.

With even the slightest increase in light, the output voltage swings rapidly as high as it can go, to within a volt or so of the

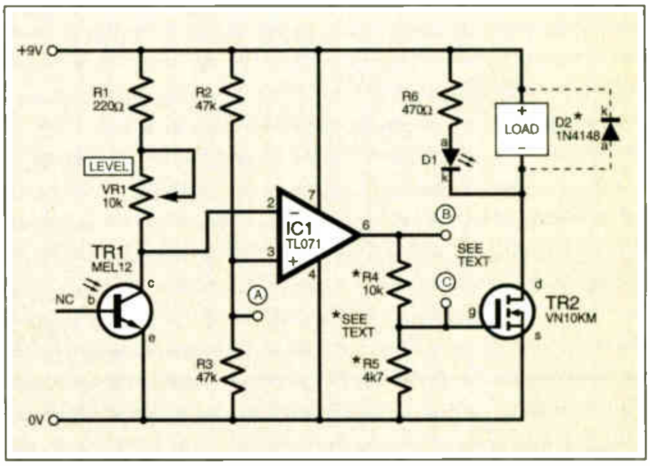


Fig.1. Trigger circuit diagram of the Versatile Optical Trigger.

COMPONENTS

BASIC TRIGGER

Resistors

R1	220Ω (see text)
R2, R3	47k (2 off)
R4	10k (see text)
R5	4k7 (see text)
R6	470Ω

All 0·25W 5% or better

See SHOP TALK page

Potentiometer

VR1	10k rotary carbon (or preset or fixed, see text), linear

Semiconductors

TR1	MEL12 phototransistor
TR2	VN10KM *n*-channel MOSFET
IC1	TL071 bifet op.amp

positive rail. If the light level falls even slightly, the reverse occurs and the output falls rapidly to about 1V with respect to the 0V rail.

OUTPUT DRIVE

The next stage is a MOSFET, TR2. Typically, this is turned on when the gate-source voltage exceeds 2·5V. Thus, it would be turned on by a 4·5V output from the op.amp.

However, we drop the output voltage by using a potential divider, made up of resistors R4/R5. The ratio of these resistors is 10:4·7 so, if the op.amp output is 4·5V, the voltage at the gate (g) of TR2 is only 4·5 × 4·7/14·7 = 1·4V.

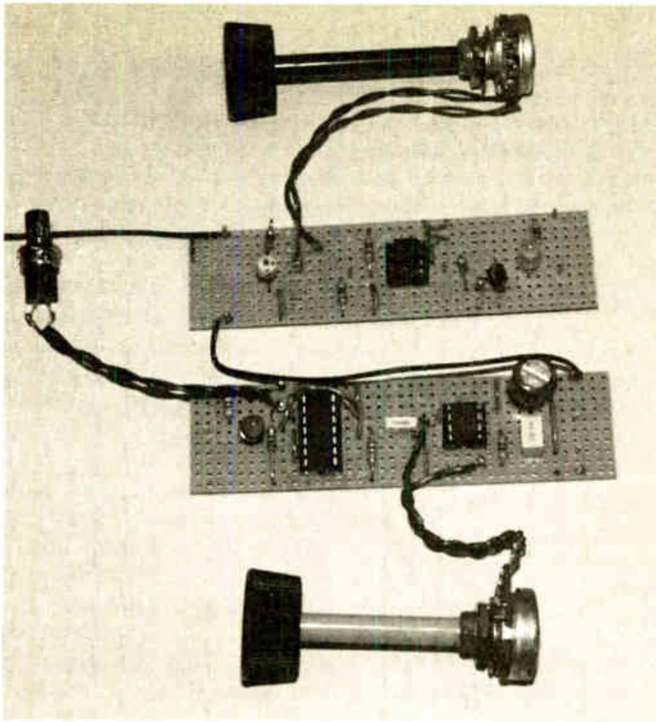
This is not high enough to turn TR2 on. As a result, TR2 is off if the incident light is less than the triggering level. As light increases and the op.amp output swings to around 8V, the gate voltage rises sharply to 2·56V and TR2 is switched on.

Current flows through the load, such as a relay coil, when TR2 comes on. The load could be a lamp, a buzzer, a siren, a solenoid, a d.c. motor or any other d.c. operated device, provided that it takes no more than 500mA. This is the largest current that a VN10KM can safely handle. To switch a larger current, substitute a MOSFET of higher current rating, such as a VN66AF, which can carry up to 2A.

A light emitting diode (l.e.d.), D1, is shown in parallel with the load in Fig.1. This is an indicator, which lights when the load is switched on. If the load is inductive, such as a relay, motor, or solenoid, then a large reverse current is generated when the load is suddenly switched off. To conduct this current away safely, add a signal diode such as a 1N4148 type in parallel with the load. This diode must be connected with *opposite* polarity to that of D1.

DIFFERENTIATOR

The Differentiator circuit diagram is shown in Fig.2 and is based on a second op.amp, IC2. It takes its inputs from the Trigger circuit. Input *A* is from the junction of the voltage divider resistors R2/R3, which sits at half the supply voltage. Input *B* comes from the output junction of the trigger op.amp, IC1, and is coupled to the inverting input (pin 2) of IC2 through capacitor C2. The output of this op.amp is then used to drive TR2 and switch the load and l.e.d. on or off.



Prototype circuit boards for the Opto-Trigger (top) and Differentiator.

The output voltage of an op.amp Differentiator is given by:

$$V_{OUT} = -RC \times dv_{IN}/dt$$

In this equation, *R* is the series resistance of R7 and VR2, and *C* is the capacitance of C2. The differential expression dv_{IN}/dt means the *rate of change* of input voltage, in volts per second. It can be seen that the output is proportional to this too.

This expression shows several things:

- An increase in input voltage produces a fall in output voltage.
- Output is proportional to *R* and *C*. We can adjust the sensitivity by adjusting VR2.
- Output is proportional to the rate of change of input voltage. This means that even a very short and small input pulse can produce a high output pulse provided that the rate of change is high.

The third point above makes the circuit a little too sensitive to small "spikes" on the signal from IC1. Therefore, capacitor C1 is connected across the input to eliminate the effect of such spikes.

When the light level on the sensor rises quickly, the output of IC2 falls. A low pulse passes across capacitor C3 to the input of the flip-flop IC3b/IC3c. This type of flip-flop, built from two NAND gates, is stable if both its inputs are high. Resistors R8 and R9 provide for this.

However, a negative pulse arriving by way of C3 will briefly make pin 6 low and so set the flip-flop; its output at pin 4 goes high. The rising output is used to switch the transistor TR2 in the Trigger circuit (Fig.1). The load is energised and D1 comes on. The flip-flop is reset by briefly pressing pushswitch S1.

MODIFICATIONS

To make the basic circuit operate in the opposite sense, simply exchange TR1 with R1 and VR1. If you are using the circuit with the Differentiator, the sense of operation may not be relevant. When a person (say, an intruder), briefly shades the sensor, the pulse from IC2 rises as the sensor is shaded and falls as the sensor is exposed. The flip-flop is triggered as the person moves away.

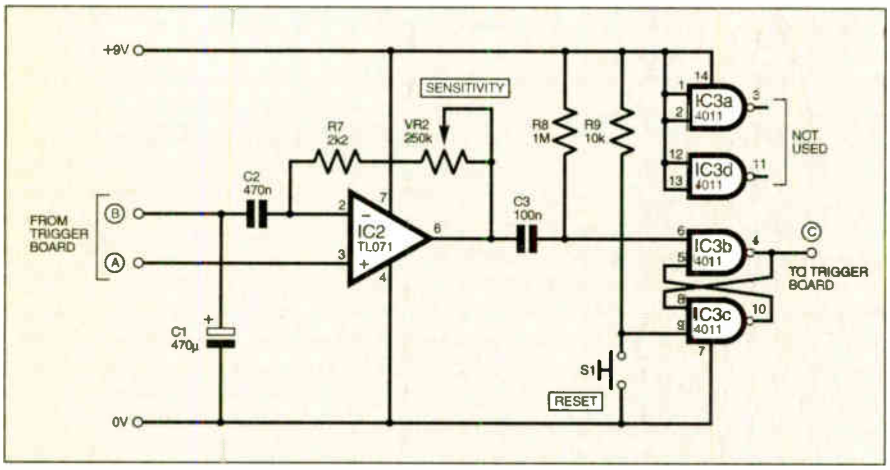


Fig.2. Circuit diagram for the Differentiator section. Switch S1 is a "normal-open" type.

D1 5mm l.e.d., red
D2 1N4148 signal diode, if load is inductive (see text)

Miscellaneous
Stripboard, 10 strips x 39 holes; 1mm terminal pins (9 off); 8-pin i.c. socket; PP3 battery clip; s.p.s.t. toggle switch (optional); load according to application; multistrand connecting wire; solder, etc.

DIFFERENTIATOR

Resistors
R7 2k2
R8 1M
R9 10k
All 0·25W 5% or better

Potentiometer
VR2 250k rotary carbon or preset, linear

Approx. Cost Guidance Only £10

Capacitors
C1 470µ radial elect. 16V
C2 470n plastic film
C3 100n plastic film

Semiconductors
IC2 TL071 bifet op.amp
IC3 4011 CMOS quad 2-input NAND gate

Miscellaneous
S1 pushswitch, push-to-make
Stripboard, 10 strips x 39 holes; 1mm terminal pins (9 off); 8-pin i.c. socket; 14-pin i.c. socket; multistrand connecting wire; solder, etc.

The values of R1 and VR1 given in Fig. 1 are more suited to operation in full daylight. If you want to operate the circuit in dim light, a larger resistance is needed to produce the required voltage drop of about 4·5V. Try increasing the value of R1 to, say, ten kilohms (10kΩ) or more. You could also try increasing VR1 to 47kΩ.

The circuit will also work on a 6V supply, but in this case the value of R5 should be increased to 22kΩ. It works on 12V without modification.

CONSTRUCTION – TRIGGER BOARD

The phototransistor type MEL12 is supplied with three terminal wires, but the base is not used and the wire can be cut short before mounting. Mount R1 and TR1 on the stripboard as shown in the component layout diagram of Fig. 3. In some applications it may be necessary to mount phototransistor TR1 off-board, with leads running to terminal pins at *E*8 and *G*8. Level control VR2 is off-board with leads running to terminal pins at *C*11 and *E*11. However, if the unit is to be used for a specific application, there may be no need to vary the sensitivity. In that case, experiment to find what total resistance is required and then replace R1 and VR1 by a fixed resistor between *A*10 and *E*10.

Check this section of the circuit by monitoring the voltage at the collector of phototransistor TR1 as the sensor is exposed to all the differing light levels that it will receive in use. The voltage should be more than the mid-rail voltage (4·5V for a 9V supply) when the incident light exceeds the required triggering level.

Complete the board assembly, noting that the terminal pins at (A) and at (B) are not needed if you are *not* intending to add the Differentiator. Resistors R4 and R5 are not needed if you *are* adding the Differentiator circuit.

Apply power and check that the output of IC1 rises above 4·5V only when the light level exceeds the triggering level. If you are not adding the Differentiator, check that the diode D1 comes on when the circuit is triggered. Now connect the load device by leads running from points *A*36 and *G*36 on the Trigger board. Small devices can be mounted directly on the board, with flying leads to these holes.

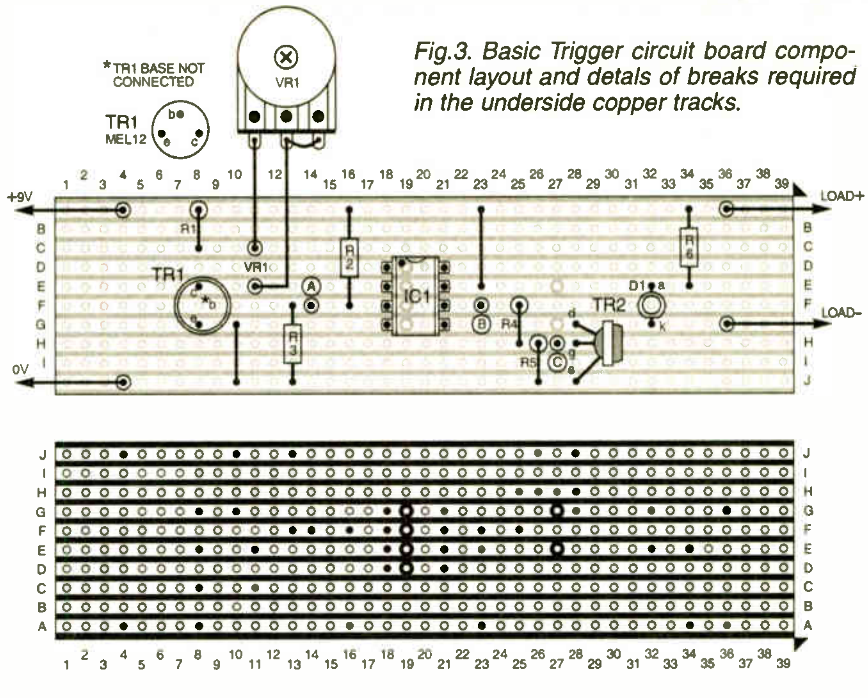
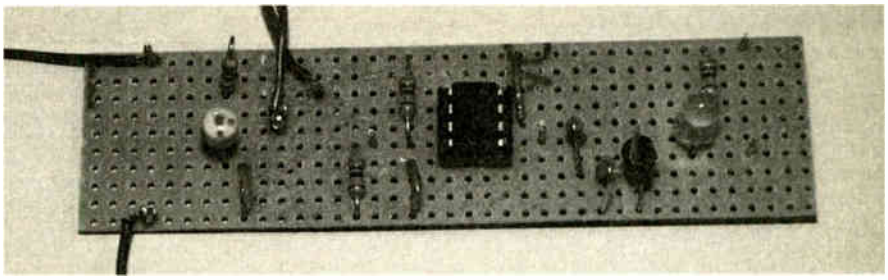


Fig.3. Basic Trigger circuit board component layout and detals of breaks required in the underside copper tracks.



Completed prototype board for Trigger stage of the Versatile Optical Trigger.

DIFFERENTIATOR

The Differentiator stripboard component layout and details of breaks required in the underside copper tracks are shown in Fig.4.

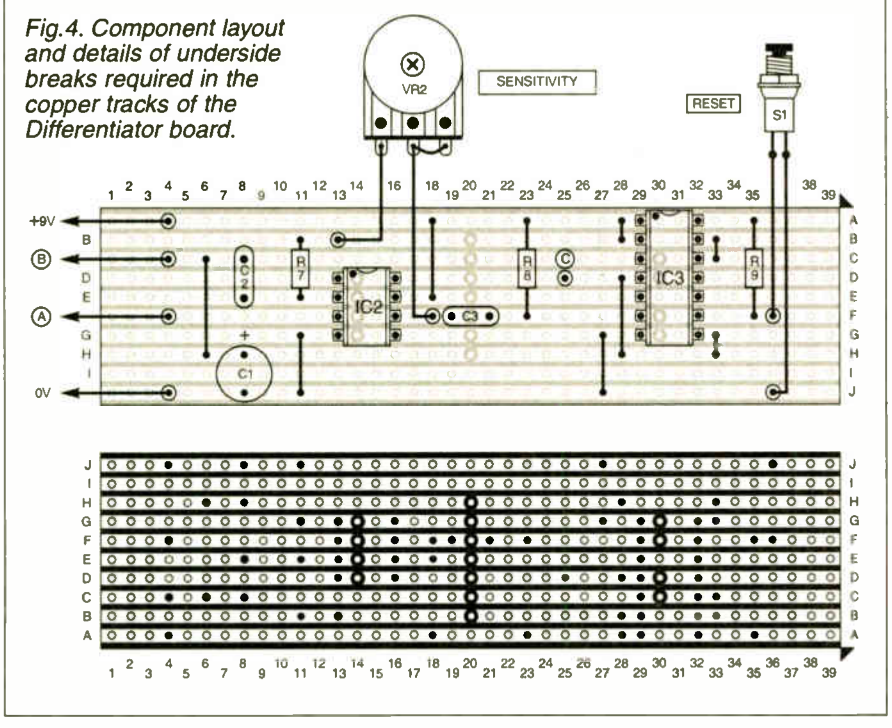
Assemble the differentiating section (all components in columns 1 to 19 in Fig. 4). Check it by connecting the power rails to the same supply as the Trigger board, and by connecting input pins (A) and (B) to identical points (*F*14 and *F*23) on the Trigger board.

Switch on the power and check that the output at pin 6 of IC2 is normally high (more than half the mid-rail voltage) but falls rapidly when the phototransisor TR1 is rapidly shaded or exposed. Also check that it does not fall with a slow change of light level. Adjust VR2 if necessary to increase sensitivity.

Next, add the flip-flop section. Note that two gates of IC3 are unused. The unused inputs at pins 1, 2, 12 and 13 *must* be connected to the positive rail as shown in Fig.2. Apply power and confirm that the flip-flop is reset by briefly pressing pushswitch S1 and that the l.e.d. goes out. After this, a rapid change in incident light sets the flip-flop and the l.e.d. comes on. It stays on until the flip-flop is reset again.

If you had previously been using the basic trigger circuit (Fig.3), remove resistors R4 and R5. Now run a lead from point (C) (*D*25) on the Differentiator board back to point (C) (*H*27) on the Trigger board. Apply power. The l.e.d. should now light when there is a rapid change of light level on the sensor. Connect the load as previously described for the Trigger board. □

Fig.4. Component layout and details of underside breaks required in the copper tracks of the Differentiator board.



News . . .

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

MILLIPEDE RECORDING NEARS COMMERCIALISATION

Flat, non-rotating magnetic data storage and retrieval comes out of the lab. Barry Fox reports.

MILLIPEDE, IBM's electromechanical data store, is close to commercialisation. IBM's researchers now feel confident to predict that future pocket phones and computers will use a single Millipede chip to store two full length movies, a week's worth of MP3 music or a 200-metre tall stack of printed paper.

IBM's Research Lab in Zurich believes its laboratory project can now be mass-produced at low-cost, within five years. This dovetails with the likely date when magnetic technology reaches its physical capacity limits.

Atomic Level Storage

"I can now dream of a new age when we store at atomic level, and process signals mechanically", says Peter Vettiger, the scientist who heads the Millipede project. "We will integrate as many mechanical devices on a single chip as we currently do by the million with transistors. And the chip can be of whatever size you want".

Magnetic discs can store around 15 Gigabits of data per square inch of surface area, and read it at around 200 Megabits a second. Optical discs store less than magnetic discs and read more slowly, but are cheaper. Solid state memory reads faster, but stores less, costs more and usually loses data when the power is switched off.

Advances in magnetic recording double capacity each year but this will stop around 2004 at 100 Gbits per square inch because of superparamagnetic effects; the magnetic domains, like tiny bar magnets, become so small and tightly packed that they interfere with each other, losing data unpredictably over time and with temperature changes.

In the mid-nineties Peter Vettiger and Gerd Binnig, Nobel prize-winner for his work on the scanning tunnelling microscope, looked at the possibility of using similar technology to store data. Instead of creating a magnified image with electrical readings taken by nanometer tip probes, IBM used the probes to indent a smooth surface. They proved the principle with a spinning polycarbonate disc, like a CD, coated with polymethylmethacrylate (PMMA), but dared not predict when – or even if – the technology might leave the Lab.

"The Millipede project now looks so promising that we are ready to talk about commercialisation within five years", says Vettiger, who now heads a team of ten researchers in Zurich, with more at IBM's Labs at Almaden in the US.

From Spinning to Linear

Confidence comes after IBM switched from using a spinning disc, to a flat plate of hard silicon substrate, spin-coated with PMMA. The probes are cantilever arms, arrayed in 32 rows of 32 probes on a silicon chip and doped to make them flex and conduct electricity. This heats the arms while moving them towards the plate to indent the coating, right down to the substrate. The substrate chip moves past the array chip while the probes write data line by line, much as a TV picture is scanned with a raster of lines.

For readout the probes are lightly warmed and the contact heat loss measured. This varies depending on whether the probe is in an indentation and thus touching the substrate, or only on the PMMA surface. Using a sliding plate instead of a spinning disc makes it easier to keep the surface perfectly flat, which improves write and read accuracy.

The early plan to erase data in bulk by heating the whole plate has now been changed to allow local erasure of targeted areas with a heated lever.

500Gb Per Square Inch

A single tip can already store up to 500 Gbits per square inch, writing data at 50 kilobits per second and reading 1 Megabit per second. When all the probes in a scanning line are working together, data speeds increase proportionally. There is a trade off between speed and power consumption. Mains-powered devices can deliver the high currents needed for rapidly heating and moving the probes and media; battery-powered portables will run at slower speeds.

"Ultimately there should be atomic resolution" says Vettiger. "What we have now is the tip of the iceberg.

"The technology is currently called MEMS, micro electro-mechanical system. But I would now like to start talking about NEMS, because we are approaching nanometre scaling.

"NEMS is a natural progression from magnetic recording, The price will be very competitive because hard discs need assembly. Millipede chips can be mass-produced like silicon chips, on the same fabrication lines", says Peter Vettiger.

Texas Instruments has already proved the viability of micromechanics by putting more than a million hinged mirrors on a single chip and using it to control the light in a video projector.

DRILL PLAN

MINICRAFT tell us that in their continuing efforts to improve their service, they have included two *free* project plans in their four most popular ready to use rotary tool kits.

The projects are intended to give users the necessary know-how required to create, repair and build. They include: refurbishing small metal objects, engraving glass, regrinding, sharpening, drilling and carving.

For more information contact Minicraft, Dept EPE, 1 & 2 Enterprise City, Meadowfield Avenue, Spennymoor, Co Durham DL16 6JF. Tel: 01388 420535.

Web: **www.minicraft.co.uk**.

AMSTRAD E-MAILER

AMSTRAD tell us that "the ideal alternative to the burden and expense of a new PC this Christmas" is their new **e-m@iler**.

Dubbed by some as "the phone with attitude", the equipment not only offers E-mail access but also provides a digital answering machine, 700 name address book, SMS text message and fax facilities, plus a portable data bank. It simply plugs in to your existing phone line and a power socket.

Amstrad founder, Sir Alan Sugar, said "The e-m@iler takes E-mail to the masses with its easy to use format and affordable pricing". The cost of the unit itself is £79.99, although there is a charge payable per usage session. The charges are subsidised by occasional adverts being displayed on the unit's screen.

The Amstrad e-m@iler is available from Dixons, Curry's, The Link and selected retail outlets. For further stockist information call the Amstrad help line on 01277 208811 or visit **www.amstrad.com**.

FML Electronics

THE 2001 mail order catalogue for FML Electronics is now available. Split into eight sections the 26-page A4 size catalogue has its first section totally devoted to semiconductors, 13 pages of them. It appears to be one of the most comprehensive selections of semiconductors available to the hobbyist constructor.

The second section is crammed with hardware items while the other sections itemise computer and office products, surface mount devices, development and bulk purchase packs.

The catalogue is without illustrations and is set in a smaller type face than used by some other suppliers, although it is still easy to read. FML also do kits for selected *EPE* projects, for which a separate catalogue is available. They can also supply data sheets.

For more information contact FML Electronics, Dept EPE, The Business Centre, Bridge Street, Bedale, N. Yorks DL8 2AD. Tel: 01677 425840.

Greenweld's Bargains

GREENWELD'S Christmas 2000 32-page catalogue has arrived at HQ. Quite naturally part of it details seasonally-orientated products. The rest of it, though, contains the type of bargains that you have come to associate with Greenweld.

Greenweld say that they hold quite literally thousands of lines, from resistors and capacitors to power supplies and electric motors; from surplus electronic bargains, hardware and tools to radio controlled models and hobbyist equipment.

Interestingly, Greenweld say that they will produce a fuller catalogue next year, and that it will be a "truly bumper edition". They also periodically issue a free E-mail News and Latest Surplus Arrivals listing.

For more information contact Greenweld Ltd, Dept EPE, PO Box 144, Hoddesdon, Herts EN11 0ZG. Tel: 01277 811042. Fax: 01277 812 419.

E-mail: **service@greenweld.co.uk**.

Web: **www.greenweld.co.uk**.

CAR VOLTAGE TO BECOME 42V

By Barry Fox

EARLY motor cars used 6 volt batteries but over the last fifty years 12 volts (in practice usually 13·8 volts) has become the *de facto* standard. The motor industry is now on track to increase the working voltage from today's 12/13·8V to 42V. Philips has developed a range of 42V controllers in readiness for production line changes expected in 2003.

Cars are becoming mobile offices and entertainment centres, with the engine, brakes, steering, air-conditioning and safety systems all under electric and computer control. This has already pushed power consumption past one kilowatt and drains of around 4kW are expected in the near future.

Two years ago the Massachussetts Institute of Technology proposed a voltage hike to 36V. Now the manufacturers favour a larger leap, to 42V. Tripling the voltage reduces current flow to a third, letting thinner and less expensive wires carry the power needed without risk of overheating. The voltage change means a complete re-design of all the electronic and electromagnetic components. So the change will only affect new models.

EXPERIMENTING WITH BRUNNING

BRUNNING Software have announced the fourth release in their *Experimenting with . . .* series, titled *Experimenting with the PIC16F877*. It is a companion to their existing *Experimenting with PIC Microcontrollers*, but largely assumes no prior knowledge of PICs.

Peter Brunning tells us that he starts the discussion with the simplest of all experiments to provide you with a basic understanding before moving on to other programming techniques and demonstrations, including some based on the PIC16F877's 10-bit A/D converter. A new version of Brunning's PIC Assembler has also been created to complement the book.

The book together with the latest software suite is £45 inclusive. It is available from Brunning Software, Dept EPE, 138 The Street, Little Clacton, Clacton-on-Sea, Essex CO16 9LS. Tel: 01255 862308.

Sherwood Catalogue

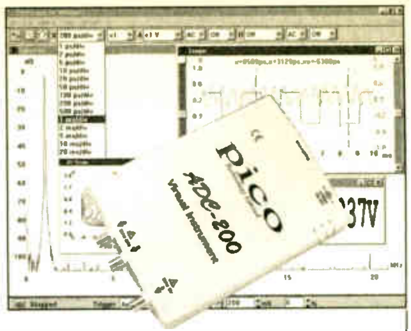
REGULAR advertisers Sherwood Electronics have released their 2001 edition catalogue. Costing £1 and with around 100 A5 pages, it itemises a good variety of commonplace components needed by any regular hobbyist designer/constructor.

Whilst the ranges are not stocked "in-depth", if you are after "everyday" component types, this catalogue is worth adding to your library. There is £1 pound's worth of discount vouchers included to offset the cost of the catalogue.

For more information contact Sherwood Electronics, Dept EPE, 7 Williamson Street, Mansfield, Notts NG19 6TD.

INGENUITY UNLIMITED

Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**
Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. (We **do not** accept submissions for *IU* via E-mail.)
Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE

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

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours.
Every six months, Pico Technology will be awarding an ADC200-50 digital storage oscilloscope for the best IU submission. In addition, two single channel ADC-40s will be presented to the runners-up.

Wide Range Squarewave Generator – Mark the Space

ANYONE considering building a variable frequency squarewave generator might choose the ubiquitous NE555 or its low power counterpart (ICM7555) running as an astable oscillator. Unfortunately, if the frequency is varied by changing the timing resistor, not only does the frequency change but the mark/space ratio as well.

The squarewave generator proposed in Fig.1 uses an op.amp operating as an astable oscillator. It produces near text-book perfect square waves with a 1:1 mark/space ratio throughout its wide range of 0·3Hz. to 300kHz., in six switched decade ranges.

An EL2045C (IC1) is used as a comparator with a push-pull output stage. The output at pin 6 will swing almost to either power supply rail depending on which input is the more positive. The timing capacitor (C2 to C7) is selected by rotary switch S1 and charged and discharged via resistor R3 and multi-turn preset VR1, which alters the frequency over the selected range. Resistors R1, R2 and capacitor C1 provide a mid-rail bias voltage for the op.amp.

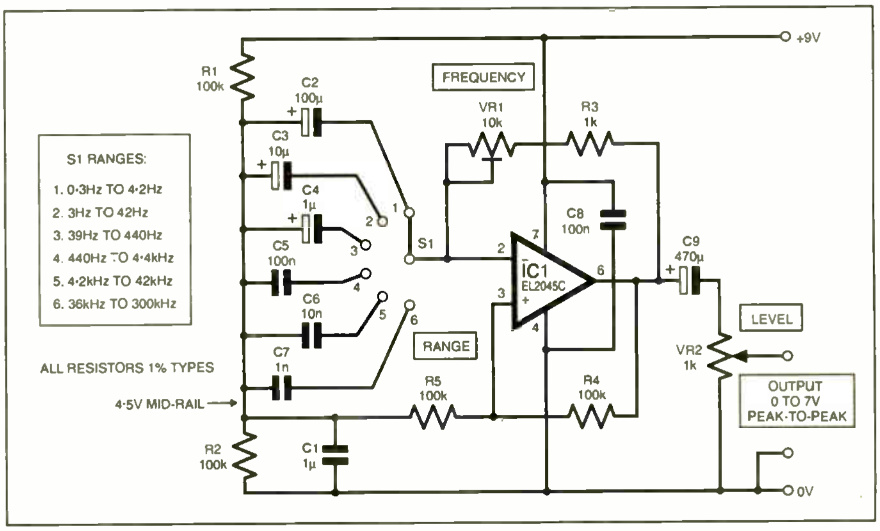


Fig.1. Wide Range Squarewave Generator circuit diagram. Note that VR1 should be a multi-turn type.

Oscillations are produced as follows. Assuming that the mid-rail is already established and the timing capacitor (C2 to C7) is discharged, the voltage at IC1 pin 2 is 4·5V. The output on pin 6 swings close to the positive rail (8V approx.) and the voltage at pin 3 will be at 6·25V. The timing capacitor will charge via VR1 and R3 until it exceeds 6·25V.

At this point the output of the op.amp will swing close to the 0V rail – approximately 1V. The voltage at pin 3 will instantaneously switch to 2·75V and the timing capacitor will be discharged until this new threshold is crossed; then the op.amp output switches back to 8V. This cycle continues repeatedly, thus sustaining oscillations.

The op.amp output (pin 6) is taken, via C9, to control potentiometer VR2 which forms a basic attenuator. The decoupling capacitor is large in value due to the low frequencies involved on the first two ranges of the oscillator. To ensure good performance at high frequencies a physically small 100nF decoupling capacitor, C8, is soldered directly across the positive and negative supply pins on IC1.

D.Allen, Cheltenham, Glocs.

PICO PRIZEWINNERS – JANUARY 2001

It's time once again to award three lucky *Ingenuity Unlimited* contributors with prizes of superb PC-based oscilloscopes, generously donated to *Everyday Practical Electronics* by PICO Technology, to whom we extended our thanks once again for sponsoring the column. You can learn more about PICO's groundbreaking range of PC oscilloscopes by checking their web site at **www.picotech.com**.

All entries were judged on the criteria of originality, "lateral thinking" or novelty, technical merit, resourcefulness, appropriateness and overall completeness. Presentation was used as a tie breaker. The final choices were selected by *EPE* Editor Mike Kenward and *Ingenuity Unlimited* host Alan Winstanley from the circuits published in the June-December 2000 issues.

WINNER – receives a superb top of the range PICO AD200-50 Digital Storage Oscilloscope, worth over £450!

Steve Dellow – MACROVISION BLANKER (November 2000)

This fully-developed discrete circuit offered an alternative way of blanking Macrovision signals without resorting to the complex programming of a microcontroller.

RUNNERS-UP – two readers are lucky winners of PICO ADC-40 single-channel PC-based oscilloscopes.

Lim Chung – VOM Continuity Buzzer (August 2000)

This practical circuit showed how a moving-coil multimeter could benefit from the addition of a continuity buzzer.

David Corder – Missed Call Indicator (December 2000)

This circuit is a simple, convenient and non-invasive way of monitoring telephones in order to alert the user to a missed call.

Etch Tank/UV Light Box Control System – The Right Time

THE circuit diagram shown in Fig.2 is a combined circuit board etch tank and UV light box controller which may be of use to anybody who fabricates their own p.c.b.s (printed circuit boards) on a regular basis.

Etchant temperature is measured with a thermistor (R18), which is placed inside the tank and protected by a thick plastic bag. The single supply op.amp IC1 forms a simple comparator, with hysteresis provided by resistor R5 to ensure a clean switching action for the heater. Potentiometer VR1 controls the heater switching point and should be adjusted so that it switches off at approximately 40°C to 45°C. The heater is switched through transistor TR1 and relay RLA; l.e.d. D1 indicates that the unit is heating.

The etch tank temperature is displayed by the bargraph l.e.d. driver IC2 and l.e.d.s. D2 to D11, which are colour-coded yellow, green and red. Although a standard negative-temperature co-efficient (n.t.c.) thermistor is a non-linear device, the limited range in which it is used here provides adequate linearity.

Preset VR2 adjusts the temperature scale and should be set so that the heater switches *off* just before the green l.e.d. D9 illuminates. If either of the red l.e.d.s illuminates, then the heater switch-on point should be lowered using Temperature Set control VR1.

The UV light box controller uses a ready-made countdown timer for good accuracy and versatility together with a built-in display. The prototype circuit utilised the Maplin RJ82D Timer, which must be carefully opened and modified by soldering an output lead to each connection on the piezo sounder. A small hole must then be drilled into the back and the leads pushed through so that they can access the outside world. *This will obviously invalidate any guarantee.*

The timer is interfaced with the circuit via the potential divider resistors R11 and R12, and is connected to an OR gate (IC3) constructed from a 74LS00 quad 2-input NAND gate (see inset). The positive feedback causes the output to latch when the countdown timer expires and the alarm sounds.

Capacitors C1 and C2 aid reliable operation and prevent spurious triggering, and the push-to-break switch S2 resets the latch. Transistor TR3 switches the normally closed relay contacts RLB, l.e.d. D12 illuminating when the light box has been switched off.

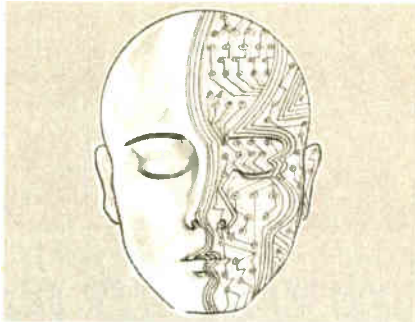
It should be noted that switching some types of load (e.g. an air pump aerator) on the same mains plug socket may cause unwanted triggering, however this can be remedied by using a mains-rated *RC* snubber or filter if necessary.

The circuit is powered by a 9V 500mA supply and regulated by IC4; preset VR3 being adjusted for a rail voltage of 6·25V. Resistor R15 and Zener diode D16 provide 5·1V for the TTL logic chip, and can be omitted if a CMOS device is used for IC3 instead.

Power consumption is quite high when most of the l.e.d.s are on and both relays are energized, and the current drawn from the supply can exceed 300mA. Leave pin 9 of IC2 floating for a moving dot display which draws less current.

M. A. Jones,
Harrogate, North Yorks.

WHY NOT SEND US YOUR CIRCUIT IDEA
Earn some extra cash and possibly a prize!



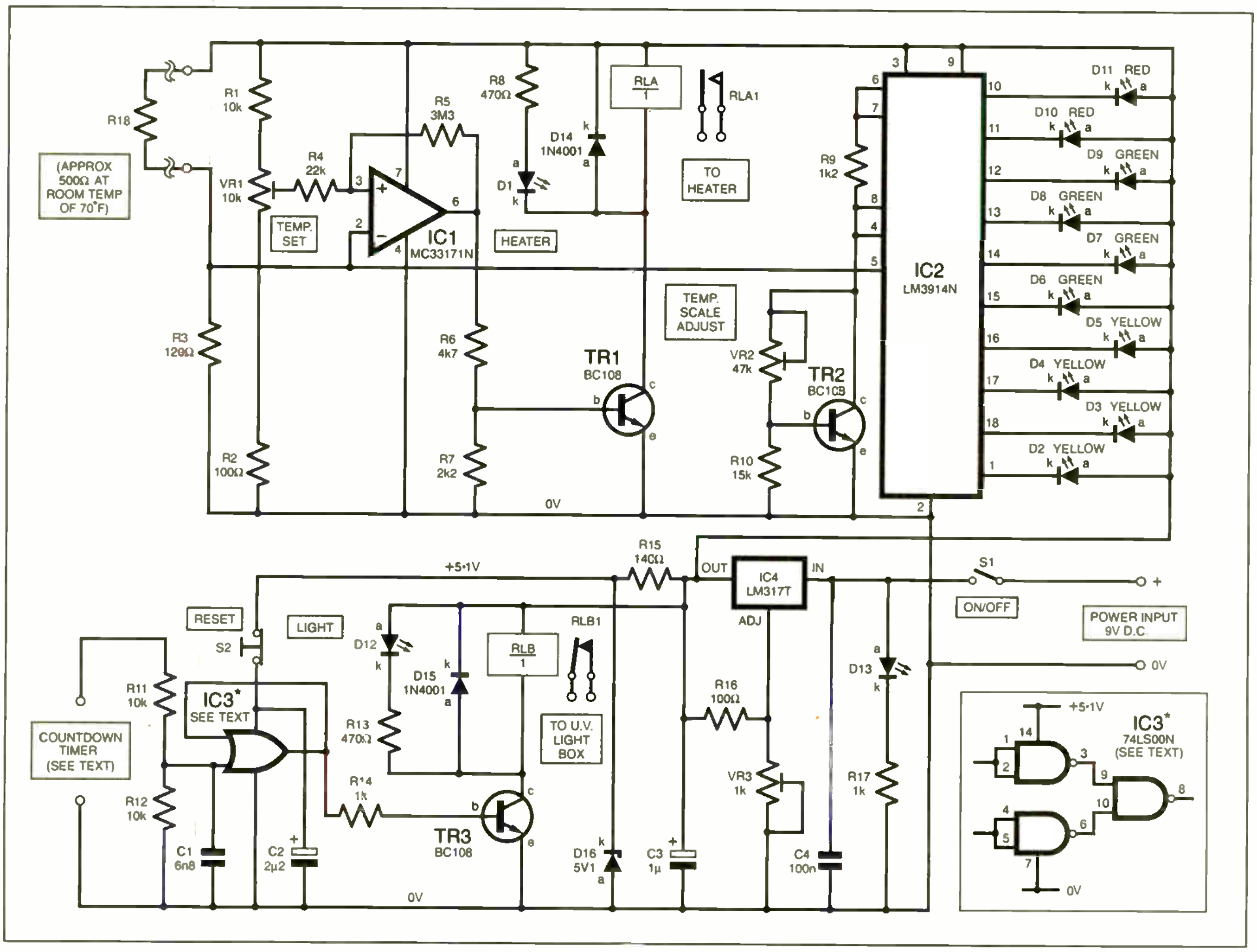
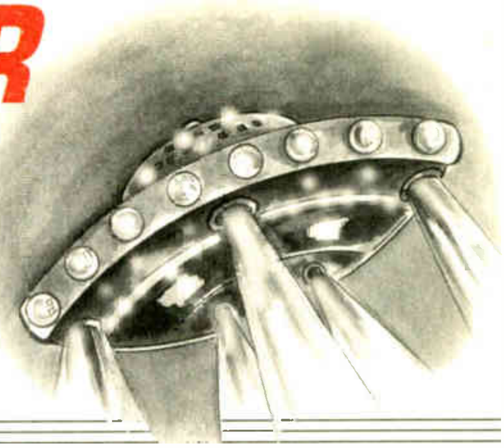


Fig.2. Circuit diagram for a combined Etch Tank/UV Light Box Control System.

Constructional Project

UFO DETECTOR AND EVENT RECORDER



RAYMOND HAIGH

Are you a die-hard disbeliever, or could alien space ships really be crossing the sky at night? This equipment might provide the proof you've been searching for (and detect "normal" magnetic field movements).

ALTHOUGH some ancient texts are said to contain references to spacecraft, the UFO (Unidentified Flying Object) enigma really began on the afternoon of June 24, 1947, when aircraft pilot Kenneth Arnold reported nine crescent-shaped objects crossing the sky at great speed near Mount Rainier in the State of Washington, USA.

Since then there have been countless sightings world-wide, and private and government organisations have been set up to investigate and report on the phenomena. And there has been no shortage of encounters to fill the researchers' files.

Whilst many incidents have been shown to have a terrestrial origin, there remains a solid core of cases where inexplicable phenomena and reliable witnesses combine to challenge our disbelief.

One thing running like a thread through many of the reports is the powerful magnetic disturbance which accompanies the craft. Car and aircraft ignition systems falter or fail (presumably the ignition coil core becomes saturated), and dashboard and navigation instruments behave erratically.

As recently as the 30 March 2000, a family travelling along the Klondike Highway in Canada claim to have observed a saucer-shaped UFO closing on their car. Headlights dimmed, the tape recorder stopped playing and battery operated watches malfunctioned.

The equipment described here will detect and record far weaker magnetic perturbations than these. Stand-by current is extremely low, and the battery powered units can be operated economically in remote locations.

DETECTION METHODS

Three methods of detecting changes in a magnetic field were explored during the development of the unit. First, Hall effect devices, in which the field induces a voltage in a strip of semiconductor material. Second, an oscillator with a magnetically polarised ferrite core in its tuning inductor. Third, and the oldest of them all, the magnetic compass.

Experiments revealed that the best results could be obtained, with least complexity and cost, by adapting the traditional magnetic compass.

DETECTOR CIRCUIT

The complete circuit diagram of the equipment is shown in Fig.1. It comprises two units: a Detector which responds to changes in the ambient magnetic field, and a Chart Recorder with visual and audible alarms.

Infra-red (IR) light emitted by diode D1 is screened from the base of phototransistor TR1 by a vane attached to the end of a compass needle. With the vane blocking the radiation, the current through TR1 is extremely small, typically 5nA. When the compass is deflected by a magnetic disturbance, infra-red reaches TR1 and current flow increases dramatically.

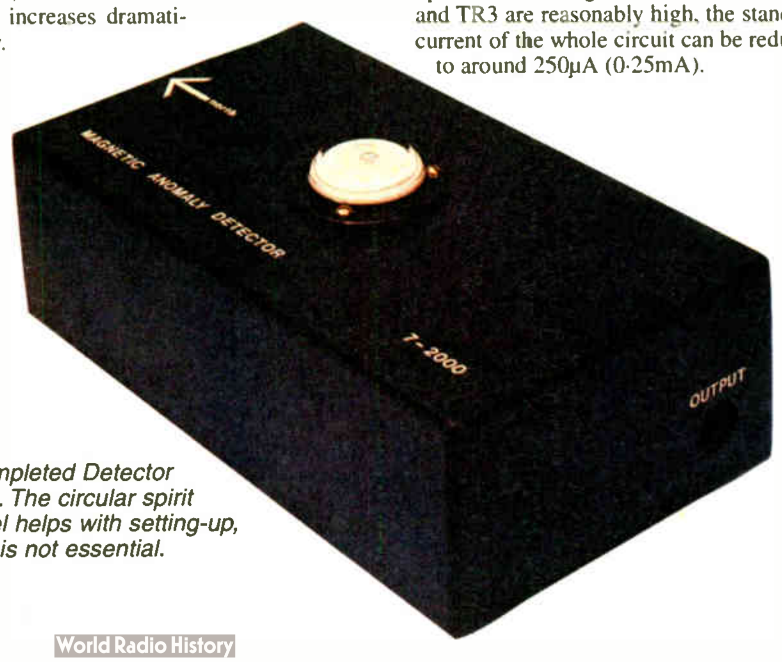
Transistors TR2 and TR3, configured as a Darlington pair, amplify this current to a level where it can actuate a relay (RLA).

The operating point of the circuit is controlled by preset potentiometer VR1, which enables the "on" current to be set so that the relay just triggers.

Diode D2, connected across the relay coil, clips the voltage spike which occurs when the current is switched off.

The combination of the phototransistor, TR1, and Darlington pair, TR2 and TR3, makes the circuit extremely sensitive. A phototransistor is around 100 times more sensitive than a photodiode, and the gain of a Darlington pair is equal to the product of the gains of its two transistors (i.e., TR2 h_{FE} × TR3 h_{FE}).

This, together with the close proximity of the infra-red devices, enables the circuit to function with a low current through IR diode D1. Preset potentiometer VR2 enables it to be reduced to the lowest possible level consistent with reliable operation. If the gains of transistors TR2 and TR3 are reasonably high, the stand-by current of the whole circuit can be reduced to around 250µA (0·25mA).



Completed Detector unit. The circular spirit level helps with setting-up, but is not essential.

EVENT RECORDER

Being able to detect weak magnetic anomalies is not a lot of use without some means of recording them and the time when they occur. The event recorder comprises a paper chart wrapped around a drum (a Bird's Custard container!) which is rotated once every twenty-four hours by a quartz clock movement. Events are recorded on the chart by a pen driven across it by a small electric motor.

The circuit used to limit the travel of the pen and control the direction of the electric motor is similar to that used in satellite dish drives.

Reference to the photographs, and Fig.5 later, together with the circuit diagram, should help to make the following description clear.

When the relay (RLA) is actuated, current is applied to the motor (M1) which begins to turn a threaded rod anti-clockwise, drawing the pen carrier to the right. Diode D3, wired across limit switch S1, permits current to flow until the carrier has moved far enough for S1 to close.

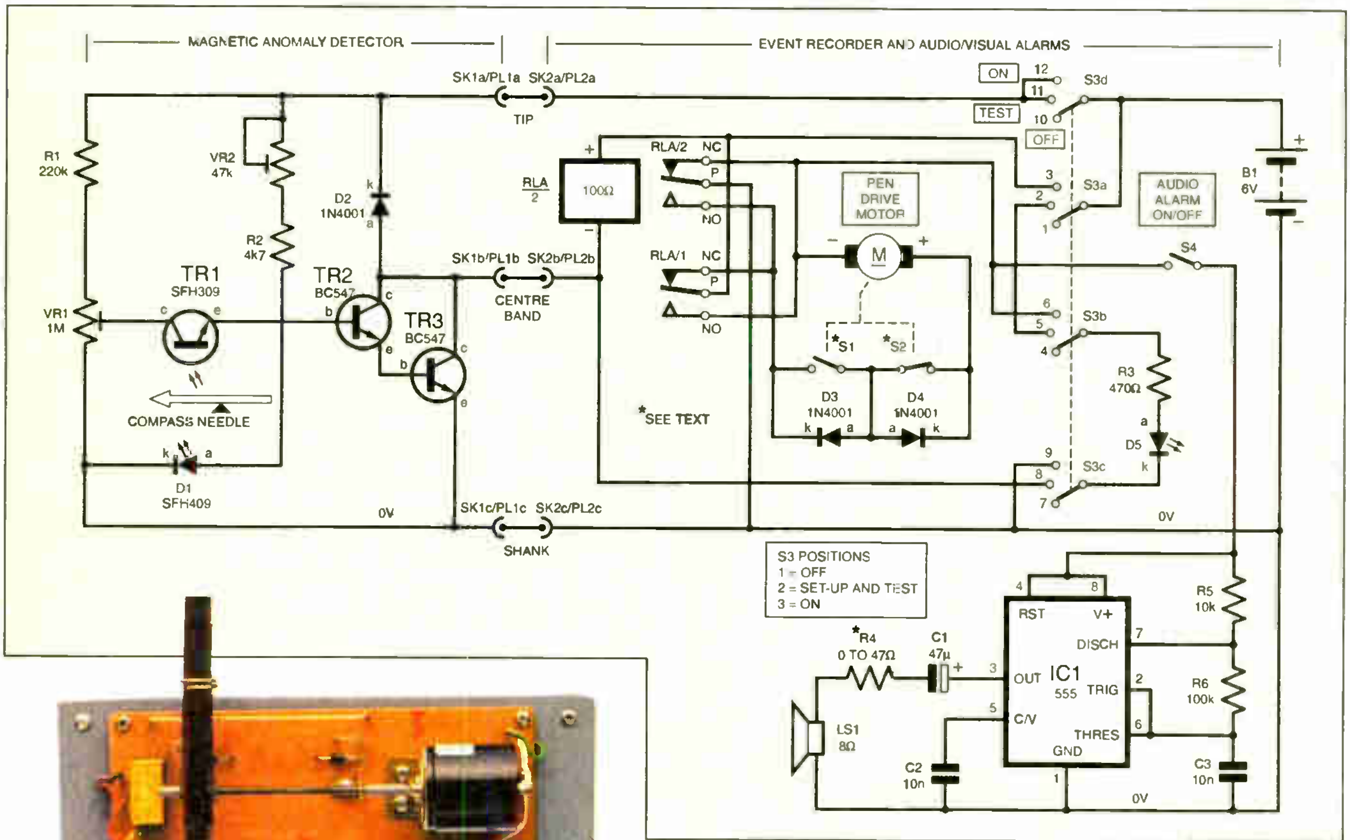
On reaching the motor end of the rod, the carrier forces S2 open and, as diode D4 is connected to oppose the current flow, the motor is switched off.

When the detector stops activating the relay, the relay's changeover contacts reverse the polarity of the voltage to the motor. Diode D4, across the open contacts of S2, will now conduct and the motor begins to rotate the threaded rod clockwise, driving the pen towards the left until limit switch S1 is opened. The system has now returned to its original "at rest" position, ready to be triggered by the next event.

The 4-pole 3-way rotary switch, S3, connects light emitting diode (l.e.d.) D5, together with its current limiting resistor, R3, into circuit in place of the relay coil. This permits the setting up and testing of the equipment without the pen being driven across the chart.

ALARM CALL

The pen driver operates fairly silently, and an audible warning of an event is desirable. A tone is provided by a 555 timer, IC1, connected as an astable multivibrator. Frequency of oscillation is determined by resistor R6 and capacitor C3, and the stated values produce a signal of around 800Hz.



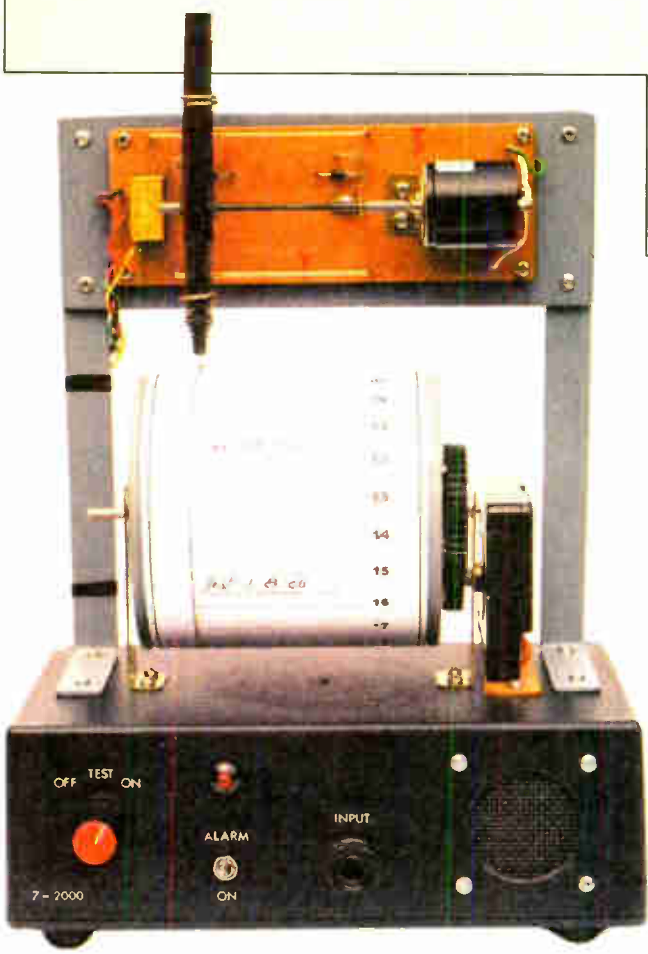


Fig.1. Complete circuit diagram of the UFO Detector and Event Recorder. The circuit consists of a Magnetic Anomaly Detector, 24-hour Event Recorder and Audio/Visual Alarms.

(Left). The completed Event Recorder and Alarm Unit.

The unused control voltage input, pin 5, is bypassed by C2, and blocking capacitor C1 prevents the flow of d.c. through the speaker coil, LS1.

Standard versions of the 555 (do *not* use the 7555 low power variant) can deliver up to 200mA at pin 3. This is more than sufficient to produce a loud tone in a small speaker operating at 800Hz.

Current drawn by IC1 with a 6V supply and an 8Ω speaker is around 50mA; well within the capabilities of the device. If higher supply voltages are used to suit a particular relay, a resistor, R4, should be connected in series with the speaker to limit current flow. A 22Ω resistor is suitable with 9V supplies, and a 47Ω component should be fitted when the supply is 12V. This limits the flow of current to about 50mA in all cases.

Control switch S3 connects l.e.d. D5 as a visual alarm when the system is "on". Visual and audio alarms are connected to the negative terminal of the motor and are triggered "on" immediately the relay activates the system.

They go off when there is no signal or voltage from the detector unit and the motor is driving the pen back to its "at rest" position.

The audio alarm is quite penetrating, and toggle switch S4 is included to disconnect it if required.

COMPONENT CONSIDERATIONS

The circuit is not critical, and the inclusion of presets VR1 and VR2 enable it to be adjusted to accommodate a wide range of transistor and diode types. Certain requirements must, however, be observed if the lowest levels of stand-by current are to be achieved.

The specified infra-red diode and phototransistor are manufactured by Siemens, but a variety of similar devices were tried in the circuit and they all worked well. Older phototransistors may have a base lead: it should be ignored.

For best results, transistors TR2 and TR3 must have a d.c. gain (h_{FE}) in excess of 120 when the collector current is no more than 2mA. They should also be capable of sinking the current needed to actuate the relay.

The BC547, BC239 and 2N3711 devices all worked well in the prototype.

Maximum collector current for the 2N3711 is, however, rather low (30mA), and the relay coil must be capable of working within this limit if this device is used.

Although not tried, the 2N3390, 2N3391, 2N3392 and 2N3395 should work well without this restraint. Case styles and base connections for the alternative devices will vary and should be checked.

Relay sensitivity will determine the "on" current of the circuit. A 4·5V to 6V unit is recommended, and its coil resistance should preferably be 100 ohms or higher. The recommended types will switch reliably with a current of around 30mA.

COMPONENTS

Approx. Cost Guidance Only **£27**
excluding cases, batt, hardware

See SHOP TALK page

Resistors

R1	220k
R2	4k7
R3	470Ω (see text)
R4	0Ω (wire link) or 22Ω or 47Ω (see text)
R5	10k
R6	100k

All 0·25W, 5% carbon film or better.

Potentiometers

VR1	1M preset, round
VR2	47k preset, round

Capacitors

C1	47µ radial elect. 16V
C2, C3	10n ceramic (2 off)

Semiconductors

D1	SFH409 infra-red diode (see text)
D2 to D4	1N4001 rect. diode (3 off)
D5	red l.e.d.
TR1	SFH309 phototransistor (see text)
TR2, TR3	BC547 *npn* transistor (see text) (2 off)
IC1	555 timer (see text)

Miscellaneous

RLA	2-pole changeover, d.i.l., 4·5V to 6V coil, 100 ohms approx (see text)
S1, S2	see text
S3	4-pole 3-way, rotary switch
S4	min. s.p.d.t. toggle switch
SK1, SK2	stereo 6mm jack socket (non-magnetic, see text) (2 off)
PL1, PL2	stereo 6mm jack plug (non-magnetic, see text) (2 off)
LS1	8 ohm 38mm dia. loudspeaker

Printed circuit board set, available from the *EPE PCB Service*, codes, 283 (Mag. Det.), 284 (Event Rec.) and 285 (Alarm); plastic box, 191mm x 106mm x 52mm internally (2 off); 6V battery; 8-pin d.i.l. socket; 16-pin d.i.l. socket (to suit relay); l.e.d. holder, panel mounting; 1mm terminal pins; hook-up wire; 3-core connecting cable (approx. 2 metres).

HARDWARE

Quartz clock movement and 2:1 reduction gears; 4·5V to 12V d.c. motor (see text); control knob for rotary switch S3; optional circular spirit level (see text); piano wire, 24s.w.g. (approx. 0·5mm); brass wire, 18s.w.g. (approx. 1·2mm) and 24s.w.g.; brass and aluminium strip; brass nuts, bolts and stand-offs; threaded rod, 6BA; ball-point pen top; Bird's Custard tin(!) or similar; superglue; black plastic insulating tape; small piece of hardboard or plywood.

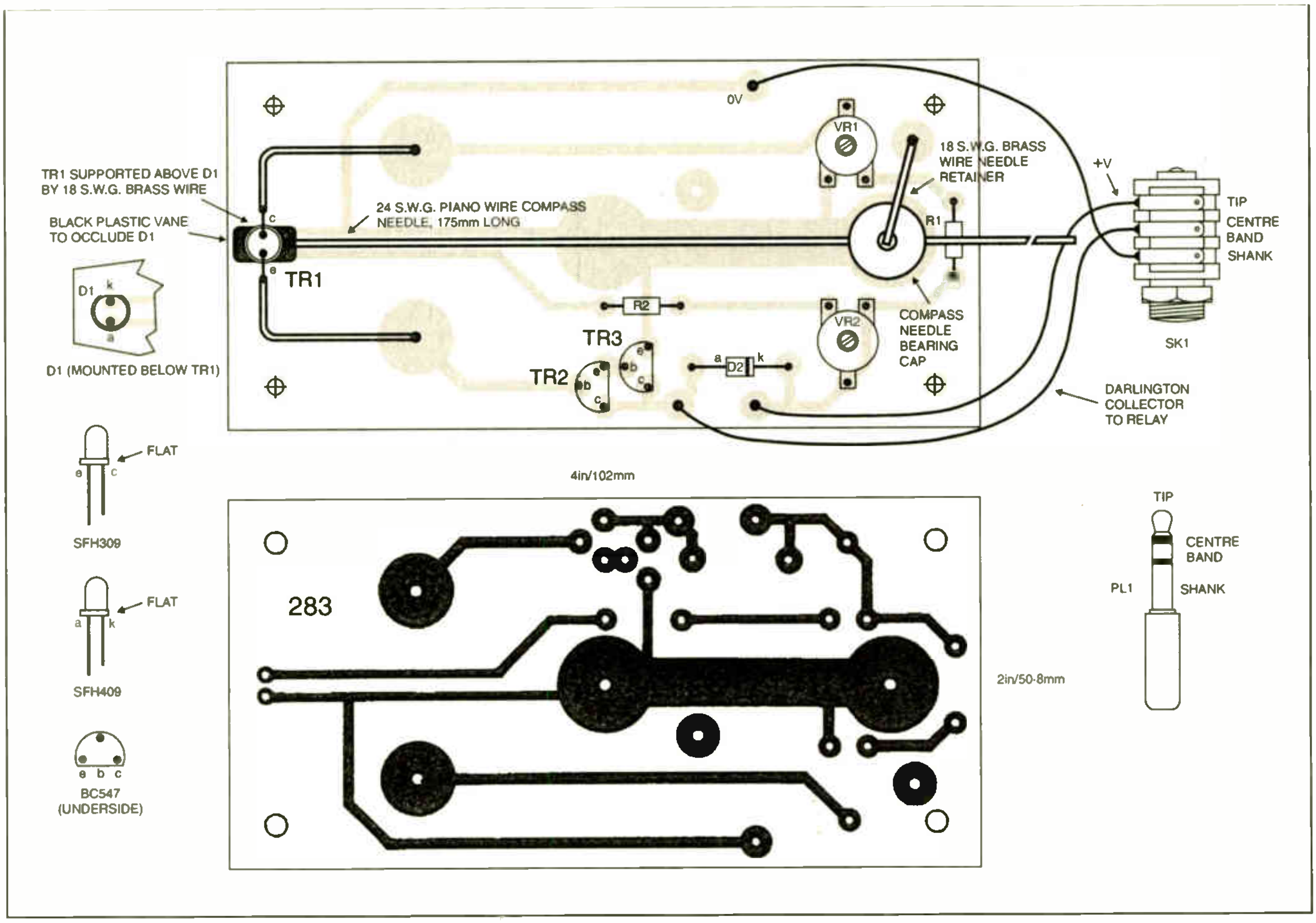


Fig.2. Magnetic Anomaly Detector printed circuit board details and wiring. Provision is made for a shorter, 100mm, compass needle to reduce unit size.

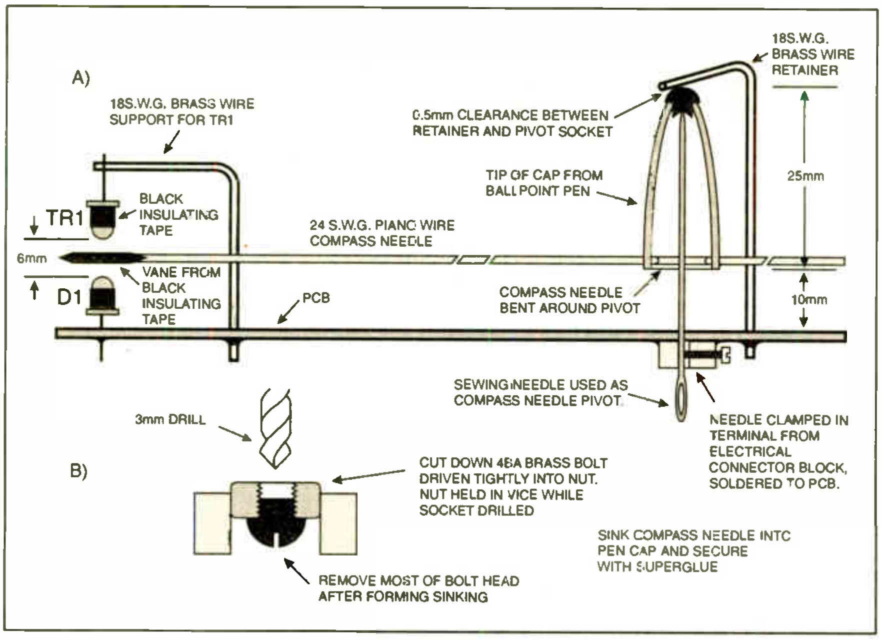


Fig.3. Suspending the compass needle between the phototransistor and IR diode. (a) section through compass pivot and (b) how to centre the sinking for the pivot socket.

Most relays will operate at 75 per cent of their rated voltage, and a 9V supply should suffice if a 12V relay is fitted. Keeping the supply voltage as low as possible will help to minimise standby current.

Miniature relays are often polarised by the inclusion of a permanent magnet. *They will only operate when the coil voltage is of the correct polarity.*

MECHANICAL CONSIDERATIONS

Very little torque is needed to drive the pen carrier, and almost any small d.c. electric motor should be satisfactory. Motors salvaged from battery operated tape recorders have a low current drain and this makes them particularly suitable.

Relay and motor operating voltages should roughly match, but the demands on the motor are so light that a 12V unit will usually deliver sufficient torque when supplied with 6V or even less.

Brass wire is used for limit switches, guides and supports, and piano wire is used for the compass needle. Brass strip is ideal for the pen carrier and spindle brackets.

Materials of this kind, together with small motors and reduction gears, are retailed by most model shops. All of the other components required to construct the units, with the exception of brass and steel wire (and Bird's Custard), are readily obtainable from many electronic suppliers (this month's *Shoptalk* page discusses some options).

A permanent bar magnet is needed to magnetise the compass needle. The rectangular ferrite units in cheap door catches are ideal. They are usually mounted in a plastic housing which is easy to prise open. Note that one large face is the north seeking pole, the other the south. These catches are retailed by almost all DIY stores.

CONSTRUCTION

Most of the components, including the compass needle, relay and pen drive motor, are mounted on printed circuit boards (p.c.b.s). This makes the construction process easier and should ensure good results.

There are three p.c.b.s, one each for the Magnetic Anomaly Detector, Event Recorder and Audio Alarm. These boards are available, as a set, from the *EPE* PCB Service, codes 283, 284 and 285 respectively.

Terminal pins, inserted at the lead-out points, will simplify the task of inter-board wiring, and holders (sockets) for IC1 and the relay are recommended. Mount the smallest components first, and solder the transistors and diodes into place last.

DETECTOR BOARD

Ferrous metals must be avoided in the construction of the Detector unit.

The only exceptions are the compass needle itself and the sewing needle which acts as its vertical pivot. Check doubtful items with the cupboard catch magnet. If non-ferrous jack plugs and sockets (PL1/PL2, SK1/SK2) cannot be obtained, adopt some other plug and socket system, or simply connect the cable directly to the board.

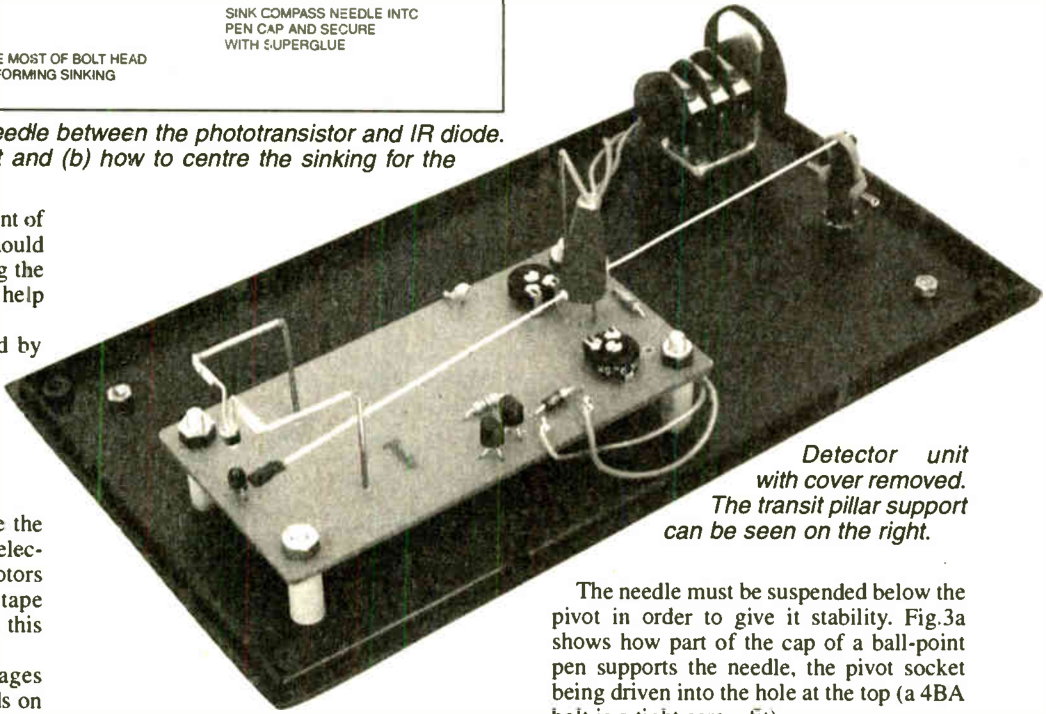
The component and track layout details of the Detector board are given in Fig.2. Phototransistor TR1 is supported above infra-red diode D1 by brass wires, which also limit the swing of the compass needle. Ensure the correct orientation of the semiconductors.

The illustration in Fig.3a shows how the vertical pivot is held in position by a grub screw and socket soldered to the underside of the p.c.b. The socket can be cut from an electrical terminal terminal block (the type encased in polythene).

With this method of mounting, the height of the pivot is easy to adjust.

MAKING THE COMPASS

A long compass needle is more sensitive than a short one, and the prototype uses an 175mm length of 24s.w.g. piano wire. Thicker wire can be used, but this will increase the load (and the friction) on the pivot. Some readers may wish to construct a smaller unit, and a pivot point is provided on the p.c.b. for a shorter, 100mm needle.



Detector unit with cover removed. The transit pillar support can be seen on the right.

The needle must be suspended below the pivot in order to give it stability. Fig.3a shows how part of the cap of a ball-point pen supports the needle, the pivot socket being driven into the hole at the top (a 4BA bolt is a tight screw fit).

Bend the compass needle around the pivot, sink it into two shallow slits cut into the pen cap, and secure it with superglue.

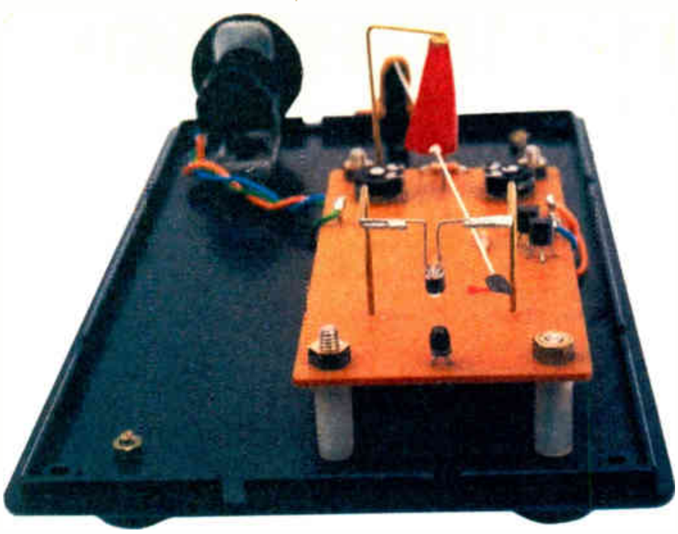
Centralising a socket in the end of a 4BA bolt can be tricky. Fig.3b shows how this can be done. If a slight flat remains at the bottom of the socket after using the 3mm drill, gently, and briefly, apply a smaller drill to remove it. When the socket is satisfactory, file away the bulk of the bolt head to reduce weight.

If the needle dips, slide a 2mm length of insulation stripped from a thin wire along the high side to balance it. A brass wire retainer, bent over the pivot but kept just clear, holds the needle "cap" in place whilst the unit is in transit.

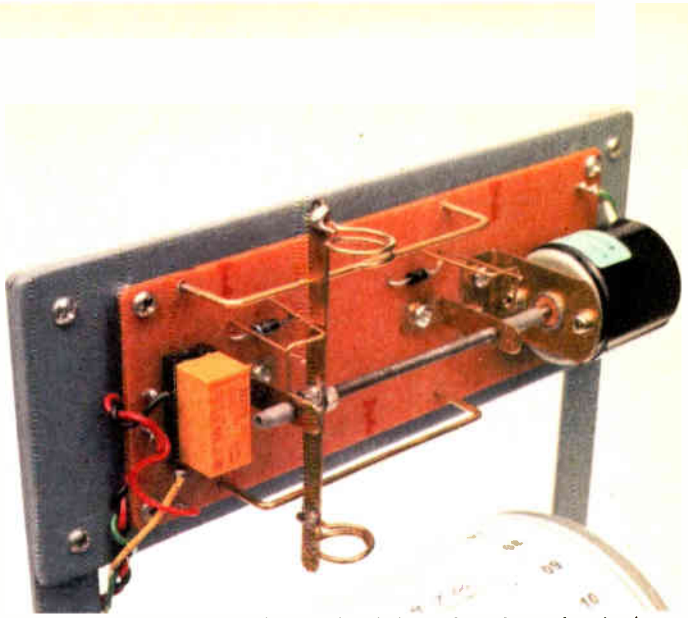
Draw one face (pole) of the cupboard catch magnet slowly down the compass needle, lift it well clear, then repeat the action, in the same direction. Piano wire is made from very hard steel which produces an excellent permanent magnet, and a dozen strokes should suffice.

BLOCKING INFRA-RED

Stick a fold (double thickness) of black plastic insulating tape at the north seeking end of the compass needle, and trim its width down to a little more than the diameter of the infra-red diode (D1).



Detector unit close-up, showing the phototransistor suspended above the infra-red diode.



Event Recorder pen drive printed circuit board and mechanical assembly.

It is a good idea to wind narrow strips of black tape around the bodies of the diode and phototransistor to ensure that the infra-red beam is contained within the diameter of the devices.

ENCLOSURE

The prototype is mounted in a 191mm × 106mm × 52mm (internally) black plastic box, and the finished unit is depicted in the photographs. The circular spirit level on top of the enclosure can be a help when setting up the unit, but is not essential.

In the photographed unit the compass needle has been painted white to make it stand out. In most of the shots it is secured by the rubber band, used to restrain it whilst the unit is in transit, to avoid a blurred image. The restraining arrangement comprises a short length of potentiometer spindle superglued to the base (see photos).

Note that quite low levels of light will raise the stand-by current appreciably, and may even trigger the relay. The enclosure must, therefore, be completely light-proof.

EVENT RECORDER

The component and track layout details of the p.c.b. for the Pen Drive unit are illustrated in Fig.5. There is sufficient space for a drive motor of any reasonable size, and the tracks will accommodate either of the standard dual-in-line (d.i.l.) relay bases illustrated in Fig.4. Other types of relay can be mounted on the p.c.b. and connected to it with hook-up wire.

Limit switches S1 and S2 are formed from 24s.w.g. brass wire. This material is springy and solders easily. After soldering into place, the switch leaves should be bent until they make a good, firm contact.

Nuts, soldered to the brass strip which carries the pen, enable the threaded rod to drive it from side to side. Clean and tin the strip and the faces of the nuts, then hold the items together on a greased 6BA bolt whilst the soldering iron is applied to sweat the items together. An 18 watt iron is more than capable of providing sufficient heat.

Support the rod with two angle brackets bolted to the p.c.b., and link the rod to the motor shaft with a short length of cable insulation. Care must, of course, be taken to ensure that rod and spindle are in alignment. Apply a little grease to the rod to ensure smooth operation.

Motor polarity (i.e., the supply connections for clockwise rotation), the orientation of the diodes, and the wiring to the relay which reverses the polarity of the supply, must all be carefully duplicated or the mechanism will not function.

DRUM AND DRIVE

The chart drum on the prototype is a Bird's Custard tin, but similar containers would be equally suitable. The drive gear is mounted on 6mm stand-offs to ensure that it clears the rim. Drum spindles are 6BA bolts with large washers to stiffen the fixings. Use drawing compasses to determine the precise centre of the lid and base.

Slots, cut down to the spindle holes in the brackets which support the drum, allow it to be lifted out for chart changing.

An inexpensive quartz clock movement drives the drum via 2:1 gearing to give a 24-hour rotation time. The spindle hole in the smaller gear must be gradually enlarged or reamed out until it is a good friction fit on the movement's hour shaft. Position the movement on the base box so that the gears mesh fully, but not tightly.

ENCLOSURE AND BASE

The Pen Drive unit p.c.b. is mounted on a hardboard panel supported above the drum by two brackets formed from 15mm × 2mm aluminium strip. The base of the unit is another 191mm × 106mm × 52mm plastic box. This houses the batteries, the Audio Alarm PCB, and the loudspeaker.

Control switch S3, toggle switch S4, indicator D5, and the input jack socket are mounted on one of the box sides. The arrangement is shown in the photographs.

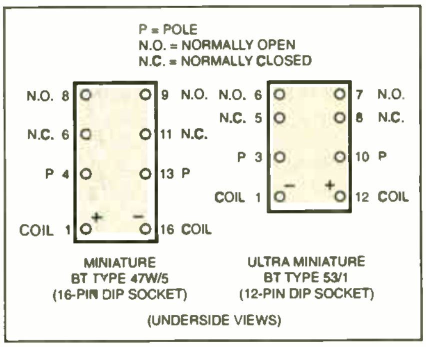
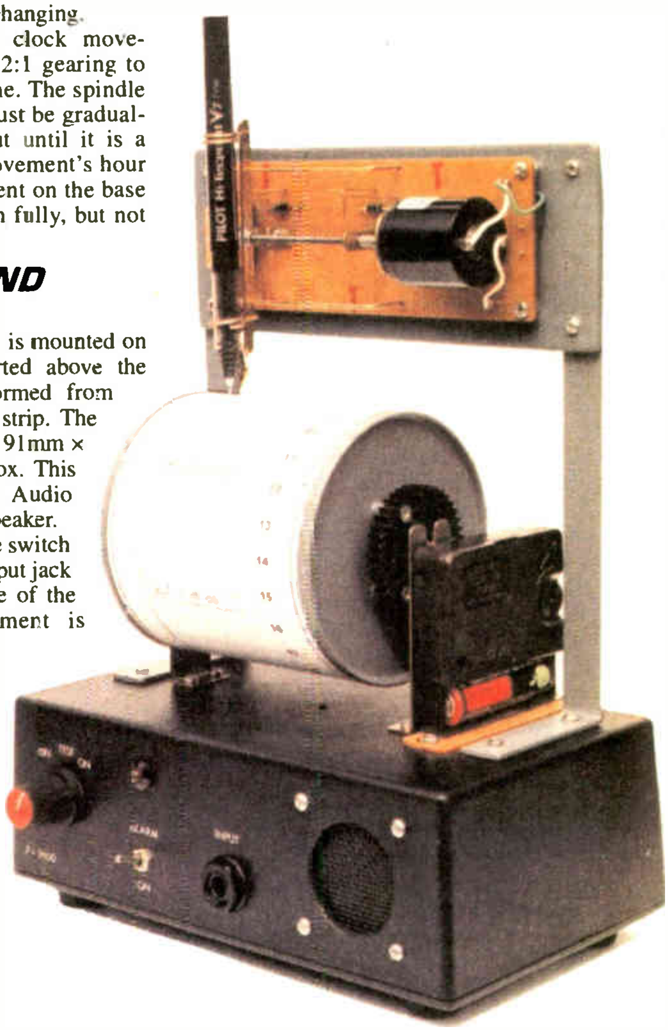
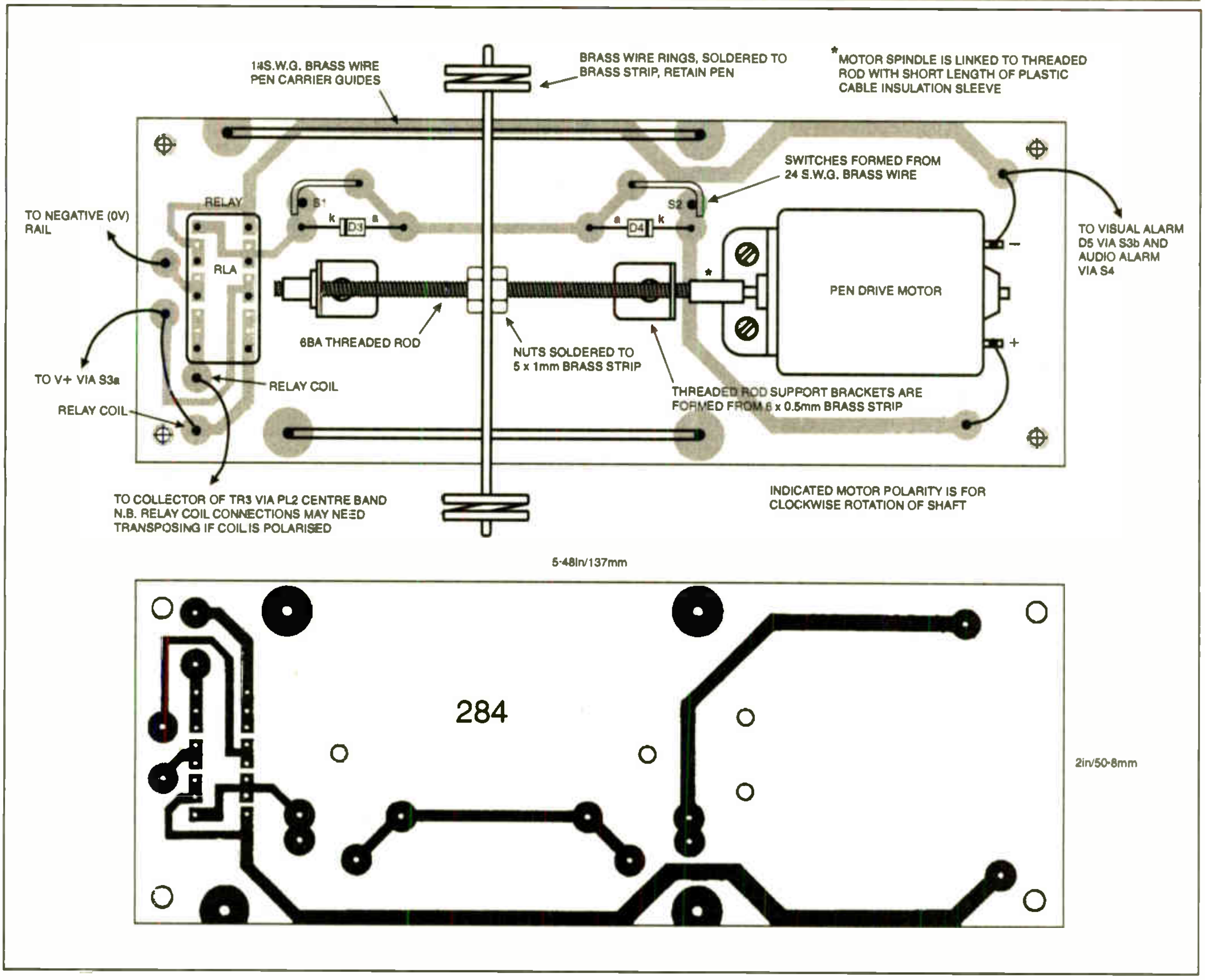


Fig.4. Relay pinout details.



Completed Event Recorder showing the pen drive assembly, chart drum and base containing the Audio/Visual Alarm components.

EVENT RECORDER PEN DRIVE AND ALARM



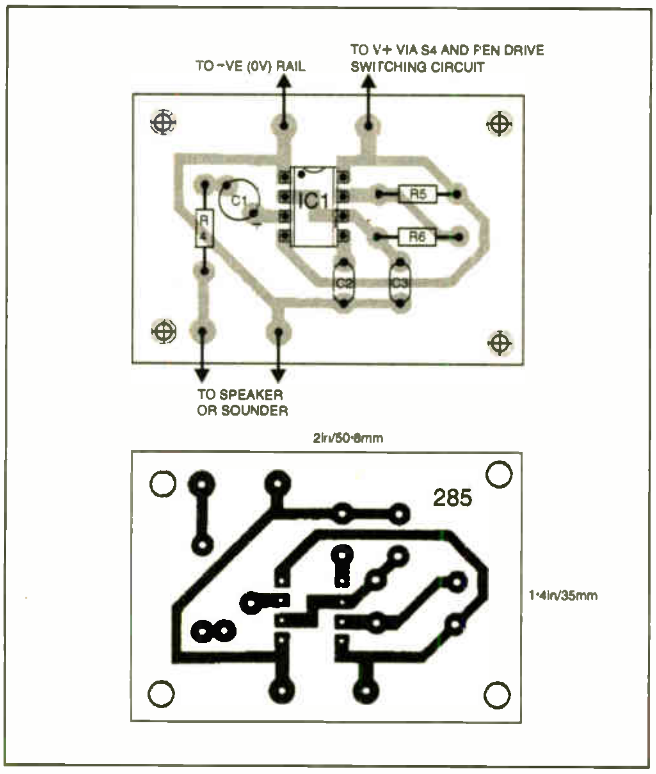


Fig.5 (above). Event Recorder printed circuit board wiring details, full-size foil master and pen drive mechanical assembly.

Fig.6 (left). Audio Alarm printed circuit board component layout, full size copper foil master and interwiring details.

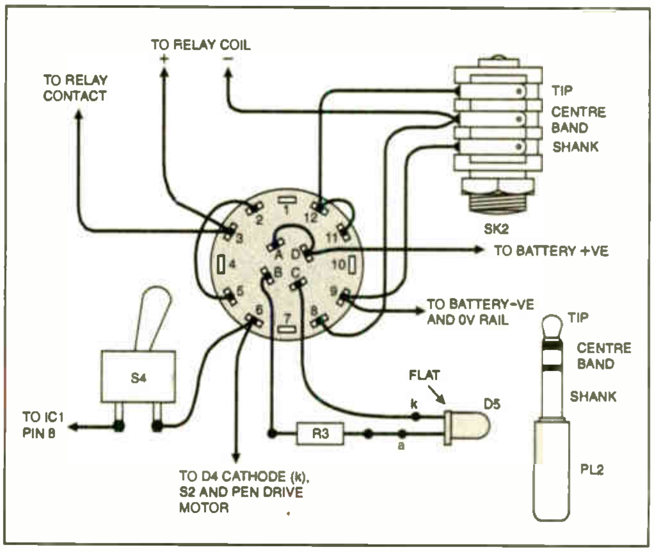


Fig.7. Interwiring details between switches, jack socket SK2 and alarm/diode D5.

ALARM UNIT AND SWITCHING

The Audio Alarm p.c.b. details are illustrated in Fig.6 and the wiring between switch S3 and other components in Fig.7. Switch contact numbering is that embossed in the switch's plastic case. Note that resistor R3 is mounted off-board between S3 and l.e.d. D5.

If a 12V supply is used, the value of the l.e.d.'s current limiting resistor, R3, should be increased to 1k2 ohms to avoid excessive dissipation.

SETTING UP

Power should be applied to the Pen Drive unit and the Audio Alarm to ensure that they are working correctly before building them into the recorder. Check the inter-board wiring and the wiring around S3. Remove the compass needle and disconnect the detector from the recorder, then proceed as follows:

1. Event Recorder

a. Switch the unit on (S3 fully clockwise), then temporarily link together the centre section and shank terminals of socket SK2 (connecting the negative pole of the relay to the 0V rail). Audio and visual alarms (LS1 and D5) should operate as the pen carrier moves to the right.

b. Remove the link. Alarms should cease when the carrier begins its return to the "at rest" position on the left.

c. Switch to the "test" position. The l.e.d. should light when the SK2 contacts are shorted as before. The pen carrier should remain stationary and the audio alarm silent.

2. Detector

a. Turn preset VR1 fully anti-clockwise (wiper to 0V rail) and VR2 clockwise (wiper to +VE), then connect the Detector to the Recorder. Switch the Recorder on.

b. With phototransistor TR1 illuminated (ambient light and infra-red from l.e.d. D1), advance VR1 until the relay is activated and the pen carrier moves to the right. Set VR1 as low as possible consistent with the reliable operation of the relay. Current drain with the relay on and l.e.d. D5 illuminated should be in the region of 40mA.

Audio Alarm p.c.b. Note the wire link replacing resistor R4.

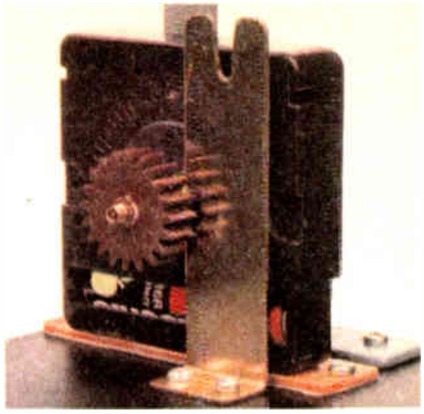


Chart drum removed to expose small gear on clock movement hour shaft.

c. Place a completely opaque barrier between D1 and TR1 and fix the cover over the detector to exclude all light. The relay should switch off and the pen carrier return to its rest position on the left. Current consumption should fall below 2mA.

d. Turn VR2 about 10 per cent anti-clockwise and remove the barrier between D1 and TR1. Replace the cover to check that the reduced infra-red level can actuate the relay. If it can't, advancing VR1 a little to increase detector sensitivity should make it trigger.

e. Continue this process until the unit will function reliably with both potentiometers turned as low (anti-clockwise) as possible. For a given set of transistors, there is a critical position for VR1 beyond which "on" current rises but sensitivity does not increase. Stand-by current should be no more than 250µA (0·25mA) when the procedure has been completed.

3. Full System

a. Place the compass needle on the pivot and orientate the detector so that the vane occludes IR l.e.d. D1. Replacing the cover will disturb the needle. With the unit switched to "test", l.e.d. D5 should flicker as the vane swings backwards and forwards over D1. When the needle settles, D5 should be extinguished (the 250µA stand-by current can produce a faint glow in sensitive l.e.d.s which is visible in low light levels).

b. Switch the system fully on. A weak magnet held 300mm to 600mm away from the detector should deflect the compass and trigger the relay.

c. Any failure of the compass needle to return to its original position when the magnet is removed will be due to imperfections in its pivot.

Select a sharp sewing needle for the pivot, and spin another needle inside the socket to polish it. Apply switch cleaner or lighter fuel to wash away debris. This will usually result in a satisfactory bearing.

d. Before orientating the detector, make sure the ambient magnetic field is stable. The slight movements of a typist's chair in front of the work bench were enough to trigger the prototype unit.

CHARTS

Wrap a strip of paper around the drum, mark the circumference, then divide it into 24 sections in order to produce a template for the charts. Two can be accommodated on a sheet of A4 paper for photocopying. Use the time setting wheel on the clock movement for the final positioning of the pen on the chart.

Connected to an appropriate detector, the unit can be used to record the time and duration of any event (frost, high or low water levels, intruders, etc.). If the events are infrequent, brief and random, the date can be written against the line on the chart and the same chart paper used for several days.

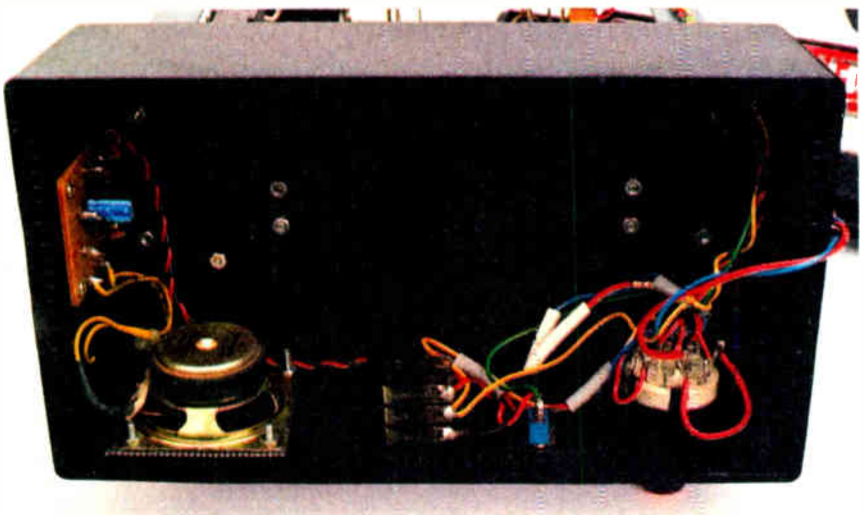
CONCLUSION

At the time of preparing this article, the unit has been operating constantly for several weeks. To date there have been no magnetic perturbations other than those induced for periodic testing. It would seem that aliens are currently missing out on the delights of South Yorkshire.

So called UFO "Hot Spots" in Great Britain include Warminster in Wiltshire (the self-declared UFO capital of the UK); Bonnybridge, Scotland; Grimsby, Lincolnshire; and Keighley and Scammonden, both in West Yorkshire.

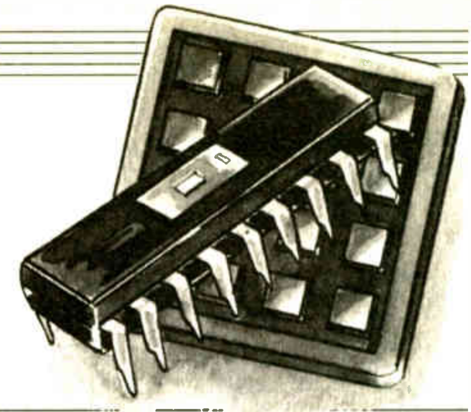
Sightings have been reported recently in Abergavenny, Leeds, London, and Manchester. Details of "Hot Spots" worldwide, and recent sightings, can be gleaned from the many Internet web sites and magazines on the subject.

The equipment is relatively inexpensive and easy to construct. Keeping a round-the-clock watch with it could expose your town or village as another UFO "Hot Spot". □



Internal component layout inside the Event Recorder base.

Special Feature



USING PICS AND KEYPADS

JOHN BECKER

How to interface your PIC to matrixed keypad switches plus an l.c.d.

READERS' questions about PICs cover many subjects but one that occurs with moderate repetition is how they can monitor matrixed keypad switches. Since for every question asked there are probably scores of readers who would also like it answered, we shall now attempt to do just that with this one!

MATRIX SWITCHES

Two of the matrix switch types readily available are those shown in the photographs. Photo 1 shows a standard 4 × 4 keypad, often referred to as being for "data entry". In Photo 2 is shown a 3 × 4 "self-adhesive membrane keypad", which is also available as 4 × 4 and 1 × 4.

A schematic diagram of the internal connections of the 3 × 4 keypad in Photo 2 is shown in Fig.1. The 4 × 4 self-adhesive version is the same with another column added.

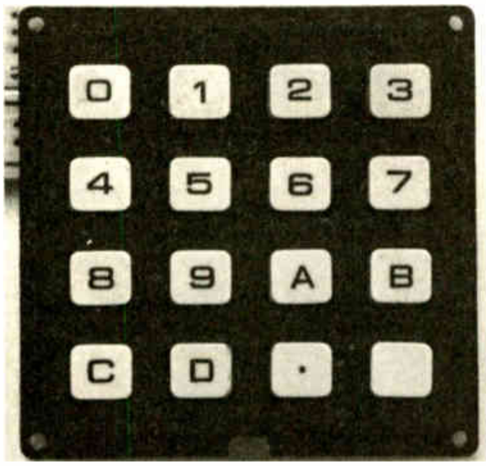


Photo 1. Standard "data entry" 4 x 4 keypad, with legends re-arranged by the author (see text).

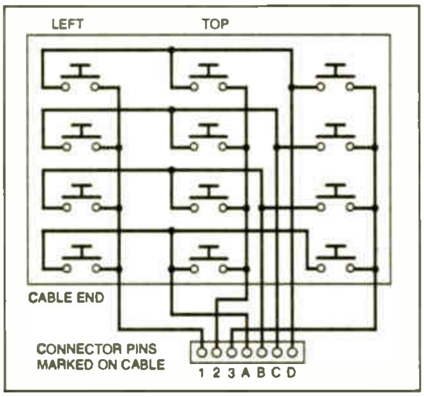


Fig.1. Internal connections of the 3 x 4 keypad in Photo 2.

Each column has one side of its switches connected to a "bus" line common only to that column. Similarly, each row has the other side of its switches connected to a bus, one for each row. There are thus seven buses brought out to a connector for the 3 × 4 keypad, and eight for the 4 × 4. The "data entry" keypad has similar connections but also has a ninth connection, which is used to ground (earth) the frame of the assembly.

Membrane keypads use a special type of ribbon cable that integrally connects them to a 0·1 inch-pitch pin-header socket several centimetres from the pad. This is formed from a tough plastic strip on which the tracks are "printed", column tracks on one side, row tracks on the other. They are numbered for the columns, and lettered for the rows (as in Fig.1).

Photo 2. A 3 x 4 self-adhesive membrane keypad. The legends can be customised using "slide-in" tabs.

Your own customised legend strips can be used to identify the individual keys, inserted between the covering surface and a separating layer. The example in the photograph shows the legends for the author's *EPE Time Machine* (Nov '97).

Data entry keypads have their connections made to a 0·1 inch-pitch 9-pinned connector block on the rear panel, numbered as shown in Fig.2a, and allocated as in Fig.2b.

The pads of the data entry type have legends moulded into their tops, probably the character set shown in the photograph. It is worth noting, though, that it is possible to carefully unscrew the rear panel of the keypad and rearrange the pad order. Such has been done with the pads in the photograph. Component catalogues typically show a different order.

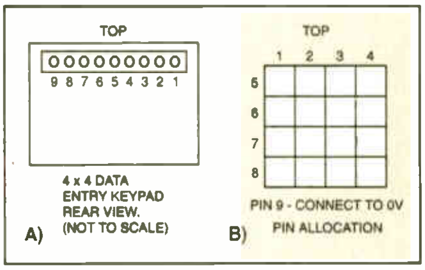


Fig.2. Data entry keypad pin arrangement and numbering.

When any switch is pressed, it connects together one column track and one row track and an electrical current has to flow from one to the other. There is, however, no inhibiting arrangement to prevent two or more switches being pressed simultaneously, with consequent connection of several tracks.

In a normal paired connection, knowing the source of the current for one track and the destination of the other allows each key to be pressed and for circuitry to respond and recognise which key is active. This is where the problem lies for those readers who have queried the method required and how their PICs should be programmed to achieve it.

CIRCUIT CONSIDERATIONS

As with all programming problems, there are many ways in which a solution can be reached. We shall illustrate one way in which the keypad can be monitored by a PIC16x84, while it is additionally used to output data to an alphanumeric liquid crystal display (l.c.d.). The circuit diagram for the demo is given in Fig.3. Only the connections relevant to this discussion are shown.

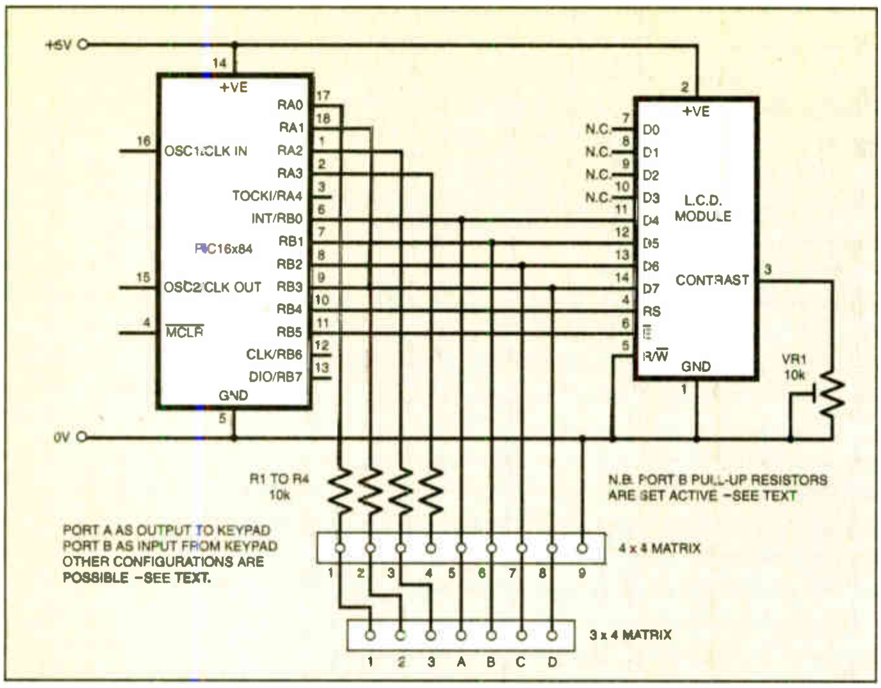


Fig.3. Circuit diagram for the keypad and l.c.d. demo.

We shall also only discuss software pertinent to the switch monitoring itself. A full length demo program (with notations) is available in which this and other routines, notably for l.c.d. output, are incorporated (see later).

The circuit connections shown in Fig.3 can be changed to meet individual needs, and the software is readily modifiable to suit. The l.c.d. does not need to be used in other design situations and the identified keypress value can simply be used as data within a program. The software illustrations are applicable to other members of the PIC family, such as the PIC16F87x series, for example.

MATRIXED CONNECTIONS

In the circuit diagram it will be seen that four input/output lines of the PIC (PORTB, RB0 to RB3) are matrixed to jointly serve the l.c.d. and the keypad, for which the 3 × 4 and 4 × 4 connectors are illustrated. The other keypad connections are from PORTA, RA0 to RA3.

The matrixed lines are those which serve l.c.d. data connections D4 to D7 when the display is operated in conventional 4-bit mode. The display control connections (RS and E) are uniquely served by PIC pins RB4 and RB5.

Note that the design deliberately does not use the RB5/E line for keypad matrixing since data on the E-line must only be used as a clock signal for the l.c.d. during data transfer. Toggling it at other times will disrupt the display details. The RS line could be matrixed, however, since its logic level only matters during l.c.d. data or command transfer.

Pins RB6 and RB7 can be used for any desired function, as can open-collector pin RA4.

It is partly because of the constraints imposed on pin RB5, that RB0 to RB3 have been chosen for one aspect of the matrixed keypad. Using these pins also slightly simplifies the software. Pin RA4 has been avoided because it requires an external pull-up resistor.

As will be apparent, one set of switch lines must be connected to a voltage source while the other set is connected to an input destination. In theory it does not matter which set is used for which route, the software can be programmed accordingly.

What is crucial, however, is that the input destination must additionally have its pins resistively biassed to one or other power line levels so that default logic levels are always present when the normally-open switches are unpressed.

Fortunately, PORTB can have all eight pins biassed to the positive power line via internal pull-up resistors. Consequently, PORTB is chosen as the input destination. To use other PIC ports (and some PICs have more than two available – but only PORTB has internal pull-ups) external biassing resistors should be used, connected to either power line, and typically of between 10kΩ and 100kΩ.

If PORTB is not required to also control the l.c.d., RB4 to RB7 could be used as the voltage source rather than PORTA.

A further consideration is that a short-circuit condition between pins active as outputs must never occur. In the situation shown in Fig.3 this would be a definite occurrence without ballast resistors R1 to R4. These allow a key to be pressed while its twin port pins are at opposite output logic levels. The resistors could be in the other four lines (input side) if preferred.

PROGRAM OPERATION

The program concept is that PORTA cycles a turn-on voltage across each of its four outputs in sequence. On each occasion, PORTB is read and which input is active is determined. Knowing which output and input pins are connected via a pressed switch enables the column/row position of that switch to be established.

PORTB's inputs are biassed high by their pull-ups, consequently PORTA must normally hold all its pins high, taking the required line low to produce an active input response from PORTB when a key is pressed.

Before the program gets to this stage, however, it has to be initialised following power-up. All the usual "housekeeping" commands are required, such as equating register names and addresses, setting port pins for input and output, plus, in this instance, initialising the l.c.d. for 4-bit mode etc.

The latter also requires a start delay following power-up before the commands can be given. The set-up process therefore requires the PIC's timer to be activated (although there are other delay techniques possible). The source code listing of the demo program covers such matters, and in relation to a 3·2768MHz controlling clock rate for the timing delay.

PIC INITIALISING

The setting of the port directions and timer rate is shown in Listing 1.

PORTA is set as an output since it controls the switch voltage source. Note that PORTB is also fully set for output, even though part of it will be used later for input. It is necessary to have at least RB0 to RB5 set as outputs at this stage because of the l.c.d. initialisation that takes place before the main program. Once the l.c.d. has been initialised, pins RB0 to RB3 are set as inputs.

Bit 7 of the OPTION register is set low to activate the pull-up resistors. Bits 0, 1 and 2 control the timer rate, in this case 1/25th second for a 3·2768MHz crystal.

With the commands illustrated in Listing 1 complete, the main program is entered, represented by the first two commands in Listing 2.

These two commands form a repetitive loop, forever calling the GETKEY subroutine in which the switches are monitored. On return from the subroutine, the loop is repeated. In a full program many other commands would likely precede and follow the **CALL GETKEY** command.

Most of the time that a full program is running, the keypads are unpressed.

LISTING 1. Initial ports and timer settings

```
PAGE1
CLRF TRISA              ; set all PORTA as output
CLRF TRISB              ; set all PORTB as output
MOVLW %00000110         ; pull-up resistors on (bit 7), timer 1/25 sec
MOVWF OPTION            ; (for 3.2768MHz crystal)
PAGE0
LCD & other settings initialised here, followed by:
PAGE1                   ; RB0-RB3 as inputs, ready to monitor switches
MOVLW %00001111
MOVWF TRISB
PAGE0
from here the main program can be entered
```

Consequently, to allow the program to speedily resume its other activities if the keys are not pressed, the overall keypad status is first examined. If no keys are pressed, the routine is exited.

For this first check PORTA is set for all outputs low (even RA4 which is not used, although if it were used for some other purpose, it might be preferable to set low only RA0 to RA3, e.g. MOVLW %000x1111, MOVWF PORTA (where x can be 0 or 1)).

The PIC requires a delay of one clock cycle between ports being written to and then read, otherwise the read value could be erroneous, hence the NOP command following CLRF PORTA.

PORTB is read with the command COMF PORTB,W which pulls the data into the W register as an inverted value since the port is normally biassed high. It is the *low* status of any PORTB pin which indicates a key press, but it is easier to check if *none* of the switches are pressed (all RB0 to RB3 high) by inverting the value and looking for a zero condition.

Bits 0 to 3 are isolated from the full 8-bit PORTB value with the ANDLW %00001111 (decimal 15) command, and then the zero condition is looked for, with a return to the main program if it exists.

If the value is *not* zero, then at least one of the keys is pressed. The next routine then finds out which one.

There are many ways in which this can be done, for example:

- poll each pin in turn
- read both port values and use look-up tables
- a mixture of both

It is the latter process that is shown in Listing 2.

Adventurous readers might care to see if they can write a simpler routine to do the same thing, sending a listing to the Editorial office to possibly share with other readers through *Readout* – a nice challenge (but no prizes – just the satisfaction of achievement!)

LISTING 2. Switch monitoring routines.

```
MAINPROG:
   CALL GETKEY          ;get keypress, if any
   GOTO MAINPROG
GETKEY:
   CLRF PORTA           ; all PORTA low
   NOP                  ; pause to allow PORTA to stabilise
   COMF PORTB,W         ; get & invert PORTB
   ANDLW %00001111      ; isolate bits 0-3
   BTFSC STATUS,Z       ; is result NOT zero (keys pressed)?
   RETURN               ; no, so return to main prog
   MOVLW %00000111      ; yes, a key is pressed so get it
   MOVWF PORTA          ; initial val for PORTA
   CLRF COL             ; clear col number count
GK2:
   COMF PORTB,W         ; get & invert PORTB
   ANDLW 15             ; isolate bits 0-3
   BTFSS STATUS,Z       ; is result NOT zero (keys pressed)?
   GOTO GK3             ; yes
   INCF COL,F           ; no, so increment col val
   RRF PORTA,F          ; rotate PORTA right
   BTFSC STATUS,C       ; is Carry zero?
   GOTO GK2             ; no, so repeat
   RETURN               ; yes, so return to main prog
GK3:
   MOVWF STORE          ; store isolated PORTB value
   CLRF ROW             ; clear row number count
GK4:
   RRF STORE,F          ; rotate right PORTB store val
   BTFSC STATUS,C       ; is carry flag set?
   GOTO SUMIT           ; yes so key pressed, go & finish answer
   MOVLW MATRIX
   ADDWF ROW,F          ; add matrix val to ROW count
   GOTO GK4
SUMIT:
   MOVF COL,W           ; reverse column notation order
   SUBLW 3              ; by subtracting from 3
   MOVWF COL            ; store as column
   MOVF ROW,W           ; sum up results to single answer
   ADDWF COL,W          ; add ROW to COL (total of 0-15)
   CALL VALUE           ; convert val to allocated table character
   MOVWF ANSWER         ; store it
   CALL SHOWIT          ; show it
   RETURN               ; return to main program
```

GETTING KEYPRESS

The key-getting routine in Listing 2 starts off by setting RA0 to RA2 high and RA3 low. Column counter COL is then cleared.

Next starts a loop (GK2) that is repeated until either the pressed switch is found, or the limit of four cycles is reached. Note that although the test at GETKEY showed a key to be pressed, it is possible that it might have been released by the time GK2 is in progress.

PORTB is then read, as an inverted value. Its bits 0 to 3 are isolated and a check for zero is made. If the result is zero, the active row has not been found. In this case the loop has to be repeated. First the column count (COL) is incremented, and the value in PORTA rotated right by one place, on this occasion in the loop to allow RA2 to become an active control line.

It does not matter that RA3 remains low because its influence has already been proved to be ineffective.

It should be noted, however, that if RA4 is in use as an output in another application, the rotate right command affects that pin as well. Should this be significant, it would be better to use a named register to hold the value that needs to be output to PORTA, and to perform the rotation on that. The register value would then be moved into W, and bit 4 corrected to suit the needs of RA4 before outputting the value to PORTA.

Following the rotation of PORTA, its value is checked for zero which, if true, causes a return to the main program (four loop cycles having been completed). Whilst the rotate command (RRF) does not affect the Zero flag, it does affect the Carry flag, which takes on the value of the bit just rotated into it from PORTA.

Since PORTA (normally) only has one bit set, then if the Carry flag becomes set, it is because PORTA's set bit has been rotated into it, leaving RA0 to RA3 at zero. Consequently if Carry is set, the loop cycle is complete.

WHICH ROW?

Going back a few program lines to the isolation of PORTB bits 0 to 3, a non-zero result means that an active column has been found. The next question is which row is active, answered through the routine starting at GK3, to which the action jumps.

At GK3, the first command stores the isolated PORTB value in STORE, then the ROW counter is reset, after which the loop at GK4 is entered. Here STORE's value is repeatedly rotated until the set bit within it is rotated into Carry, signalling that the active row has been found, and a jump to the summing routine at SUMIT is made.

If Carry is not set, the loop has to repeat, but before doing so the ROW counter value has to be increased by the same amount as the number of keypad columns (3 for a 3 × 4 keypad and 4 for a 4 × 4). The value to be added is held in MATRIX and needs to be .EQUated at the head of the program according to the keypad used (e.g. **MATRIX .EQU 3**, for a 3 × 4).

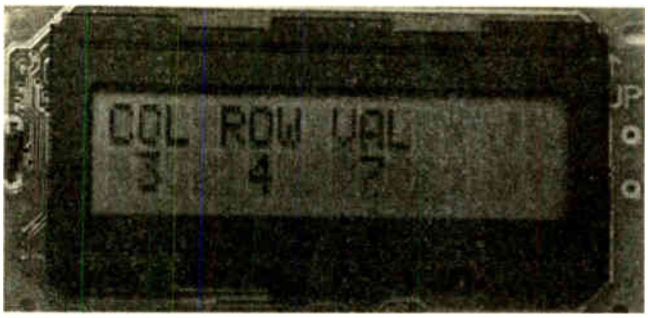
When the active bit is found and a jump made to SUMIT, the COL value is subtracted from three to relate the answer to a left-to-right column order (0 to 3 instead of 3 to 0).

Next the COL and ROW values are added to produce an answer (held in W) between 0 and 15 for a 4 × 4 keypad, or 0 and 11 for a 3 × 4. This could be used by any program as the final value required. However, the value can be converted to any other in the range 0 to 255 via a 16-jump look-up table, named VALUE.

In the demo program, table values representing ASCII characters 0 to 9 and A to F are allocated in numerical order. The table is called, a jump is made according to the total row plus column value, and a

LISTING 3. Preparation for outputting value to l.c.d.

```
SHOWIT:
PAGE1
CLRF TRISB          ; PORTB as output (for display use)
PAGE0
MOVF ANSWER,W
CALL LCDOUT         ; show character result
PAGE1
MOVLW %00001111
MOVWF TRISB         ; reset RB0-RB3 as inputs
PAGE0
RETURN              ; end of display
```



Example l.c.d. display (but using a different look-up table to that in the demo for the "VAL" result).

return made with the equivalent character held in the W register. This is stored in ANSWER, and a call made to the l.c.d. output preparation routine, at SHOWIT (see Listing 3).

In Listing 3, PORTB is reset so that all pins are outputs, the ASCII character held in ANSWER is pulled into W and a call to routine LCDOUT is made. This outputs the character to the l.c.d. screen, following which RB0 to RB3 are reset as inputs, and a return to the main program is made. End of mission!

DEMO PROGRAM

In the demo program, the l.c.d. also displays COL and ROW information (see photo). COL is displayed as a value between 0 and 3. ROW is displayed in hexadecimal as its MATRIX-incremented value, e.g. 1, 4, 8, <. The converted ASCII value is shown below VAL.

The l.c.d. controlling routines in the demo are those frequently used in the author's published PIC projects. They are discussed at length in the PIC *Tutorial* series (Mar-May '98), and in the *PICtutor* CD-ROM.

The software is written in TASM and is available from the Editorial office on 3·5-inch disk (for which a nominal handling charge applies). It is also available for *free* download from the *EPE* web site. See this month's *Shoptalk* page for more details.

PIC Toolkit Mk2 (May-June '99) is an ideal programmer for loading the software into a PIC16x84 and viewing it on an l.c.d. *Toolkit* also allows external hardware (such as a keypad and its resistors) to be connected to the PIC16x84 port pins. □

SHOP TALK
with David Barrington

UFO Detector and Event Recorder

As there appears to be some "alien" components required for the *UFO Detector and Event Recorder* project we shall try to take some of the mystery out of where to find them. For starters, most of the "hard-to-find" parts seem to be listed by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***).

The Siemens SFH309 photo-Darlington transistor and matching SFH409 infra-red diode came from the above company, codes CY86T and CY84F respectively. Although, as pointed out in the article, a variety of similar devices were all tried successfully in this circuit. Older phototransistors may have a base lead which should be ignored or snipped back close to its body. The transistors should be no problem, you have a choice of the BC547, BC239 and 2N3711 which all worked well in in the model. However, the relay must be capable of working within the confines of the 2N3711 maximum collector current (30mA approx.).

For the UK, the 4·5V coil BT 16-pin 47W and 12-pin 45W d.i.l. type relays should be widely stocked. However, the one in the model came from Maplin (code GU35Q) and is of Matsushita manufacture. Other low-voltage coil types would be: Fujitsu FBR46NG005 (12-pin) and IMO-NEC MR62-4·5SB (16-pin).

The author used standard 6·35mm (¼in.) plastic-bodied (barrel) stereo jack sockets and plugs to interconnect the two units together. Of course, you may prefer to solder the cable directly to Detector p.c.b. and Recorder unit, avoiding any problems of finding non-ferrous materials.

The quartz clock movement (crystal frequency 32·768kHz) came from Maplin, code YU49D, together with the spur gear set, code WC81C, and the optional circular spirit level, code BP61R.

This just leaves us with the low-voltage d.c. motor, p.c.b.s and hardware. The printed circuit boards are available as a *set* of three from the *EPE PCB Service*, codes 283, 284 and 285 (see page 77). You should find that nearly all the hardware materials are stocked by your local model shop.

We do not have the complete answer to the low-voltage pen drive motor, except to reiterate the author's comments that with so little drive torque needed, almost any small d.c. electric motor should do the job. You could try contacting **Bull Electrical**, **J&N Factors** and **Greenweld**, who sometimes have small low-voltage d.c. motors on "special offer".

Two-Way Intercom

All the components called up for the *Two-Way Intercom* project should be readily available and most of our components advertisers should stock suitable parts. The "biased" toggle switches come in a variety of combinations and are usually found listed under sub-miniature or miniature types.

Just one small word of warning regarding the transistors. When ordering, be sure to specify the suffix L after the type number as the pinout arrangements of other BC184 and BC214s are different.

The LM386N-1 low-voltage audio amplifier chip is a National Semiconductor device and appears to be widely stocked. The small printed circuit board is available from the *EPE PCB Service*, code 282.

Versatile Optical Trigger

We do not expect any buying problems to be encountered when putting together parts for the *Versatile Optical Trigger*, this month's Top Tenner project. The MOSFET device should be widely stocked, but if any readers do have trouble finding the VNK10KM device it is currently listed by **Electromail** (☎ ***01536 304555*** or ***http://rswww.com***), code 655-537. The MEL12 photo-Darlington transistor is stocked by **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code HQ16R.

Using PICs and Keypads

The software for the *Using PICs and Keypads* feature is written in TASM and 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 77). It is also available *free* via the *EPE* web site: **ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/PICkeys**.

PIC-Monitored Dual PSU – Part 2

All sourcing problems regarding components for the *PIC-Monitored Dual PSU* were ironed out and given in Part 1, last month. This month's article deals with final construction and running of the software, plus details of a Simple PSU.

For the *Simple PSU* version (without PIC monitoring), intended to supply a "down-rated" fixed or variable supply, a much less robust (cheaper) mains transformer, with a single 9V secondary winding, rated anywhere from 100mA up to about 250mA or even 1A, can be used. Likewise, the working voltage of the smoothing capacitor C1 can be reduced to around 25V in this version. Note, however, that the voltage regulator should still be bolted to the metal case, using a TO220 insulating kit, as in the "full" PSU model.

The same power supply board is used for the Simple PSU version as the main unit, except only about half the p.c.b. is populated with components. The code for this printed circuit board is 280 and is obtainable from the *EPE PCB Service*, see page 77.

PLEASE TAKE NOTE

Festive Fader (Christmas Supplement) *Dec '00*

Page 8. Circuit diagram, Fig.3. The unconnected lead from the mains input "live" should run horizontally across the circuit to link up with the unconnected lead running down to the junction of R8/MT2. The p.c.b. is correct.

Also, the values of capacitors C3 and C6 on the circuit diagram should be $1\mu F$ multi-layer ceramic. The parts list is correct (also, see *Shoptalk* Dec '00). Although *not* listed by Farnell (☎ ***0113 263 6311***), we understand that they stock the Dagnell D3607 3VA, p.c.b. mounting, mains transformer as used in the prototype, code 330-3809.

High Performance Regenerative Receiver *March/April '00*

Page 301, April '00. Main Receiver printed circuit board copper foil master, Fig.5. As shown, all the leadout pads for the dual-gate MOSFET (TR3) are connected together by the "circular track" (just above the p.c.b. number), shorting out all TR3's pins and stopping it operating. To remedy this error, the thin copper circle should be cut away, and the thicker tracks can be trimmed back to their first solder pads if you wish.

New Technology Update

"Going Organic", takes on a new meaning with the introduction of organic lasers. Ian Poole reports.

LASERS are now used in many areas of electronics technology. In consumer electronics some of the most widespread examples are in compact discs for hi-fi systems and computers and for the light pointers often used for giving presentations using overhead slides. They also find uses in medical surgery, and some areas of i.c. manufacture.

Lasers are also widely used for optical communications. Here they generate the coherent light that is sent along optical fibres enabling very wide data bandwidths to be achieved. In this respect they offer a much greater capacity than their radio frequency equivalents. Now with the increased requirements for data bandwidth and speed that has arisen from the use of the Internet, optical communications and hence lasers are in much greater demand.

Lasers operate by a phenomenon called "stimulated emission" that was first postulated by Albert Einstein before 1920. Although a number of mediums including gases, liquids and amorphous solids can be used for lasers the first ones were realised in 1960 using rubies. A helium-neon gas laser followed this in 1961 but it was not until 1970 that semiconductor lasers were made to run at room temperature.

Today semiconductor diodes are in widespread use, but new developments in semiconductor technology mean that new forms of diode are beginning to appear.

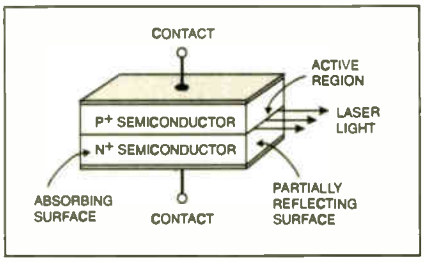


Fig.1. Basic structure of a laser diode.

Semiconductor Diodes

Before looking at the new developments it is worth taking a view of today's traditional Gallium Arsenide diodes to see how they operate.

The semiconductor diode is constructed as shown in Fig.1. It consists of heavily doped *n*+ and *p*+ regions. For manufacture it is normal to start with an *n*+ substrate and then the top layer can be grown onto this. Doping can be introduced in a variety of ways, either by diffusion, ion implantation or deposited during the epitaxy process.

A variety of materials can be used for laser diodes, although the most common starting substrates are Gallium Arsenide (GaAs) and Indium Phosphate (InP). These are known as type III-V compounds because of their places in the chemical periodic table of elements. Whatever material is used, it must be possible to heavily dope it as either a *p* type or *n* type semiconductor. This rules out most of the type II-VI materials, leaving the group III-V materials as the ideal option.

Apart from the basic semiconductor requirements, there are a number of optical requirements that are needed to enable the laser diode to operate. For starters, it needs an optical resonator. This must occur in the plane of the required light output. To achieve this the two walls of the diode that form the resonator must be almost perfectly smooth, forming a mirror surface from which the light can be reflected internally. One of the walls is made slightly less reflecting to enable the light to come out from the diode.

Another requirement is that the two mirror surfaces must be perfectly perpendicular to the junction, otherwise the laser action does not occur satisfactorily. The two other surfaces perpendicular to the one of the required light output are roughened slightly to ensure that the laser action does not occur in this plane as well. In this way a resonant optical cavity is created. Although it is many wavelengths long it still acts as a resonant cavity.

Going Organic

Today many new materials are being used in semiconductor devices. One exciting development being undertaken at Bell Labs in New Jersey USA is into the use of organic semiconductors.

Recently they announced that they have demonstrated the first laser using the organic semiconductor material Tetracene. It has been known for some time that this family of materials demonstrates some of the attributes required for laser action. However, this is the first time that it has been demonstrated.

This development is particularly important because it was previously thought that organic materials would not be capable of supporting the very high current densities required in laser diodes. Tetracene is a very suitable form of organic semiconductor because the electron and hole mobilities that it offers are particularly high – around $2cm^2/Vs$ at room temperature.

Its four benzene rings enable it to conduct electricity very well. A further advantage is that Tetracene absorbs very little light and this enhances the lasing effect and the light output.

In addition to this, they are cheaper to manufacture than their more traditional counterparts. This means that once the development of these organic semiconductors is established the manufacture of lasers will be much cheaper. Currently laser diodes are quite expensive, as anyone replacing a laser diode in a CD player will be able to testify.

Manufacture and Operation

Tetracene is grown as a single crystal using vapour phase techniques. Field effect device structures are then grown onto the crystal surface as shown in Fig.2.

Source and drain structures are added with a channel length of about 25 microns and width of several hundred microns. An amorphous layer of aluminium oxide is then sputtered onto the crystal and then an aluminium doped zinc oxide gate is added on top of this.

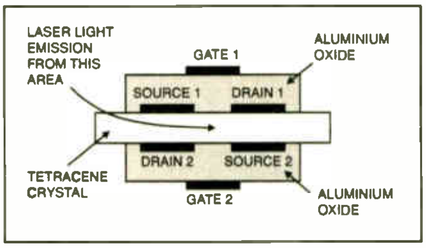


Fig.2. Tetracene laser diode structure.

Essentially the device consists of two field effect devices that enable holes and electrons to be injected into the Tetracene crystal. Carrier concentration in the channel region is determined by the voltage on the gate.

More specifically, holes are injected into the laser area of the device by applying a positive source-gate potential to the bottom of the device and a negative source-gate potential at the top. The potentials are also arranged so that a potential of approximately 5V is applied across the Tetracene crystal, whilst up to 50V can be applied to the gates. This enables carrier densities of about $10^{13}A/cm^2$ to be achieved.

The current flowing across the Tetracene crystal causes light to be emitted. To enable laser light to be generated there are reflecting surfaces at either end of the device. In this way the light is reflected back inside the device causing it to become an optical resonator and this results in further coherent light being emitted.

In The Future

As the new organic lasers will be so much cheaper than their traditional counterparts it opens up many new areas in which they might be used. They could be tailor-made to suit individual applications.

For further information about these lasers refer to **www.bell-labs.com.**

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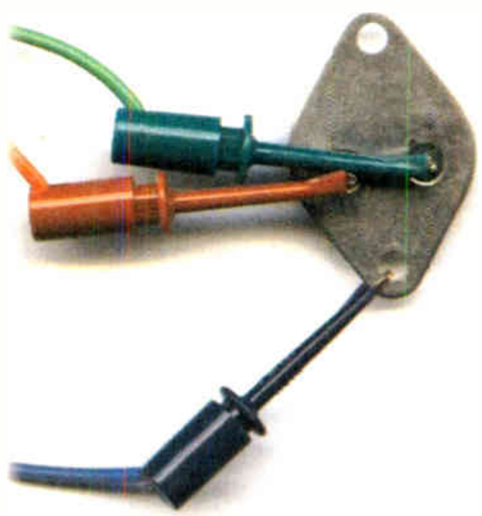

What components are supported?

- Bipolar transistors
- Darlington transistors
- Diode protected transistors
- Resistor shunted transistors
- Enhancement mode MOSFETs
- Junction FETs
- Low power triacs and thyristors
- Diodes and diode networks
- LEDs including 2 lead and 3 lead bicolours

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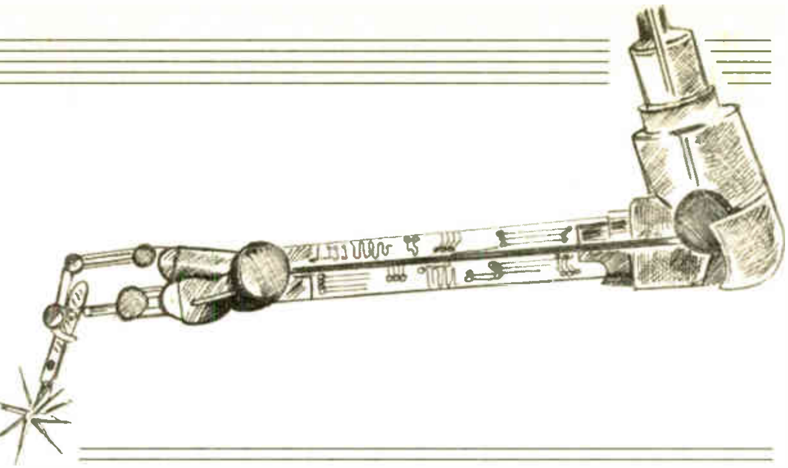
CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

Our team of troubleshooters unravel the principles of voltage multiplier circuits.

LAST month we introduced a few ideas behind the use of simple inverter circuits including the Royer converter to produce higher voltages, and we outlined a few ways in which switched mode power supplies can be designed, highlighting the use of on-line design tools such as those provided by National Semiconductor (**www.national.com/appinfo/power**). In spite of the availability of these and other aids, designing a switched-mode power supply is not so easy especially if at the end of the day you're restricted to using off-the-shelf parts instead of expensive bespoke components.

Voltage Multipliers Analysed

Another way of generating higher voltages from a lower voltage source is to use a *voltage multiplier*. These are often easily spotted in circuit diagrams, as they typically consist of a network of diodes and capacitors which are used to step up the voltage in stages.

Voltage multiplying networks take an a.c. input and produce a d.c. output as a multiple of the peak a.c. voltage. Doublers, triplers, quadruplers etc. can be made, and they are most commonly used in very high voltage supplies.

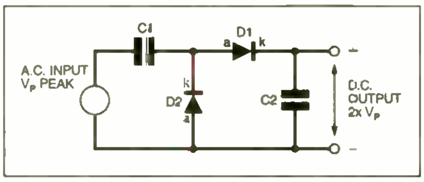


Fig.1.Circuit diagram for a half-wave or cascade voltage doubler.

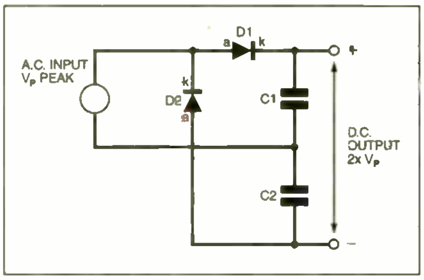


Fig.2. A full-wave voltage doubler circuit diagram. The d.c. output voltage is twice the a.c. peak input voltage.

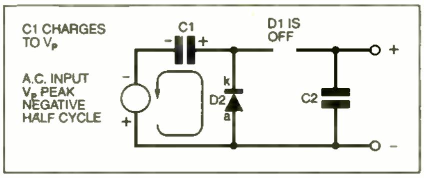


Fig.3a. During the negative half-cycle capacitor C1 charges to Vp via diode D2.

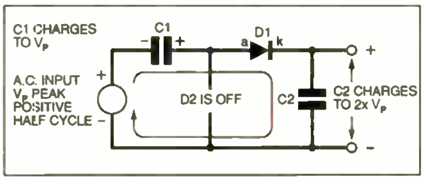


Fig.3b. During the positive half-cycle, capacitor C2 charges from C1 via diode D1 and the a.c. input to 2 x Vp.

However, they may seem a little difficult to understand at first. It helps to consider a couple of basic facts: first, an a.c. voltage connected to a capacitor, via a diode, will charge the capacitor to the **a.c. peak voltage** during one half cycle of the alternating cycle. The diode will be *reverse biased* in the other cycle and so the capacitor will *store the charge*, retaining the voltage across it.

Secondly, if we already have a capacitor which has been charged in one half-cycle, then (if we arrange the circuit correctly) the voltage stored on the capacitor will be added to the a.c. input voltage during the other half cycle. Thus, we obtain a maximum voltage in the circuit of **twice** the a.c. peak voltage – this is the basic operation of the *half-wave* or cascaded voltage doubler shown in Fig.1. Alternatively, we can charge two capacitors to the peak voltage, one in each half cycle – this is the basic operation of the *full-wave* voltage doubler shown in Fig.2.

Half-wave Doubler

The current "movements" in a half-wave doubler during the two half cycles of the a.c. input are shown in Fig.3.

In Fig.3a, capacitor C1 is charged to the peak a.c. voltage via diode D2 during the negative half cycle; D1 is off (reverse biased) because of the higher voltage that pre-exists on capacitor C2.

In Fig.3b, during the positive half cycle capacitor C2 (which carries the output voltage) is charged, via diode D1, **both** by the input voltage **and** the charge now stored on capacitor C1: these voltages sum to two times the peak voltage, rather like putting two batteries in series and applying them across C2.

Full-wave Doubler

In Fig. 4 we have shown how the currents flow in a full-wave doubler during the two half cycles of the a.c. input. Hopefully, this should make it clear that each capacitor is charged to the peak voltage, so that the output across the two capacitors in series is twice the peak voltage. In both these circuits the a.c. input usually comes from a transformer secondary, or even from the mains directly.

The half-wave circuit can be cascaded to give further multiples of input voltage, this in fact is the *Cockroft-Walton* multiplier to which our reader, ***Richard Tarpey***, referred last month. Fig.5 shows a voltage quadrupler of this form and Fig.6 shows a voltage

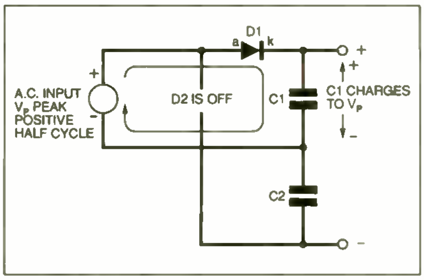


Fig.4a. In a full-wave doubler, during the positive half-cycle capacitor C1 charges to Vp via diode D1.

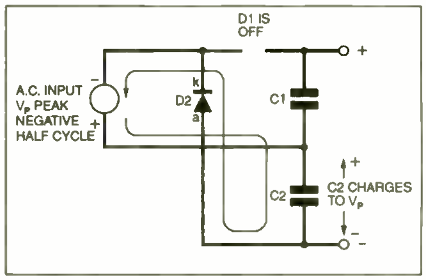


Fig.4b. During the negative half-cycle capacitor C2 charges to Vp via diode D2.

sextupler, no less, drawn in a format commonly used for this type of circuit. Considerable care must be taken when using voltage multipliers to make sure that the diodes and capacitors have *sufficient* voltage ratings to withstand the multiplied voltages.

Unfortunately, voltage multiplier circuits do not give very good regulation and they perform poorly with high loads. They are typically used for applications where very high voltages are required at reasonably *low* currents, or where some ripple can be tolerated, e.g. an ioniser circuit. Note that the multiplied voltage does not appear instantly at the output when power is applied – it takes several a.c. cycles to build up, and recovery from a loading peak will also take a while.

Fig.5. Circuit diagram for a voltage quadrupler, this is a Cockroft-Walton multiplier.

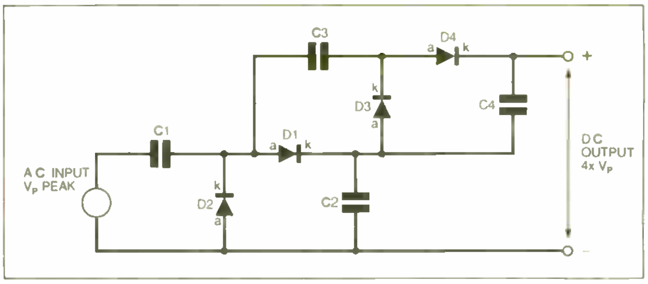
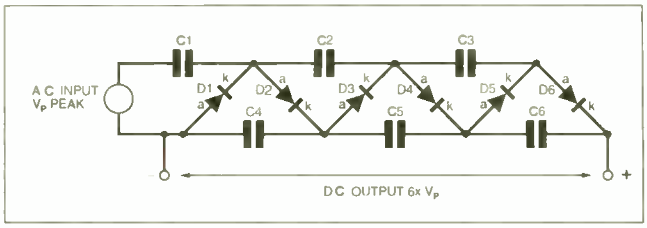


Fig.6. Cockroft-Walton voltage multiplier producing six times the a.c. peak input voltage.



Clock this Clock

I bought an old American Howard Miller 1950's mains electric clock. The motor is 110V 60 cycles (Hz), 3 watts. I bought a Tacima voltage converter for small appliances rated at: input 220V/240V a.c. 50Hz/60Hz; output 110V/120V a.c. 50Hz/60Hz, maximum load 30VA.

The clock runs well but loses time at about 10 minutes every hour! I'm told this is because the US mains supply is 60 cycles (Hz), whilst UK mains is 50Hz. Is this correct? Thanks, from ***Peter Ball*** (by E-mail).

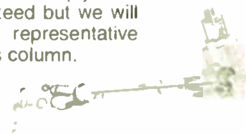
We're afraid so! Transformers are simply voltage-dropping or voltage-increasing devices which have no effect on the frequency of the alternating supply. The output frequency will be the same as the input, so your clock will indeed run successfully at the UK voltage but also at its frequency.

The clock probably uses a "synchronous" shaded-pole motor – one whose speed is synchronised to the applied mains frequency. In the UK this is 50Hz (50 cycles per second) whilst in the USA it is 60Hz. So the clock is running slower by 10 cycles per second.

Running at 60Hz and ignoring any possible gearbox ratios, as far as the clock is concerned one minute equals 3,600 motor revolutions. Operating at 50Hz, one minute produces 3,000 revolutions. Running it on the UK supply over a period of an hour then, the clock will be slow by (216,000 – 180,000) = 36,000 revolutions, or ten "American" minutes. *ARW.*

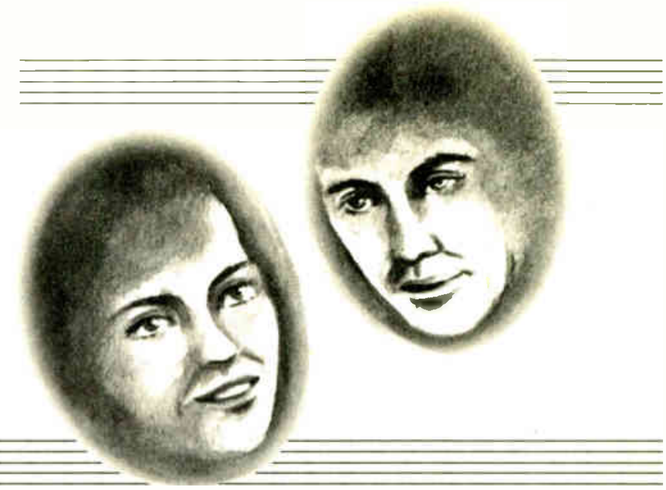
CIRCUIT THERAPY

Circuit Surgery is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom. E-mail (no attachments) **alan@epemag.demon.co.uk**. Please indicate if your query is not for publication. A personal reply cannot be guaranteed but we will try to publish representative answers in this column.



Constructional Project

TWO-WAY INTERCOM



ANDY FLIND

How to create your own local two-way chat zone.

INTERCOM projects used to be part of the staple diet of electronic construction enthusiasts with at least one appearing somewhere in publication every year.

Over time they seem to have become less common, perhaps because they can be bought quite cheaply nowadays, so when a reader asked if *EPE* had recently published one, Editorial eyebrows rose at the discovery that some eight years had passed since the last appeared. It seemed timely, therefore, to present a new intercom design.

VOICING QUERIES

It might be asked why anyone would build an intercom when they can be bought cheaply. In fact, there are several reasons.

A home-built design can be customised, built into other projects, modified and used in ways its original designer never intended. Parts of the circuit might be adapted for use in other projects. The constructor can easily repair it if it goes wrong and an intercom is a good starter project for those seeking electronics experience.

Last, but by no means least, constructors with children will probably find that an intercom's entertainment potential will earn them lots of brownie points with the kids! Given all this, a new design seems well worth while.

INTERCOM PRINCIPLES

The basic principle of an intercom circuit is simple. As many readers will know, a loudspeaker can function as a moving-coil microphone, so all that is required are two speakers and an amplifier with a 2-pole 2-way switch for the "listen-talk" function, as shown in Fig.1.

With the switch in the position shown, the Remote station acts as a microphone with its speaker connected to the amplifier input whilst the Base station's speaker is connected to the output, allowing the user at the Remote end to talk to the Base. Operating the switch reverses these connections to allow the Base user to speak to the Remote. Only two wires are required to link the two stations, cheap "bell wire" usually being adequate.

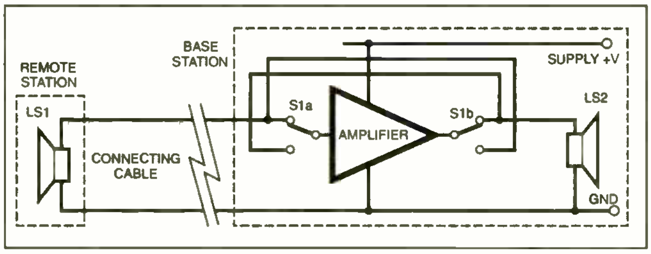


Fig.1. Basic principle of Intercom operation.

If only it were so simple! Before the users can speak to each other they must be present at the two ends and the Base unit must be switched on. This requires a means of sending a signalling tone from either end, and in the case of the Remote this must work when the Base unit is switched off.

Of course this would be simple if there were more connections between the two ends but most users would like to continue using just the two cores of cheap bell wire to link them. This adds extra complexity to the circuit but if it results in cheap and easy connection it is worthwhile.

Commercially produced intercoms often use biased switches with as many as four poles. Designs for home construction usually use panel-mounted switches because these are readily available and easy to fit, but they normally have a maximum of just two poles.

SWITCH ROUTING

The aim with this design, therefore, was to accomplish the signalling with simple 2-pole switches. As this switching is a little difficult to follow, some simplified diagrams of the operation are included here to explain it.

Shown in Fig.2 is a simplified version of the whole circuit with the amplifier and signalling tone generator shown as symbols and all the coupling capacitors omitted. The base (b) drive resistor for transistor TR1 is also not shown. The switches are labelled in the same way as those of the full circuit diagram and all are shown in the "off" position.

Since connections to normally-open poles of the switches are not doing anything useful, Fig.3 shows the same circuit with all these inactive connections omitted. It is now easy to see that the Remote speaker is connected to the input of the amplifier, although even this is not actually doing anything useful.

The Base speaker, however, is connected to the output of the tone generator via S2b, which is one side of the "call Remote" switch and S4b, part of the "on-off" switch.

The two inputs to the tone generator are both "active low", in that negative inputs activate them, so when the Base unit is

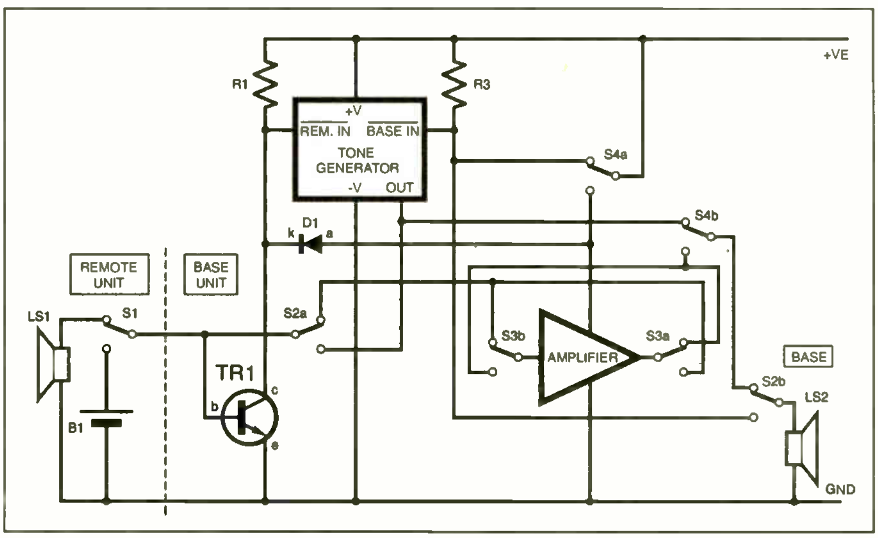


Fig.2. Simplified circuit diagram of the Two-Way Intercom, with tone signalling.

switched off S4a forces the Base unit's input high to prevent inadvertent calling of the Remote.

CALLING BASE

In Fig.4 is shown the Remote user calling the Base with switch S1, a biased single-pole changeover switch fitted in the Remote unit. This disconnects the speaker and instead connects the line to a battery which turns on transistor TR1, which in turn switches on the tone generator. (The transistor's base resistor is again omitted for illustrative clarity.) The tone output goes to the Base's speaker via S4b and S2b.

In Fig.5 the Base unit has been switched on with S4. S4a applies power to the amplifier and S4b connects the Base speaker to its output, via S2b. The Remote speaker is still connected to the amplifier input via S1, S2a and S3b so if the user at the Remote end speaks they will now be heard at the Base.

When the amplifier is powered, a "high" signal from the diode D1 is used to force the Remote's tone generator input high so that inadvertent operation of S1 will not give the user at the Base an unpleasant surprise! Note that in the final circuit, a current limiting resistor is used in the transistor's collector path, to prevent excess current from the powered diode ever being shorted to ground.

CALLING REMOTE

If the Remote user is not present when the Base is switched on the Base user will want to signal them. Fig.6 shows how this works. S2b disconnects the Base speaker and uses it to pull the Base tone generator input low.

Meanwhile S2a disconnects the Remote speaker from the amplifier input and couples it to the Base tone generator output, so the signalling tone will be heard at the Remote unit.

The action of S3, the "listen-talk" switch, is not shown in these drawings because its operation should be clear from Fig.1. All the switches with the exception of the on-off switch are biased types, so the user at the Base has "on-off", "press to call" and "press to talk" functions which are easy to understand. The Remote user has simply "press to call".

The arrangement provides a couple of useful interlocks in that the Base cannot call the Remote unless it is switched on and the Remote cannot call the Base unless it is switched off.

POWERING REMOTE

The decision to use a battery in the Remote unit came about as follows. The most practical way to signal without it would be to place a large electrolytic capacitor in series with the speaker, energise the line with a positive voltage through a resistor, and short this voltage to ground with a switch to initiate signalling at the Base.

However, this capacitor would then appear in series with the input and output coupling capacitors of the amplifier and these would also be exposed to polarity reversals between "talk" and "listen". Overcoming these problems would give

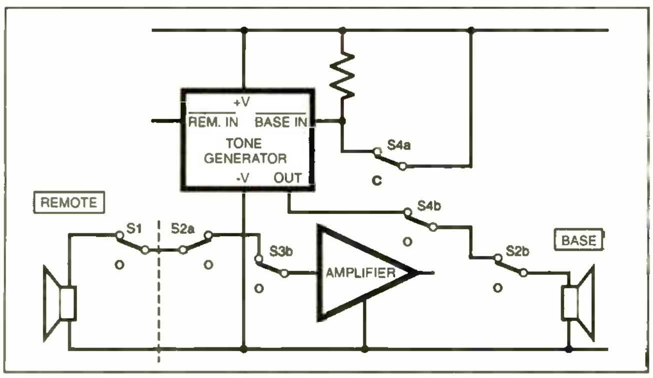


Fig.3. Base station switched off.

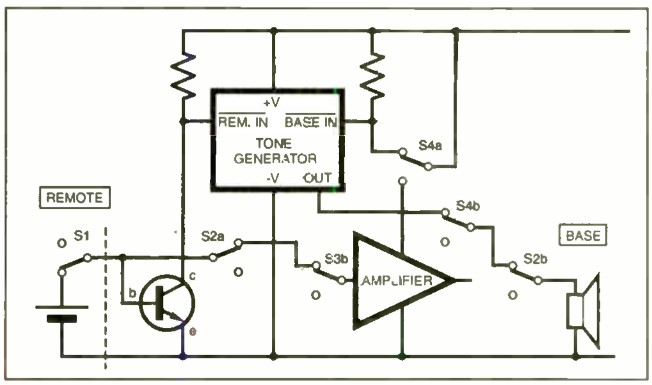


Fig.4. Remote unit calls Base.

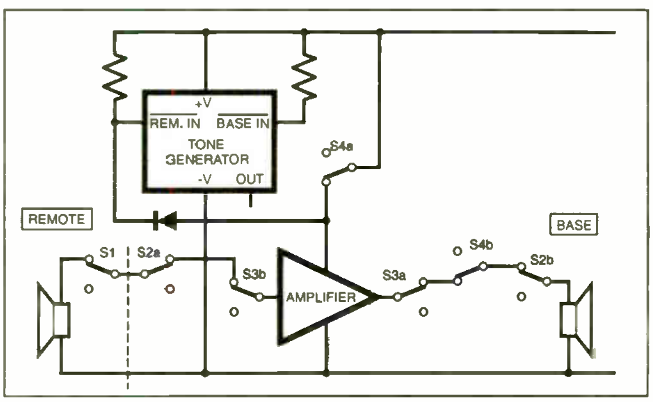


Fig.5. Base unit switched on.

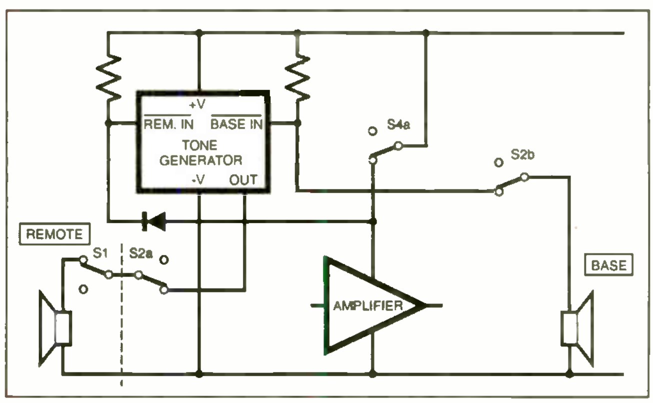


Fig.6. Base station calls Remote unit.

COMPONENTS

Resistors

R1, R3, R16	1k (3 off)
R2, R4, R7	10k (3 off)
R5	100k
R6	39k
R8, R10	2k2 (2 off)
R9, R13	22k (2 off)
R11	100Ω
R12	15k
R14	47Ω
R15	470Ω
R17	1k5
R18	10Ω

All 0·6W 1% metal film

See SHOP TALK page

Potentiometer

VR1	10k round, cermet preset horizontal

Capacitors

C1	47µ radial elect. 10V
C2, C3	10n resin-dipped ceramic (2 off)
C4, C9, C16	100n resin-dipped ceramic (3 off)
C5	1n resin-dipped ceramic
C6, C10, C11	10µ radial elect. 63V (3 off)
C7, C13	470n resin-dipped ceramic (2 off)
C8, C12, C14, C15	220µ radial elect. 10V (4 off)

Semiconductors

D1	1N4148 silicon diode
TR1, TR3	BC184L *npn* transistor (2 off)
TR2	BC214L *pnp* transistor
IC1	4011B quad 2-input NAND gate
IC2	LM386-N1 audio amplifier

Miscellaneous

S1	s.p.d.t. min. toggle switch, biased one way
S2, S3	d.p.d.t. min. toggle switch, biased one way (2 off)
S4	d.p.d.t. min. toggle switch
LS1, LS2	8 ohm 0·3W loudspeaker, 66mm (2·5in.) diameter (2 off)
B1	1·5V AAA cell, plus holder, for Remote unit
B2	1·5V AAA cell (4 off), plus holder, for Base unit
SK1	3mm mono jack socket and plug, or similar

Printed circuit board, available from the *EPE PCB Service*, code 282; 8-pin d.i.l. socket; 14-pin d.i.l. socket; plastic case, 120mm x 100mm x 45mm for Base unit (see text); plastic case, 145mm x 90mm x 30mm for Remote unit (see text); connecting wire; solder etc.

Approx. Cost Guidance Only £20 *excluding batts.*

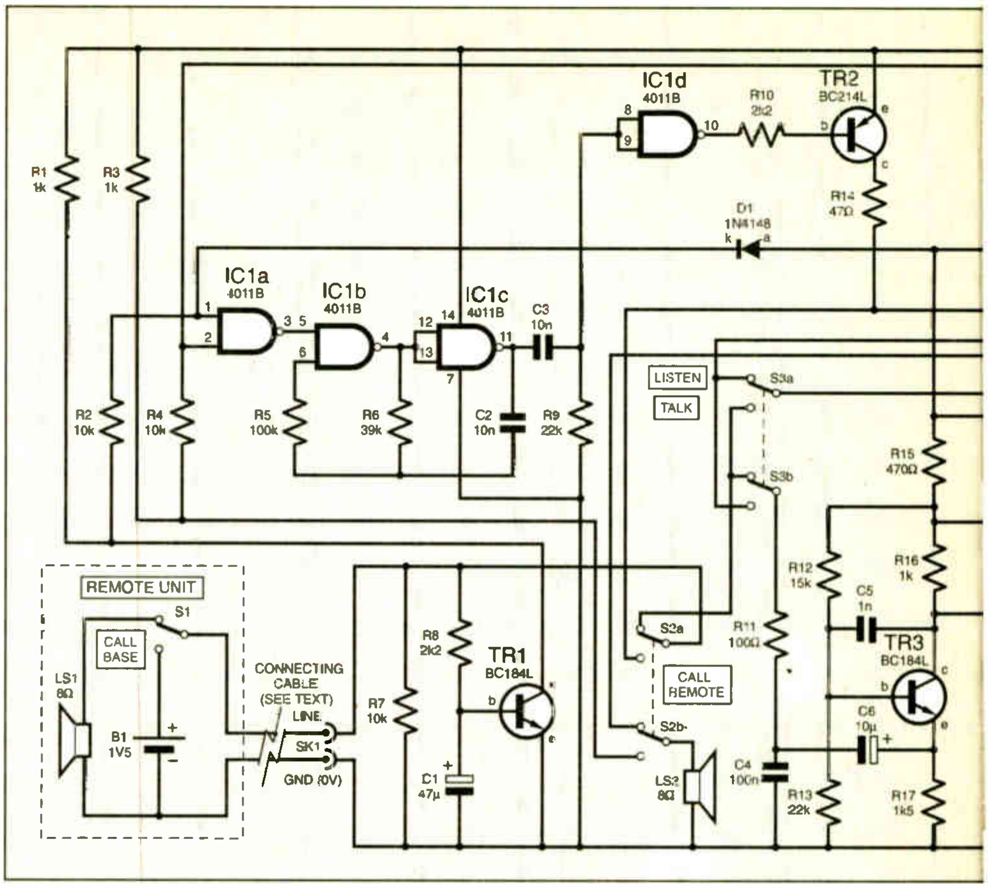


Fig.7. Complete circuit diagram for the Two-Way Intercom.

rise to quite a lot of additional complexity, all of which can be removed at a stroke by the use of a battery at the Remote end.

A potential of just 1·5V is quite sufficient to turn on a transistor in the Base unit. As only a tiny intermittent current is needed, a single AAA cell will last almost indefinitely. Its voltage is less than that at the input and output of the amplifier when switched on so their coupling capacitors are always correctly polarised.

The only time reverse polarity occurs is when the Remote unit calls the Base whilst it is switched off. This involves only the 1·5V battery across the small (10µF) capacitor, C6, which is in series with a resistance of at least 1·5kΩ so it is unlikely to cause problems.

FULL CIRCUIT

Moving to the full circuit diagram shown in Fig.7, the amplifier part of this is at the bottom right. When used as a microphone a loudspeaker has a very low output impedance which should be matched by the amplifier input, so the input stage is built around transistor TR3 using a common-base arrangement.

The signal is applied to the emitter (e) through coupling capacitor C6 and the output is taken from the collector (c). This stage has additional supply decoupling in the form of resistor R15 and capacitors C8 and C9.

Its output passes through the preset gain control VR1 to the input of IC2, an LM386-N1 which is an inexpensive audio amplifier i.c. The output is delivered through coupling capacitor C12.

The power supply to the amplifier circuit, from S4a, is decoupled by capacitors C15 and C16. Switch S3 provides the "talk-listen" changeover function. The voltage gain of the transistor stage is about five, whilst the overall voltage gain of the complete amplifier is about 1000, although this depends upon the setting of VR1. The frequency response extends from about 200Hz to 2kHz which is adequate for speech communication.

SIGNALLING FREQUENCY

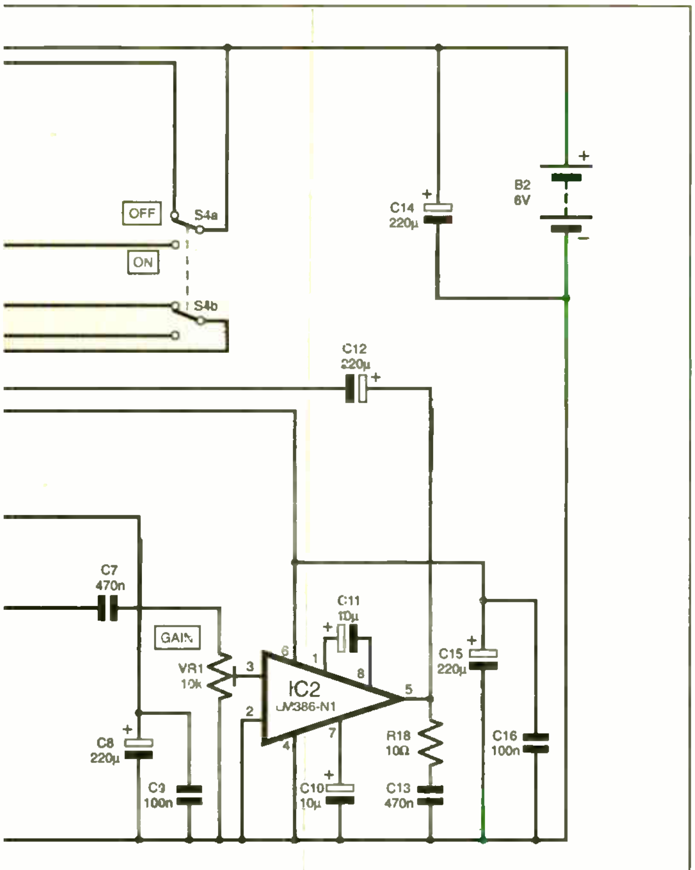
The signalling tone has a frequency of about 1kHz and is generated by an astable oscillator built from the two CMOS NAND gates IC1b and IC1c, with R6 and C2 being the frequency determining components. The oscillator is controlled by NAND gate IC1a. Its output passes to NAND gate IC1d through capacitor C3, which with R9 ensures that the output from this gate consists of a stream of negative-going pulses with a width of about 120µs.

This drives transistor TR2, whose collector output drives the speakers via the switches as described earlier. Resistor R14 sets the volume of the tone and its value may be altered if required.

Moving to the tone generator controlling gate IC1a, both inputs to this are normally pulled high by resistors R1 and R3. Operation of switch S1 in the Remote causes battery B1 to turn on transistor TR1 by supplying bias current through resistor R8.

The collector of TR1 then pulls the input to pin 1 of IC1a low so that its output pin 3 goes high, allowing the tone oscillator to operate. Capacitor C1 prevents the transistor being turned on by large transients in the audio signals when these are present on the line, and R7 ensures TR1 turns off rapidly when S1 is released.

When the Base unit is switched on, S4a applies positive voltage to pin 1 of IC1a via



Switches S1 to S3 must be biased one way types.

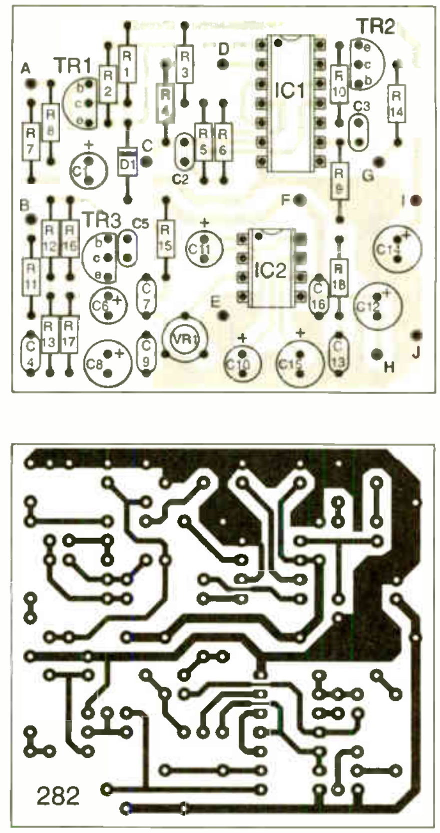


Fig.8. Component layout and full-size foil master for the Base station printed circuit board (p.c.b.).

the diode D1 to block the oscillator's action, preventing the Remote from activating the signalling tone. If S2 is operated its S2b section applies the negative voltage to pin 2 from the Base speaker LS2.

This again activates tone generation which is now applied to the line via S2a to call the Remote. When the Base is switched off S4a applies a positive voltage directly to pin 2 to prevent signalling of the Remote from taking place.

CONSTRUCTION

Construction of the printed circuit board (p.c.b.) for this project should prove straightforward. Its component and track layout details are shown in Fig.8. It is available from the *EPE PCB Service*, code 282.

Start by inserting the ten pins for external connections since these sometimes require a fair amount of insertion force. These should be followed by the eighteen resistors and the diode, then the eight small ceramic capacitors, the three transistors and two dual-in-line (d.i.l.) sockets for IC1 and IC2. These can be followed by preset VR1 and the eight electrolytic capacitors, which all have their positive connections uppermost.

Following a careful check of the soldering, especially around the "between pins" areas beneath IC1, the board should be ready for testing.

FIRST TESTS

For test purposes the connections on the board are all labelled with letters in Fig.8.

The first test is to connect a supply of +6V to point *I* with negative to point *J* and check that +6V appears at pins 1, 2 and 14 of the socket for IC1. At this point the current taken from the supply should be zero though there will be an initial surge as capacitor C14 charges.

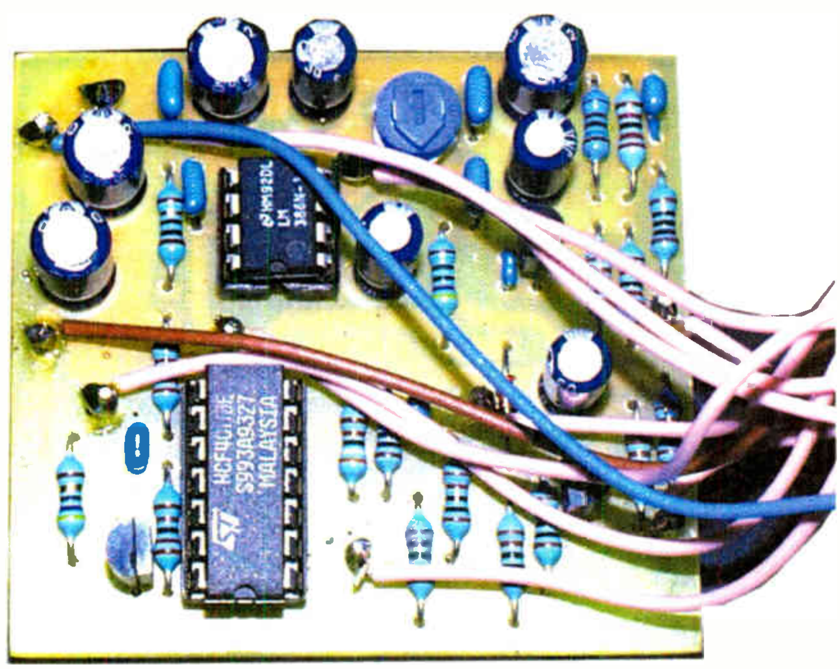
Next the amplifier part of the board should be powered by connecting +6V to point *F* with the negative still on *J*. The positive supply should now appear at pin 6 of the socket for IC2 and there should be about 4V at the collector of TR3, which can be measured at the top of C7. The supply current should be about 1·5mA.

OSCILLATOR TESTING

Now the signalling oscillator can be tested. IC1 should be inserted in its socket, and the +6V supply connected to point *I* again. Discharge static electricity from yourself by touching a grounded item before handling IC1 as it is a CMOS device.

A meter should reveal pins 1 and 2 of IC1 high (positive), pin 3 low, pin 4 high, pin 11 low and pin 10 high. The supply current should be zero.

If the +6V supply is now linked to point *A*, pin 3 should go high and pins 4 and 11 should indicate about 3V (actually



Components mounted on the completed Base unit p.c.b.

oscillating with 50 per cent duty cycle). Pin 10 will probably indicate about 5·4V since the narrow pulse output means that it spends most of its time at positive supply potential. The supply drain should rise to about 10mA.

If a speaker is connected across points *G* and *E*, making point *A* high, this should produce the signalling tone from it with a supply drain of about 25mA.

AMPLIFIER TEST

Testing of the amplifier can now be completed. IC2 should be inserted and the +6V supply again applied to point *F*. The supply current should be about 6mA and there should be about 3V present at the output of IC2, pin 5.

A speaker should be connected across points *H* (output via C12) and *E* (ground). Touching point *B* (input) should result in audible hum, the level of which will be adjustable with VR1. This completes the basic testing of the board. VR1 should be left at about half-travel.

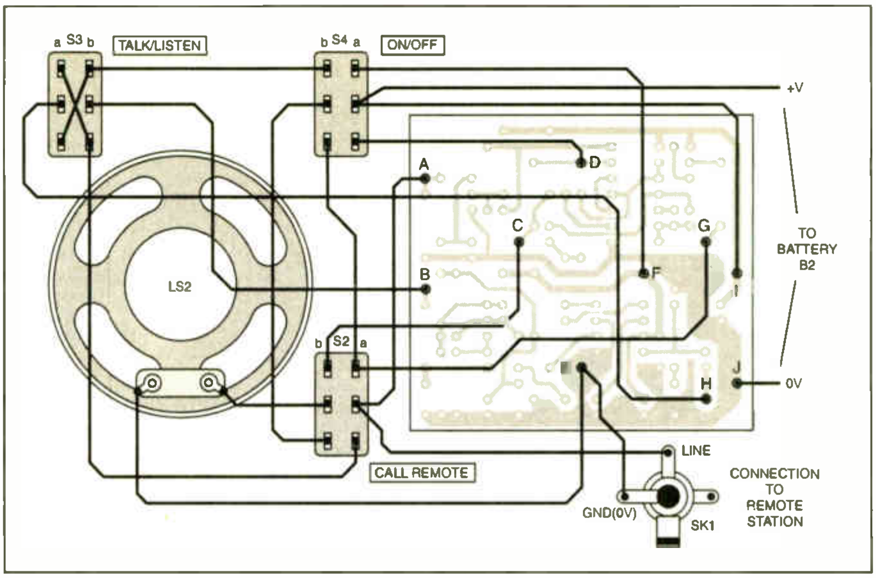


Fig.9. Base unit interwiring from the p.c.b. to off-board components.

ENCLOSURES AND WIRING

The cases for both parts of this project were ones that were already to hand in the author's workshop, and are by no means critical. Any cases of the constructor's choice may be used. A pattern of holes should be drilled in the front of each to act as a speaker "grille", the holes for the switches drilled, and these and the speakers secured in position.

The speakers can be simply glued into place with some "Evo-stick" or similar adhesive.

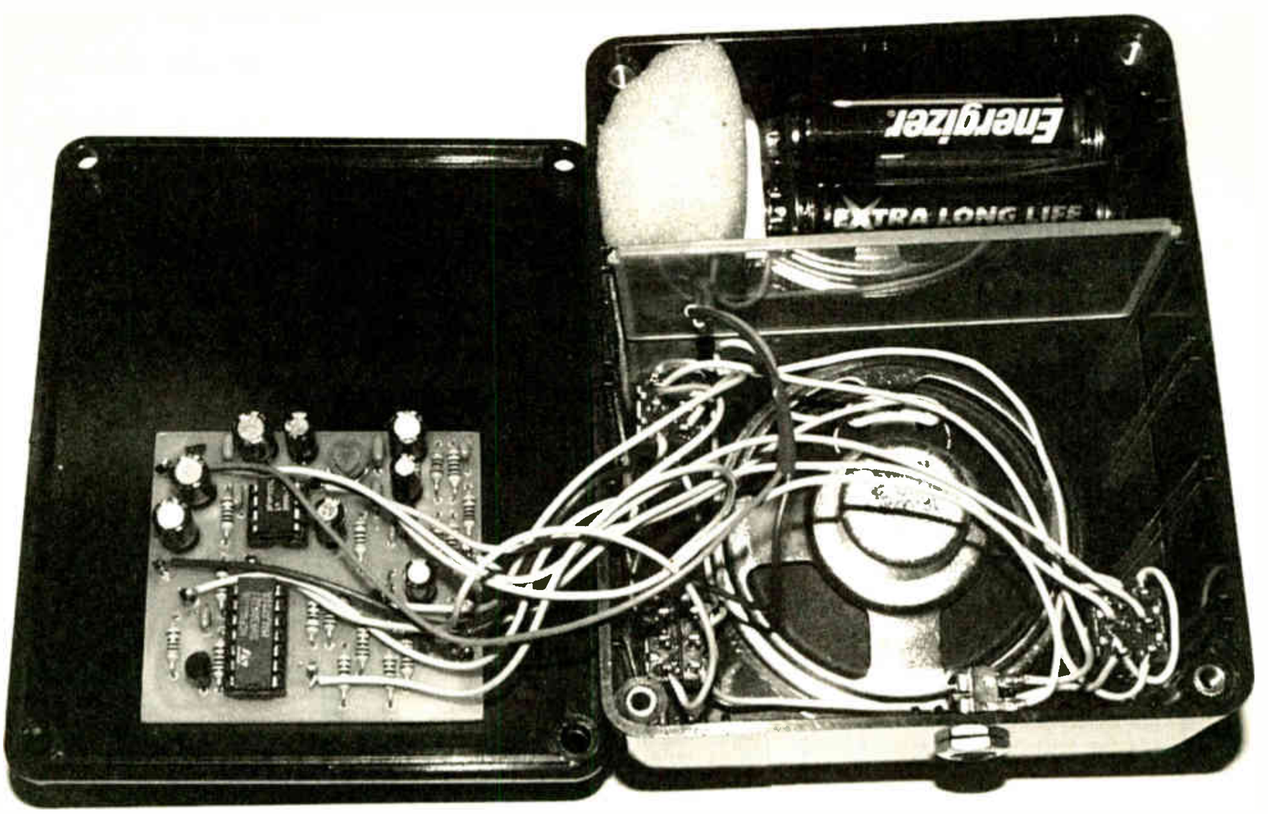
The next task is to complete the wiring between the switches and the p.c.b. and, as readers may have gathered from the earlier descriptions, this can be fun! The best method is probably to follow the wiring diagram in Fig.9 as closely as possible and perhaps tick off each connection as it is made.

Note that it is essential to connect the "ground" side of the speaker and line connections to the point just below IC2 as shown. Connecting them to the negative rail at any other point can result in output signal current sharing a path with the input which may cause severe instability.

The illustration shows the switches and speaker in their approximate actual positions as fitted in the prototype with the p.c.b. to the right, this being how they were arranged for wiring. The p.c.b. was attached to the case lid with the author's favourite adhesive, Blu-Tack! Double-sided adhesive foam would do as well.

Just enough length was given to the p.c.b. leads to allow the lid to be folded into place. The switches are all of the type having the normally-open (n.o.) contact at the top and the normally-closed (n.c.) one at the bottom so this should be checked before wiring is commenced.

Battery B2 consists of four AA cells in a holder, fitted into a compartment made inside the case by placing a piece of sheet plastic into the moulded guides provided. In the prototype a 3·5mm mono jack socket was fitted to the bottom of the case for the connection lead to the Remote unit, although readers may prefer to hard-wire the connections since this will prevent inadvertent disconnection between the units.



Layout of components inside the completed "master" unit showing the p.c.b. mounted on the lid and the battery compartment divider wall. If possible use multicoloured wires to help identify each lead.

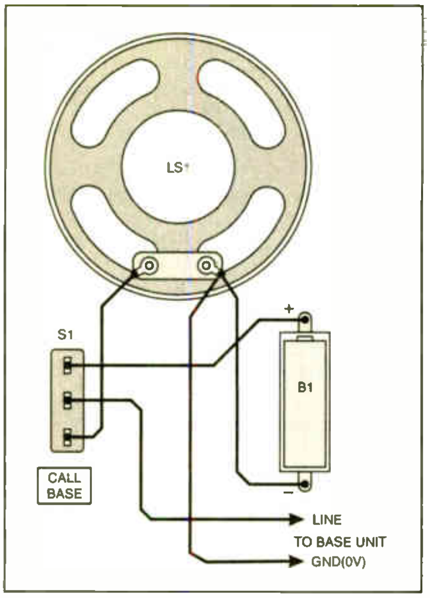


Fig.10. Remote unit interwiring.

SIMPLY REMOTE

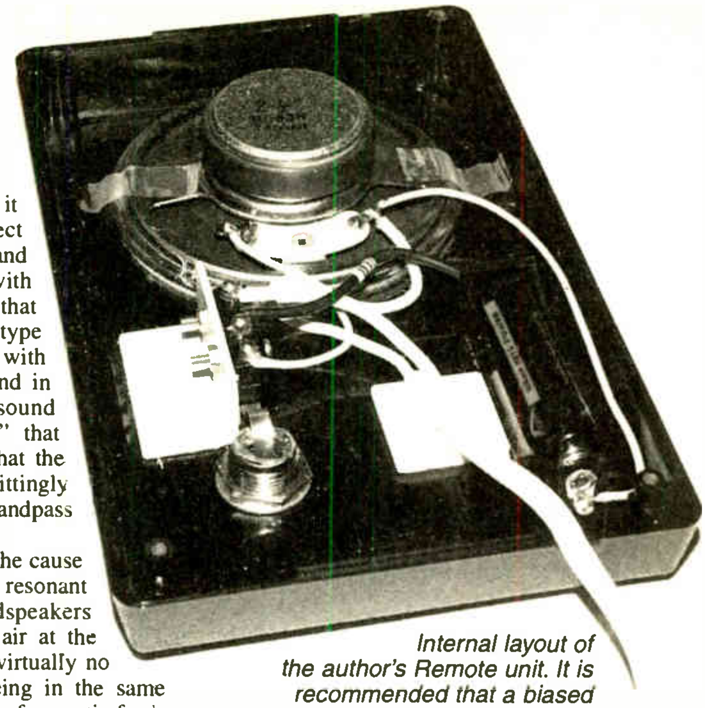
The layout of the Remote Unit is shown in Fig.10. This is extremely simple to wire as it has only three components! The connecting lead was soldered directly to the unit, although a second jack socket could be used if preferred.

The battery is a single AAA cell fitted in a holder glued to the case, though it should last indefinitely so connections can be soldered directly to it if preferred.

The switch shown in the drawing is another biased toggle type though sharp-eyed readers may notice that this is not the case in the photograph.

Originally the case was drilled for a large press-to-make pushbutton but this had to be abandoned when the battery and changeover switch were brought in.

Unfortunately, the hole left by the push-button was too large for a toggle switch and anyway the author rather liked the appearance of the large red button! To get around the problem without scrapping the case the button's innards were drilled out, a return spring inserted into it, and a micro-switch from the junk box was modified by bending its operating lever to work from the button. It looks nice but was tricky to do so the toggle switch is recommended for "production" versions.



Internal layout of the author's Remote unit. It is recommended that a biased toggle switch is used here.

JOINT VENTURE

With both units built it remains only to connect them together, test them and set the volume level with VR1. A point here is that early testing of the prototype amplifier was carried out with both speakers uncased and in the same room. The sound quality was so "boomy" that initially it was thought that the amplifier circuit had unwittingly been designed with a bandpass characteristic!

Investigation revealed the cause of the problem to be the resonant frequency of the loudspeakers which, dangling in free air at the ends of their leads, had virtually no mechanical damping. Being in the same room meant that a degree of acoustic feedback between them was inevitable and this of course also centred around their resonant frequency.

Fitting one of them into a small case improved the quality considerably and testing the project with them in different rooms helped even more. The use of loudspeakers as microphones means that this project will never deliver Hi-Fi results, but when the speakers are fitted into their cases it will be more than adequate for its purpose.

However, if large cases are used it may be an idea to put some wadding in them to improve the acoustic damping of the speakers, and testing in the same room will probably produce sound inferior to that which will be obtained when they are used as intended, over a distance.

OTHER OPTIONS

The amplifier of this project is fairly sensitive so it may well find uses as a baby monitor, a doorphone or in other applications where audio monitoring or communication is required.

It can operate from supplies down to 4V and draws surprisingly little current, so the pack of four AA batteries specified should give a fair amount of use. Alternatively a 9V supply can be used, which will last even longer, or a small mains powered supply could be built to power it.

Hopefully, constructors will find it both interesting to construct and a useful addition to the home or workshop. □

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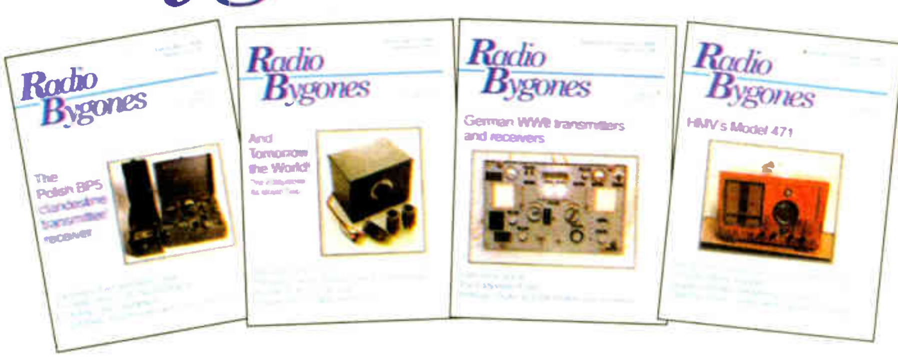

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★ LETTER OF THE MONTH ★

QBASIC AND WINDOWS 2000

Dear EPE,

I've been following the discussion regarding QBasic and Windows and felt it was my turn to "throw my penny's worth in", so to speak. First, QBasic does not seem to be on the Windows 2000 Server edition CD-ROM and it doesn't seem to ship with Service Pack #1 either. I copied a version from my Win98 PC and it runs just fine under Windows 2000.

I do question, though, if QBasic and other programming languages that were originally designed to run under DOS are the way forward. Looking through back issues of *EPE*, I see projects that connect to the user's PC via the serial or parallel port and I'm wondering how much longer this can go on from the DOS world.

Getting a Windows programming language like VisualBASIC to talk directly to the parallel port is difficult enough (it requires drivers or a special DLL). I don't know how difficult it is from QBasic but I'm sure you won't be able to keep doing it for much longer. I read with interest that the only way to use DOS on a PC with Windows ME (Millennium Edition) installed is to boot from the emergency repair disk.

I see a time when the majority of people are running Windows, and languages like QBasic just won't cut it. I do appreciate that people out there are still using '486 PCs or older and for these people, upgrading to Windows is difficult if not impossible.

What I would like to suggest is that we start to look at perhaps making available a Windows and a DOS version of PC software for projects that require interfacing to a PC. What would be a good starting point is when DOS/QBasic software is released for a project, a document describing how it interfaces to the hardware is also released. This would make it simpler for people like me to write an equivalent Windows version of the software.

What would be even nicer is a place on your web site where we could drop off our Windows code so other enthusiasts could use it. I for one love writing Windows software and would be only to happy to let other people use and play with my attempts.

Joe Farr, via the Net

I thoroughly agree with you Joe, DOS-based codes are now something of an anachronism. But, as I have said before, in matters such as software we must try to cater for those who have not yet upgraded, as well as for those who have.

In catering for the latter, the problem is that those who submit software projects must themselves be familiar with the higher level languages such as VisualBASIC and Delphi. Whilst we are receiving a trickle of such offerings, it cannot yet be called a flood.

We will be only to happy to publish suitable VB-based designs if we are offered them. We must emphasise, though, authors who do offer them must also make available ALL code involved, including source files. We have built a reputation on providing free software for published projects so that people can not only build the design as published, but also study the software and learn programming techniques from it as well.

It is appreciated that some authors may wonder why they should release source code upon which they have spent many hours of development. But then, so too might authors argue about circuit diagrams, the same principle applies.

Authors whose projects are published do receive payment for them, pro-rata to the number of pages printed, and do receive a small additional payment for software, even when the software is not actually printed in the magazine. We willingly admit, though, that no designer/author will ever make a fortune through having their creations published.

However, to my mind (and speaking as a frequent designer/author), it is not for the money that most people offer us projects. In most cases the reason is due to the sheer driving force of a desire to solve a problem in electronic or software terms and to then share with others the pleasure and satisfaction of having achieved that target. It is not feasible, though, for authors to generate two versions of software.

Regarding a site for software exchange, we feel that this could be a dangerous move – too many options for virus writers to wreak havoc with their criminal wares, and possible problems with passing on patented or copyright code.

QBASIC, AGAIN!

Dear EPE,

I just thought you might like to know that the CD-ROM of Windows ME contains QBasic in the **Tools\Oldmsdos** directory/folder just like the earlier Windows CD-ROM. So you can happily carry on using QBasic programs for a few more years!

P.S. Does ME stand for Millstone Edition?

Alan S. Raistrick, via the Net

Highly useful info Alan, thanks. Whilst I am "well into" VB, I still see a medium-term use for QB as well.

As regards your query, perhaps other readers might care to answer it!

CONGRATS

Dear EPE,

I would like to thank you for the *PIC Tutorial* series (Mar-May '98). I followed it with great interest, as it enabled me to baffle the lecturers in college (!) and helped me obtain my degree, and my first job. So keep up the good work! Thanks, and thanks for a great mag.

John Rees, via the Net

That's great news John, congratulations. I am pleased to add that other readers have achieved similar success by following that series. It's rewarding to know that I've been able to help so many of you.

INCORRECT INFO

Dear EPE,

In Barry Fox's news item *Analogue Frequency Sell-Off Unlikely* of Nov '00, factually incorrect information was given on the mux equalisation project in the Crystal palace area.

Crown Castle International, formerly part of the BBC, is equalising the Crystal Palace transmitter along with four more at Hannington, Oxford, Hemel and Sandy Heath. These are in fact our sites. NTL does not provide a DTT service for ONdigital because Crown Castle built and operates the ONdigital network.

We would be pleased to invite Barry Fox to our premises to understand what Crown Castle does.

Melanie Dunnett,
Marketing Manager,
Broadcast, Crown Castle UK Ltd

Thank you for informing us. We have forwarded your E-mail and invitation to Barry.

Readers who wish to know more about Crown Castle can access the web site at: www.crown-castle.com. Crown Castle also invites you to visit the Third Generation Mobile Multimedia web site at www.3g.thefuture.com.

TURBO BASIC

Dear EPE,

Regarding *Readout* Oct '00, G.A. Bobker referred to Borland Turbo Basic being no longer available. Strictly speaking this is true. However, the product was sold off to the author R.S. Zaie who has since produced it under the name of PowerBasic. The contact details I have are:

PowerBasic Inc., 316 Mid Valley Centre, Carmel, CA 93923, USA.

Tel: (408) 659 8000. Fax: (408) 659 8008.

Web: **www.powerbasic.com**

On the website, the UK suppliers are listed as:

GreyMatter Ltd., Prigg Meadow, Ashburton, Devon TQ13 7DF. Tel: 01364 654 100.

E-mail: maildesk@greymatter.co.uk.

Web: **www.greymatter.co.uk**.

QBS Software, 11 Barley Mow Passage, Chiswick W4 4PH. Tel: 020 8956 8000. Web: **http://www.qbss.com**

PowerBASIC (cc 1994 V3.1) has machine code mnemonics as part of the language, is compatible with both C and Pascal and has a "bolt-on" program (PBDK) that makes your program run as a Windows program. This Basic is *very* powerful. If you can do it in "C", then you can do it in PowerBasic.

However, I tried to convert your PIC Programmer software to it, but gave up as most of the variable names used were keywords in PowerBASIC! There is no 64K memory limitation in PowerBasic and it would have been nice to have it as one program. I still use the PIC programmer software . . . a little bit of magic, and great fun!

Ivor Matell, via the Net

Thanks Ivor for your observations and the source details. As has been said on other occasions in various ways, however, we believe that we should go down the VisualBASIC route, with possible excursions into Delphi as well.

HONOURED

Dear EPE,

I am pleased to inform you that, with the help of *EPE*, I have gained a first class honours degree in Electronics and Instrumentation Systems from the University of Wales College, Newport.

As a subscriber, I always look forward to the magazine dropping on the doormat for the news, series and projects. On many occasions, articles seemed to be perfectly timed with lectures and assignments, helping my understanding of many topics. It was thanks to *EPE* that my final year project featured a PIC microcontroller, saving much time and effort over conventional logic methods.

Lyn Jones B.Eng. (Hons),
Gilwern, Abergavenny, Gwent, Wales

We are delighted to hear of your success Lyn. Congratulations and thanks for your kind words.

BLASTING CONFUSION

Dear EPE,

Thank you very much for your absolutely brilliant, confusion-blasting *Teach-In* series. I am now "hooked" – or more relevantly, I am clamped up as close to the supply rails as it is possible to be! My interest is not just some temporary "impulse response", soon to suffer exponential decay . . . It is more like the response of an op.amp integrator whose offset has not been zeroed – forcing its output to sum indefinitely up to an infinite supply rail!

More seriously, it is going to prove extremely valuable to myself and my course-mates on the second year electronics degree at Birmingham University.

I was wondering if a list of our practicals for the second year may help you to decide on future articles as there may be similarities across the country?

Andrew Massey,
University of Birmingham

Thanks Andrew for your enthusiastic words!

Editor Mike comments that the subjects listed in the rest of your letter show that the course you are on goes above the theory level that we cover in EPE. *We are also not in a position to produce and publish projects to fit in with specific courses. However, we will keep your suggestions in mind.*

VB ENCOURAGEMENT

Dear EPE,

To encourage people to use VisualBASIC, Microsoft allow any student following a course which leads to a nationally recognised qualification, primary, secondary, tertiary, or any lecturer or teacher to buy some of its products under the "educational license". This is different to the VB Learning Edition, and would be well worth starting an evening A level course for.

I believe the three products are Office 2000 (Premium costs about £145), Windows 98/NT4 (costs under £100), and Visual Studio Professional (costs about £75). To make use of this facility you have to pay the money up front, then have an educational establishment countersign a form, which in turn is sent to Belgium. About three weeks later the CDs arrive. Install the software and you are up and running the latest Microsoft software at a fraction of the recommended retail price. Love him or hate him, Bill Gates certainly knows how to entice.

I took advantage of the deal and now have more programming languages (Visual C++, Visual J, Interdev, Visual Basic) than I can learn this winter! What is even sweeter is they are totally legitimate and I am registered with Microsoft as a programmer.

I hope the information allows others to investigate and make use of this fantastic deal.

Mike Halliday, Neston, Cheshire,
via the Net

Thanks Mike, this is obviously an offer well worth following up if you have educational connections.

PICS vs 8051

Dear EPE,

I am enjoying the Online version of your magazine and was wondering why you focus exclusively on the PIC microcontroller? Here in the USA, in industry the 8051 is the most used microcontroller as it's been around a long time and has so many companies that make different versions of it.

I finally found a book that was written by practicing teachers, not engineers! The book is *The 8051 Microcontroller and Embedded Systems* by Muhammed Ali Mazidi and Janice Gillispie Mazidi. Mr Mazadi is a teacher at DeVry Institute in Texas and this textbook is used there (of course).

My background is 22 years in Analog/RF and so learning microcontrollers was a bit of a challenge and frankly didn't make much sense until this book came along. Also, I frequent the **8052.com** website's Forum, and it was brought to the groups' attention that there's a new 8051 chip out that has 20MIPS throughput. The company's web address is **www.cygnal.com**. The features that are packed on that chip put any PIC to shame.

The Atmel 8051 chips are easily programmed using the simple programmer schematic on the Atmel applications notes page, so that should set someone back between \$15-\$20 US. Secondly, there is a *free* ANSI C compiler available on the web at **http://sdcc.soundforge.net**. For those who want to program in BASIC, the 8052 chip has a BASIC interpreter built in.

I would also like to see articles on designing and building a DSP (digital signal processor) circuit, maybe using a microcontroller.

Keep up the good work on your excellent magazine.

Randall Seden,
Simi Valley, California, USA,
via the Net

Editor Mike replied to Randall, saying that:

EPE is essentially a hobby/educational magazine and the PIC is much more suited to such users. PIC programmers cost about \$20 US (in kit form) with in-circuit emulators for around \$60 US in kit form. There is also plenty of free software around for these chips. The chips themselves are very cheap (starting at around \$3) and relatively easy to learn how to program. Hence their popularity in this area of the market.

The 8051 may well be the industry standard but because of the relative complexity and cost, it is not popular with the hobbyist or in schools, and frankly its extensive features are rarely required for the type of project most readers want to build.

WIND-UP TORCH

Dear EPE,

I would like to thank you for the *Wind-up Torch* of Oct '00. It's my first project that I am attempting. I have only been studying electronics over the past few months, and find it more and more fascinating every day.

I wondered if you could perhaps help me with a couple of queries. I have received all of the components, which I might add came close to £18 as stated in your approximate costing. I have also managed to get hold of an old photocopy machine which had lots of goods inside such has lenses and motors. Some of these motors have six, seven and even eight wires to them, I'm not quite sure how to wire them to the bridge rectifiers. Can you help?

Darran McGee,
via the Net

We are very pleased to learn that you have discovered the pleasures of our hobby Darren. Regrettably, though, we can never offer advice on modifying published projects to suit constructor's needs. Basically this is because we simply do not have the time to do so, but in this case is also due to us being unfamiliar with photocopier motors!

FLIGHT LOGGER

Dear EPE,

I am a disabled person due to an RTA some years ago but am, however, a keen microlighter. Due to my disability I have difficulty in turning around whilst in flight in order to see the contents of the fuel tank. As I have a keen interest in electronics, I thought I would build a microlight microprocessor design to overcome this, but am finding it too difficult to write the software.

You can imagine how excited I was on reading about your *8-Channel Data Logger* of Sept '99 which uses the PIC16F877 microcontroller. I am looking for some software for this range of PIC that would give me five A/Ds, with an external interrupt, outputting to an l.c.d. It should be capable of toggling through the l.c.d. displays – engine temp, fuel flow, air speed, r.p.m., etc.

Mike Woodmansey, via the Net

So sorry Mike, but I don't have the time to write the software for you. However, my Data Logger *already shows how PICs can do A/D, although the interfacing to the various sensors you need would seem complex.*

You might care to give thought to another option, though. I recently bought a new car that has the majority of the functions you need built into its dashboard. It might be worth enquiring of a car dealer if such equipment can be bought separately.

IR HEADPHONES

Dear EPE,

I am looking to make infra-red headphones/speakers for my A-level major project. I wrote off to Sanyo and they sent me a service manual of one of their models but it is very complicated. Have you published any such designs?

Chris Logan, via the Net

We published Mono Cordless Headphones *in Aug '96 and* Stereo Cordless Headphones *in Dec '95. See our back issues page for details on purchasing copies of them.*

ACTIVE PORT FINDING

Dear EPE,

Printer and serial port addresses have often caused much consternation and confusion when accessed directly by programs used to control hardware connected to the port, mainly because not all PCs use the same port addresses.

The usual base addresses for printer ports LPT1 to LPT3 are H378, H278 and H3BC respectively but this cannot be guaranteed.

Hardware addresses are of no consequence to the user if the PC is used as was intended, i.e. using calls to the BIOS. But how does the BIOS know the port addresses? Simple, they are stored in RAM.

To find the addresses in your computer open a DOS Window or shut down Windows to DOS mode. At the command prompt type **debug**. Then type **d0000:0400**. This command will print on screen a hex dump starting at the specified address. The printer and serial port base addresses will appear on the first line, for example:

```
          COM1   COM2   COM3   COM4
0000:0400 F8 03  F8 02  00 00  00 00
          LPT1   LPT2   LPT3
          78 03  00 00  00 00  13 02
```

If the hardware does not exist or is disabled the address is zero. As you can see from the above my computer has two serial ports and one printer port. Any programming language that has a PEEK function (or equivalent) can access this memory. QuickBASIC has PEEK and DEFSEG. This makes it very easy to write a setup program to determine port addresses by asking the user which port number to use.

Peter Hemsley, via the Net

Hello again Peter, and yet more thanks! (Keep your useful suggestions coming . . .)

More letters on page 49

NEW OLD READER

Dear EPE,

Would you believe that the *EPE* November issue is the first electronics mag I have bought since 1995! Although I have been an electrons "nut" for 30+ years and have over this time had most of the electronics mags (I still have some 1960's issues of *PE*).

I generally build with a specific purpose in mind, and use a lot of recovered parts from old boards. My last major project revolved around a Maplin Z80 development board, driving a MIDI keyboard interface for my Elka E19 Electronic Organ, some 20+ i.c.s. It has RS232 PC connection for download of .OBJ files. I now find I can do the same thing with a PIC and a couple of i.c.s.

The web support from Microchip is excellent, especially for MPLAB. I am now building a PIC16F874 version of my MIDI interface, so was pleased to read *EPE*'s articles. I'm considering building the *Pulsometer* (Nov '00) as I have most of the components. The other articles will be useful for pinching a few circuit ideas, keep it up!

I also run a components swap site, at **oldicbank@b98oqp.freeserve.co.uk**.

Les Clarke, via the Net

Welcome back, Les. Keep up your enterprises too!

PIC TUTOR

Dear EPE,

I purchased the *PICtutor* CD-ROM and deluxe development kit from you a few months ago. The board and software are very good, but now I have programmed the PIC16F84, I need to go the next step further. I am designing a program which needs around 30 outputs. The ideal chip I need is the PIC16F877, which is a 40-pin i.c. *PICtutor* only programs the PIC16x84. How can I now get hardware and software to program the PIC16F87x range?

I like the way you can program and use the l.e.d.s and switches to test the program after you have finished programing it. Is there a kit like *PICtutor* for the PIC16F877 where I can do all this?

Rob P. Via the Net

My PIC Toolkit Mk2 *of May/June '99 (updated to V2.4 Nov '00) handles PIC16x84 and PIC16F87x devices, although it does not have development switches and l.e.d.s such as are included on* PICtutor. *I am not aware of any programmer that does offer all the features you require. Nonetheless, I am sure that Toolkit's additional features, such as automatic control of program voltages and the ease of code assembly and programming, will be of great use to you.*

DELPHI POWER

Dear EPE,

Further to the on-going BASIC discussion, why not use Delphi 2 or 3 where you can access the ports through simple in-line assembler routines, easy to write and implement. No need for DLL and runtime modules, etc. If you use Delphi 1 you can access the ports directly.

Anyway, I think that Delphi is more powerful than VB, more "modern" and through its educational value would yield more knowledge to the user for PC interface projects.

Alexandre Cazin, via the Net

It's a good recommendation you make Alexandre, and which may sway other readers. For myself, though, I am now so far advanced into using VB6 that the steepness of yet another learning curve to come to grips with makes me reluctant to examine Delphi as well. It is obvious, however, that Delphi has many attractions, and devotees.

Incidentally, thanks to all of you who have been entering into this interesting discussion, and for the helpful comments made, not only here in Readout, *but also through our* Chat Zone.

DELPHI AND PORTS

Dear EPE,

This little bit of in-line assembly should allow you to use Delphi to read any port. I currently use it in Delphi 5 Pro and find that converting some functions into assembly can really speed things up.

```
function ReadPort(nPort : Word) Byte;
begin
PortNumber:=nPort;
var nByte,PortNumber,DataPort dWord;
asm
  mov dx,word ptr PortNumber
  in al,dx
  mov byte ptr DataPort,al
end;
Result:=Lo(LoWord(DataPort));
end;
```

Feel free to use this code in anything. Also could you please consider AVRs instead of PICs sometime. I do use PICs a lot for embedded stuff interfaced with Delphi. But I do prefer using AVRs as they're faster and simpler to use.

Jamie Dainton, via the Net

Thanks, Jamie. It's interesting how we as an electronics *magazine find that so much of the correspondence is about programming aspects.*

As I know from my own personal experience, of course, there are so many electronics designs that can be simplified through using programmable devices. It is understandable that many readers feel similarly (although we recognise that many do not, and we would reassure them that we have no intention of ever ignoring their interests.)

As we have previously said in Readout, *it's PICs that most readers are interested in.*

TRANSLATION

Dear EPE,

I am interested in building the *Rev Counter* of Dec '96. I have built the *PIC Tutorial* board, and have programmed several PICs with it and find it really good.

I am having problems programming a PIC with the program for the *Rev Counter* which I downloaded from your FTP site. I know that it is meant for a PIC16C54 but I want to use a PIC16F84 because I have it available. I am having problems modifying the code for this PIC, even though the published text says that it is possible. What do I do?

Also, my technology teacher would like to know if there is any difference between the PIC16C84 and the PIC16F84.

William Quinn, via the Net

Sorry to disappoint you William, but we cannot offer advice on translation of code to suit different PIC variants. This is a matter to which readers must pit their own capabilities at logical analysis of a programming problem.

In fact there is little difference between the code required for PIC16C54 and PIC16x84 devices. We suggest you obtain the (free) data sheet for both devices from Microchip's web site at **www.microchip.com**. *In the long run, if you have programming ambitions, by solving this problem for yourself, you will be well on the way to understanding how to fully apply logical thinking to all manner of computing problems.*

On your other query, any code written for the 'C84 will run on the 'F84. However, this is not necessarily true the other way round since the 'F84 has more registers than the 'C84. Having just received Microchip's latest CD-ROM, though, it seems that the 'C84 is no longer in production, having been entirely replaced by the 'F84.

Incidentally, it seems likely that Toolkit can also program PIC16F83 devices, these having the same basic specs as the '84 except that the '83 only has 512 bytes of program memory compared to the 1024 bytes of the '84. The EEPROM data memory is the same.

PIC TRASHED?

Dear EPE,

I've been using your excellent (original) programmer for over a year. Just recently an odd thing happened. I decided to change the PIC factors in a working PIC to allow flash programming. By accident I selected an '84 (I only use F874) and hit Return – BANG! the PIC will no longer run. I've tried resetting the PIC factors, but it still won't play. What have I done? Luckily I had a spare which I successfully programmed and factored (more care taken this time!) Have I made a duff item?

Chris Jones, via the Net

I don't know, Chris. Similar problems have been reported by readers using other types of programmer too. It is not specific to Toolkit *(to which I assume you refer).*

However, I have only heard of it occurring with PIC16F87x devices, not with the PIC16x84 – you are the first to report the problem with this device.

It seems that PIC16F87x devices in such circumstances have had one or more Code Protect flags unintentionally set as active and which cannot be deactivated, even though this protection is normally under the control of the Configuration Word settings sent by the user through the Config option.

I suspect that one of my PIC16F877 chips has suffered similarly, but I have not yet looked into it, although I shall in due course. If I solve it, I'll report the method through Readout. Do any readers know the answer already?

TOOLKIT V2.4 AND V3.1

Dear EPE,

After following the excellent *PIC Tutorial* series and subsequent articles, I am hooked on PIC programming. Indeed it has found many uses in my job as a faulting Engineer with Racal. Unfortunately I am experiencing a problem when I try to assemble a particular file I am working on using *PIC Toolkit V2.4*. This displays the message "String space corrupt in line 100 of module TKPROG02 at address 15f8:0E2E".

The same message has appeared with different line numbers and addresses. The problem seems to be experienced as soon as I include any additional line in the program. If I add data after line 1827 the error is flagged when the .ASM file is assembled. The data after line 1827 is no different to data elsewhere in the program. Any help you can give me will be much appreciated.

Stuart Pearson, via the Net

Stuart attached his program file to his E-mail and running it on my computer caused Toolkit to crash as well. Examination showed that he was using too many definitions (the limit is set at 20) and too many jump calls (a limit of 1000).

Both limits were set based upon my experience at writing programs and both seemed reasonable values. I suggested to Stuart that if he had QBasic (or QuickBASIC) he could increase the limits as set by the DIM statements for DEFINE() and JUMP() near the head of TKPROG02.BAS.

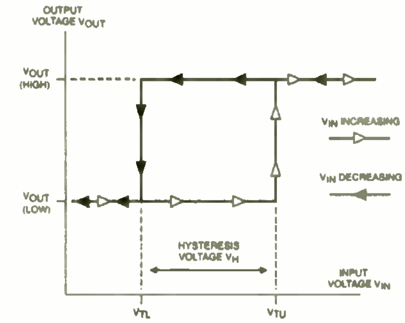
Stuart then E-mailed back to me, saying that he had changed the DIM parameters and the .ASM file now assembled correctly. Great!

It's a lesson, though, which many of us programmers can learn from. We need to periodically make assumptions about how others are going to use our software, and inevitably there will be occasions when we do not necessarily recognise all the permutations of use!

By the way, I am well advanced into writing Toolkit for Windows using VB and such feedback as provided by Stuart will be taken into account. If you would like any features added to this developing software, let me know (it won't see publication until well into 2001, though). A new p.c.b. will also be developed – any suggestions for this too will be welcomed.

Special Series

THE SCHMITT TRIGGER



ANTHONY H. SMITH

Part 3

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.

Precision Schmitt Triggers and Multivibrators

WE saw in Part Two of this series how operational amplifiers and comparators can be used as the active elements in Schmitt trigger circuits. By treating the op.amp or comparator as a "black box", the design process is often much simpler than the methods needed to design "discrete" Schmitt triggers using bipolar transistors and f.e.t.s.

Furthermore, the combination of high gain, small offset voltages and low input bias currents common to most op.amps and comparators usually results in a Schmitt trigger with superior performance to those built using transistors.

However, even when good quality op.amps or comparators are used, factors such as resistor tolerance and variations in output saturation levels can lead to ambiguities in the desired threshold levels. Furthermore, altering the value of one threshold by changing a resistor value can result in an unwanted change in the other threshold due to the interdependence of the switching levels.

This month, therefore, we take a look at methods that can reduce or even eliminate these uncertainties, resulting in precision Schmitt triggers with highly accurate threshold levels which in most cases can be varied independently of each other. We end this part by introducing two useful circuits, the monostable and bistable multivibrator, which are both based on the Schmitt trigger function.

SWITCHING OUT UNCERTAINTY

The circuit shown in Fig.3.1 uses an analogue switch, IC1, and a comparator, IC2, to form a single-supply, semi-precision, inverting Schmitt trigger. The switch (one quarter of a 74HC4066) is controlled by the logic level signal at pin 13: when this signal is "low", the switch is open; when it is "high", the switch is closed.

As shown by the circuit waveforms, the inverting nature of the circuit means that the comparator output, V_{OUT}, is at its high level, V_{OH}, when V_{IN} is more negative than the voltage V+ at the non-inverting input. Therefore, the switch is closed and the non-inverting voltage is given by:

Non-inverting input voltage,

$$V+ = V_{REF} \times \frac{R2}{R2 + R1//R_{ON}} \qquad \text{(switch closed)}$$

where $R1//R_{ON}$ is the parallel combination of R1 and the switch "on" resistance.

For the 74HC4066, R_{ON} is typically around 100Ω. Therefore, since R_{ON} is much less than R1 and R2, the expression may be simplified to $V+ = V_{REF}$, and so ignoring the comparator's offsets (typically just a few millivolts) we can say that the Upper Threshold Voltage, $V_{TU} = V_{REF}$.

When V_{IN} becomes more positive than V_{TU}, V_{OUT} goes to its low level, V_{OL}, causing the switch to open. The non-inverting input voltage is now given by:

Non-inverting input voltage,

$$V+ = V_{REF} \times \frac{R2}{R2 + R1} \qquad \text{(switch open)}$$

and again ignoring offsets, we can say that the Lower Threshold Voltage, $V_{TL} = V_{REF} \times R2 / (R2 + R1)$.

Beware that these equations ignore the effects of switch leakage currents and comparator input bias current which can result in significant errors if R1 and R2 are very large. However, R1 and R2 should not be too small or R_{ON} must be taken into consideration.

COMMON MODE RANGE

CMOS comparators like the TLC3702 are ideal for this kind of application. When operating on a single +5V supply, the input common mode range is 0V to 4V; therefore, V_{IN}, V_{TU} and V_{TL} can lie anywhere within this range.

The extremely low input bias current (typically just 5pA at room temperature) not only allows for large values of R1 and R2, but also reduces the loading on V_{IN} to a negligible level.

The TLC3702's output swings to within a few hundred millivolts of its supply rails. Therefore, provided the output is lightly loaded, and with a supply voltage $+V_S = 5V$, we can assume $V_{OL} = 0V$ and $V_{OH} = +5V$. These levels are ideal for controlling the 74HC4066, which typically requires a minimum high level control voltage of 3·5V and a low level control voltage no greater than 1·5V.

Since $V_{TU} = V_{REF}$, it is possible to set the upper threshold level very accurately. For example, V_{REF} could be a precision voltage

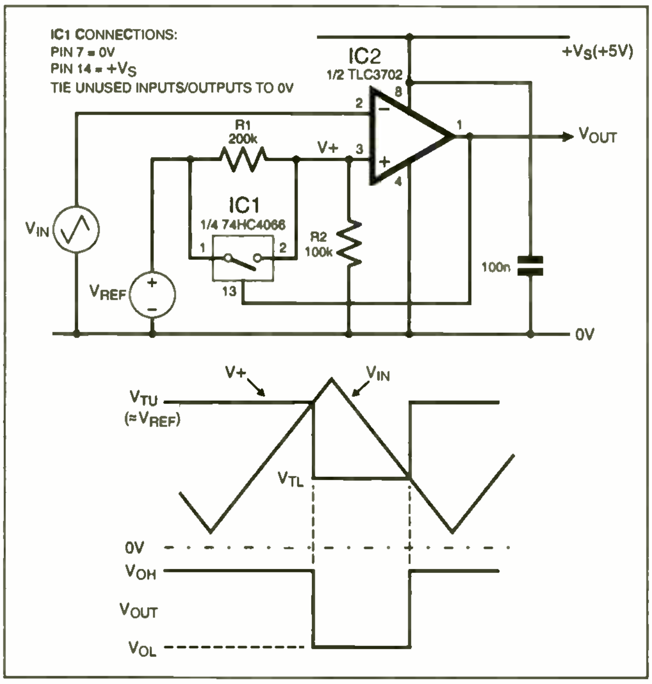


Fig.3.1. An analogue switch (IC1) allows for precise control of the Upper Threshold Level.

reference. Alternatively, V_{REF} could be derived from a DAC (Digital-to-Analogue Converter) allowing precise, digital control of the upper threshold.

The circuit can only be considered "semi-precision" because V_{TL} is influenced by the tolerances of R1 and R2, and will vary if V_{REF} is changed (i.e., V_{TL} is dependent on V_{TU}). Nevertheless, for applications that require only one accurate threshold, and where the other threshold is needed only to introduce hysteresis for noise-immunity, this circuit could be ideal.

A test circuit was built using 1% tolerance resistors and V_{REF} set to 3·0V to give nominal thresholds of V_{TU} = 3·0V and V_{TL} = 1·0V. The actual values measured using a low-frequency triangle wave for V_{IN} were V_{TU} = 3·0V and V_{TL} = 0·94V.

TWO REFERENCES

For applications requiring precise control of *both* switching levels, the circuit in Fig.3.2 can be used to provide accurate and independent control of each threshold. This circuit is a bipolar, inverting Schmitt trigger, in that the input voltage and threshold levels may be positive or negative, and the output is "inverted" relative to the input signal – see the waveforms.

A two-channel analogue switch, IC1, and two reference voltages, V_{HIGH} and V_{LOW}, are used to set the thresholds. The switch implements a "single-pole, double-throw" (s.p.d.t.) action (also known as single-pole change-over), such that when the output of the comparator, IC2, is high, the switch selects V_{HIGH} and connects it to the non-inverting input via R1. Therefore, ignoring comparator offsets, the Upper Threshold Voltage, $V_{TU} = V_{HIGH}$.

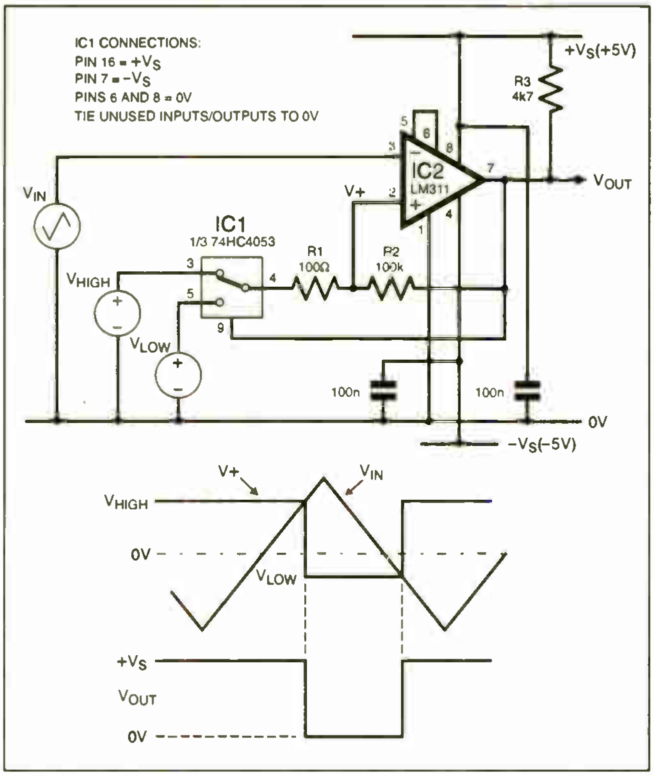


Fig.3.2. A two-channel analogue switch provides precise control of both thresholds.

When V_{IN} crosses this level, V_{OUT} goes low and the switch changes state and connects V_{LOW} to the non-inverting input. Therefore, the Lower Threshold Level, $V_{TL} = V_{LOW}$, and the circuit will remain in this state until V_{IN} goes negative and crosses V_{TL}. Clearly, the thresholds may be set accurately and independently by using suitable reference voltages for V_{HIGH} and V_{LOW}.

Depending on the comparator type and circuit layout, it may be necessary to introduce a small amount of additional hysteresis around the comparator to prevent "chatter". This is achieved by resistors R1 and R2; provided R2 is much larger than R1, the resulting hysteresis is very small (typically just a few millivolts) and has negligible effect on the thresholds set by V_{HIGH} and V_{LOW}. In certain cases, R1 may not be needed, since the switch "on" resistance alone (typically around 40Ω for the 74HC4053) may be sufficient.

ANALOGUE SWITCH TYPES

As well as having low "on" resistance, the 74HC4053 is relatively inexpensive and is well suited to this application. The 4000-series version, the 4053, could also be used if preferred. Both types typically have very low leakage currents, usually less than 1nA, although the maximum leakage can be as high as 1μA. However, even this is unlikely to cause problems unless V_{HIGH} and V_{LOW} are derived from sources with high output resistances.

When used in bipolar applications like this one, the 74HC4053 supply rails are limited to around ±6V (the 4053 can usually tolerate slightly greater supplies, around ±8V). With the V_{SS} or "GND" terminal (pin 8) connected to 0V, the logic level control voltage at pin 9 must swing between 0V and the positive supply.

This is readily achieved using the LM311 comparator which has an open-collector output and an "uncommitted" emitter terminal (pin 1). Therefore, by connecting pin 1 to 0V, and connecting pull-up resistor R3 between the output and $+V_S$, V_{OUT} will swing between 0V and $+V_S$.

When operating on ±5V supplies, the LM311 common-mode input range is typically – 4·7V to +3·5V. Therefore, V_{IN}, V_{HIGH} and V_{LOW} can lie anywhere within this range, provided, of course, that V_{HIGH} is more positive than V_{LOW}.

Alternative analogue switch types are available which enable operation at higher voltages. For example, by combining two complementary, single-pole, single-throw switches from the DG403 analogue switch i.c. to implement the s.p.d.t. function, voltages in the range ±15V can be accommodated.

Whichever type of switch package is used, always check the data sheet to determine the maximum operating voltage range, and the corresponding values of switch control levels.

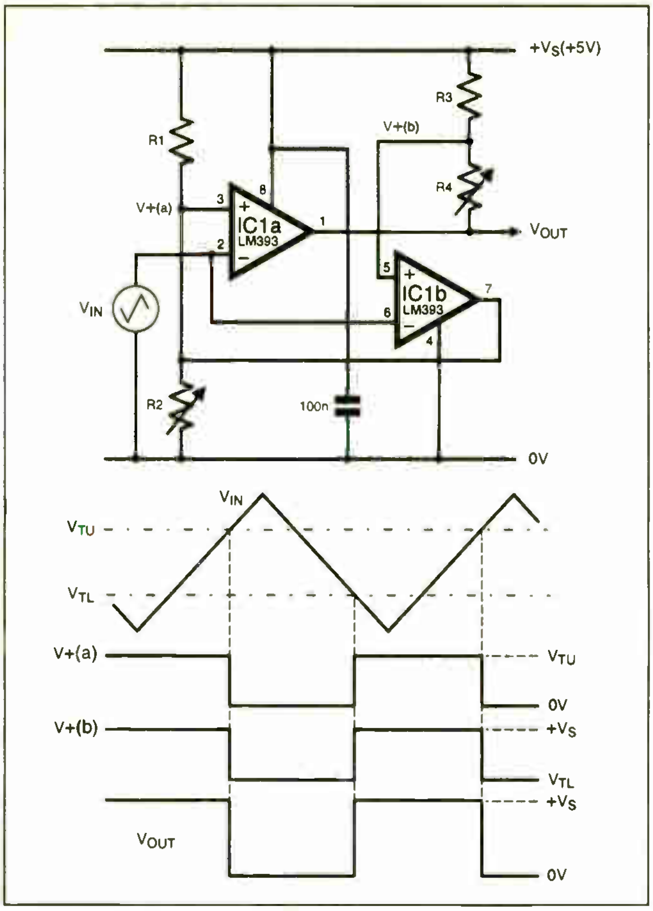


Fig.3.3. Circuit for a dual comparator Schmitt trigger having independent threshold adjustment.

DUAL COMPARATOR

For applications requiring reasonably accurate, independent adjustment of the thresholds, the circuit of Fig.3.3 forms a Schmitt trigger built using a dual, open-collector comparator. Notice how each comparator provides positive feedback for the other, resulting in *overall* positive feedback (essential to Schmitt trigger behaviour) around the entire circuit.

To understand how the circuit works, assume V_{IN} = 0V (the lowest point of the triangular waveform). The non-inverting input of each comparator is more positive than its inverting input, and so the internal output transistors are "off" and the open-collectors are pulled high by the respective resistors.

Under these conditions, IC1b's output has no effect on the R1-R2 potential divider, and so the potential at IC1a's non-inverting input is:

$$V+(a) = +V_S \times R2 / (R1 + R2).$$

Ignoring offsets in IC1a, this voltage defines the Upper Threshold Voltage:

Upper Threshold Voltage,
$$V_{TU} = +V_S \times \frac{R2}{R2 + R1} \quad \text{(volts)}$$

The circuit output, V_{OUT}, is at its high level, $+V_S$, pulled up by R3 and R4. When V_{IN} goes more positive than V_{TU}, IC1a's output goes low, and provided R3 and R4 are not too small, we can assume that IC1a's negative saturation voltage = 0V. In other words, when IC1a's output transistor turns "on", its collector pulls V_{OUT} down to 0V.

The non-inverting input of IC1b (which was previously pulled up to $+V_S$ via R3) is now pulled down to a voltage given by:

$$V+(b) = +V_S \times R4 / (R3 + R4)$$

Again, ignoring offsets in IC1b, this potential defines the Lower Threshold Voltage:

$$\text{Lower Threshold Voltage,} V_{TL} = +V_S \times \frac{R4}{R3 + R4} \quad \text{(volts)}$$

Now, at the instant of switching, the value of V_{IN} at IC1b's inverting input will be just slightly greater than V_{TU}. Therefore, provided V_{TL} is set lower than V_{TU}, IC1b's output will go low, pulling V+(a) down to 0V. This positive feedback enhances the overall switching action, and we see the regenerative behaviour essential to the Schmitt trigger function.

V_{OUT} is now at its low level (approximately 0V), and the circuit remains in this state until V_{IN} falls below V_{TL}, at which point IC1b's output transistor turns "off", and V+(a) returns to its initial value of V_{TU}.

Since this is greater than the present value of V_{IN}, IC1a's output goes high as its output transistor turns "off", and V+(b) is pulled up to $+V_S$ via R3. Again, positive feedback around the comparators enhances the switching action and rapidly forces the circuit back into its original, stable state.

RESISTOR TOLERANCE

The equations for V_{TU} and V_{TL} show that both thresholds are dependent on $+V_S$, and will be affected by resistor tolerance and by any other change in resistor values, such as temperature drift. The effects of changes in $+V_S$ could be eliminated by connecting R1 and R3 to a precision reference voltage, V_{REF}, such that:

$$V_{TU} = +V_{REF} \times R2 / (R1 + R2), \text{ and}$$

$$V_{TL} = +V_{REF} \times R4 / (R3 + R4)$$

In spite of the dependence on resistor values, the equations show that the thresholds can be set and adjusted completely independently of each other. This could be achieved, for example, by using variable resistors for R2 and R4 as shown in Fig.3.3.

A test circuit was built using the popular LM393 dual comparator for IC1a and IC1b (open-collector comparators are essential) which has an input common-mode range of 0V to 3·5V when powered from a 5V supply. With $+V_S$ = 5·0V, and R1 = 20kΩ, R2 = 30kΩ, R3 = 120kΩ, and R4 = 30kΩ, the nominal thresholds are V_{TU} = 3·0V and V_{TL} = 1·0V.

Using a low frequency, triangular wave input voltage, the actual threshold levels were measured as V_{TU} = 3·0V and V_{TL} = 1·0V, but some "chatter" was noticeable on V_{OUT} as V_{IN} crossed V_{TL}.

It was found that this could be eliminated either by reducing the resistor values (which minimises the effects of stray capacitive coupling), or by connecting a small capacitor (around 33pF) between the non-inverting input and output of IC1a.

OUTPUT LOADING

Any load connected between V_{OUT} and 0V will form a potential divider with R3 and R4, and will "pull down" V+(b) when IC1a's output transistor is "off". However, this will not affect circuit operation, provided V+(b) is not pulled below the level of V_{TU}. In most cases, a light load such as the input(s) to one or more CMOS logic gates will have negligible effect on V_{OUT}.

Heavier loads which require significant current must be connected between V_{OUT} and the supply voltage: this is the common configuration for loads connected to *npn* open-collector outputs. Two examples are shown in Fig.3.4.

Comparators like the LM311 can sink up to 40mA or so, and are thus capable of driving relays as shown in Fig.3.4a. (The diode must be included to protect the comparator output against inductive "spikes" occurring when the relay coil de-energises).

The circuit diagram in Fig.3.4b shows an l.e.d. (light-emitting diode) load. The series resistor should be chosen to give adequate light output for a given l.e.d. type. Since the circuit is an inverting Schmitt trigger (i.e., V_{OUT} goes low when V_{IN} is more positive than V_{TU}), the l.e.d. will be illuminated when V_{IN} exceeds the upper threshold and will remain "on" until the input voltage falls below V_{TL}.

Beware that high-current loads may cause a significant increase in the comparator's negative saturation voltage, which has been assumed equal to 0V in the calculations for V_{TU} and V_{TL}. For example, with one of the LM311 comparators loaded only with a 15kΩ pull-up resistor, a negative saturation voltage of just 31mV was measured.

However, with an l.e.d. and 560Ω series resistor connected as shown in Fig.3.4b, the 5mA l.e.d. current resulted in a negative saturation voltage of 236mV. Clearly, for loads such as relays, which require several tens of milliamps, the saturation voltage could rise toward half a volt, or so.

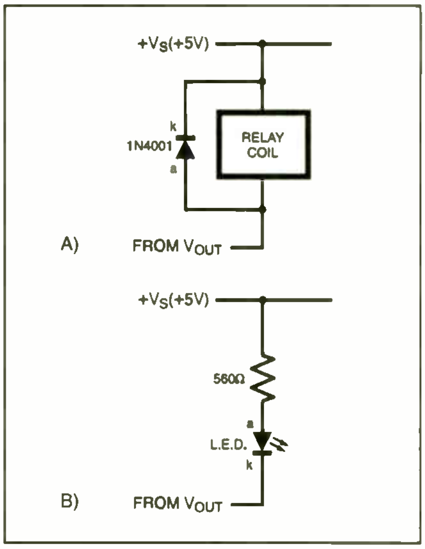


Fig.3.4. Open-collector loads: (a) relay; (b) l.e.d.

Although the circuit in Fig.3.3 is shown with a 5V supply, higher supply voltages can be used if the comparators are rated accordingly. The LM311, for instance, can be powered by voltages as high as 36V. As well as providing for a much greater input common-mode voltage range, the higher supply voltage also means there is more power available to the load.

COMPLEMENTARY PRECISION

The Schmitt trigger shown in Fig.3.5 is ideally suited to digital systems in which an analogue input signal must be converted accurately into two, complementary digital outputs. Although a dual op.amp, the ST Microelectronics TS912, is shown, a dual comparator with suitable input and output characteristics could be used equally well.

The TS912 is a CMOS device with "rail-to-rail" input and output voltage ranges. This means that the voltage applied to the inputs can take any value between the negative and positive supply rails (in this case, 0V and +5V, respectively), and the output voltage will swing to within 50mV of each supply rail when lightly loaded.

However, when used as a comparator, an essential feature of the TS912 is the fact that the *differential* input voltage range, that is, the voltage between the inputs, can be as much as $\pm V_S$ without causing damage or malfunction.

Not all op.amps have this capability. For instance, the TS922 is also a rail-to-rail op.amp, but is not suitable for use as a comparator since its differential input range is limited to just ±1V. If you wish to use an op.amp as a comparator in an application where the inputs may differ by several volts, always check the specifications to ensure the differential input range is adequate.

S-R LATCH

The NOR gates (IC2) function as a simple S-R latch with complementary outputs. NAND gates could also be used, but the input connections to IC1a and IC1b would need to be swapped over. Circuit operation can be understood by referring to the waveforms and assuming V_{IN} and V_{OUT} are at 0V, and that op.amp offsets are so small as to be negligible.

As V_{IN} rises above V_{LOW}, IC1b's output changes state and goes low, but this has no effect on the latch which remains in its "reset" state. Now, when V_{IN} rises above the upper threshold established by V_{HIGH} at IC1a's inverting input, IC1a's output responds by going high and "sets" the latch, causing V_{OUT} to go high, also.

The latch remains "set" until V_{IN} falls low enough to cross the lower threshold set by V_{LOW} at IC1b's non-inverting input. At this point, IC1b's output goes high and resets the latch, causing V_{OUT} to go low. For low frequency input signals, the accuracy of the thresholds depends only on V_{HIGH}, V_{LOW} and the op.amps' input offset voltage.

At high frequencies, however, the op.amps' response time introduces delays t_{DR} and t_{DF} before the rising and falling edges, respectively, of V_{OUT}. When V_{IN} crosses the upper threshold set by V_{HIGH}, IC1a takes a finite time to come out of negative saturation.

There is then a further delay caused by its limited slew rate (indicated by the sloping edges of its output waveform) before its output voltage reaches IC2a's input high logic level, at which point the latch is set and V_{OUT} goes high.

The overall delay, t_{DR}, means that the *apparent* upper threshold level is higher than the nominal level set by V_{HIGH}. A similar delay, t_{DF}, caused by IC1b, results in the *apparent* lower threshold level being less than the nominal value set by V_{LOW}.

CIRCUIT TESTS

With V_{LOW} = 1·0V and V_{HIGH} = 4·0V, the circuit was tested using a 70Hz input signal and the thresholds were found to be 1·0V and 4·0V, respectively. However, with the input frequency increased to 6kHz, the t_{DR} and t_{DF} delays (each around 46μs) caused a shift in the apparent thresholds:

$$V_{LOW} = 0{\cdot}57\text{V and } V_{HIGH} = 4{\cdot}6\text{V.}$$

Consequently, for precision operation at high frequencies, it would be necessary to replace the TS912 with a faster dual device. For low frequency applications, however, the TS912's very low input current (typically just a few picoamps) makes it ideal for use with high-impedance voltage sources.

As it stands, the circuit is restricted to single-rail operation, since the op.amp outputs must not swing below the NOR gates' negative rail, which in this case is 0V. For bipolar operation, the TS912 op.amps could be replaced with two LM311 comparators, with the emitter terminals (pin 1) connected to 0V as shown in Fig.3.2.

Although it is not essential for IC1a and IC1b to have rail-to-rail outputs, their output swing must satisfy the input logic level requirements of the NOR gates. For a 74HC02 working on a 5V supply, this means the comparator outputs must swing lower than 1·5V, and higher than 3·5V.

Without realising it, you might have used a modified version of this circuit many times already – it forms the heart of the ubiquitous 555 timer! Unfortunately, however, the 555 doesn't provide access to all the comparator inputs, and two of them are connected by an on-chip resistor network, so it isn't possible to use it as a precision Schmitt trigger.

VERSATILE CIRCUIT ELEMENT

As well as being essential for converting analogue signals to digital levels, the Schmitt trigger's versatility means that it can be adapted to implement a variety of other functions.

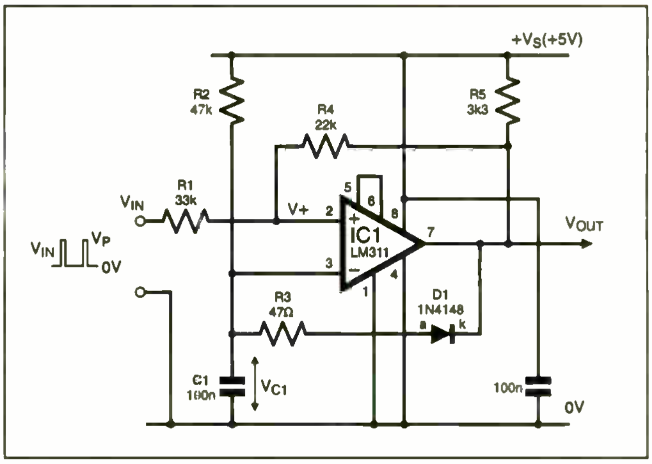


Fig.3.6. Monostable multivibrator circuit based on a Schmitt trigger.

The circuit diagram in Fig.3.6, for example, shows a *monostable multivibrator* (also known as a "one-shot"), in which a narrow input pulse, sometimes of varying width, must be "stretched" into a much wider pulse of specific duration.

There are many "flavours" of monostable: it can be implemented using transistors, op.amps and comparators, and we'll see in a later article how it can be built using "digital" Schmitt triggers. The comparator-based one-shot in Fig.3.6 is just one of many different types. The monostable can be inverting or non-inverting, retriggerable or non-retriggerable, and can be triggered with positive- or negative-going pulses.

The monostable has one stable, and one unstable state. It remains in its stable state until a trigger pulse is applied which initiates switching to the unstable state, where it remains for a period of time determined by the timing components.

To understand how the circuit in Fig.3.6 works, assume V_{IN} is at 0V and V_{OUT} is in negative saturation (we can take this to be 0V provided pull-up resistor R5 is not too small in value). Diode D1 is forward biased, so V_{C1}, the voltage on timing capacitor C1, is roughly 700mV.

If a narrow input pulse of amplitude V_P is applied to resistor R1, the voltage at the non-inverting input, V+, will rise to a positive level. Provided V_P is large enough, V+ will go more positive than the 700mV at the inverting input and the comparator will trip. V_{OUT} now goes high and remains there even when V_{IN} has returned to 0V, since the positive feedback via R4 holds V+ at a voltage greater than V_{C1}. The circuit is now in its "unstable" state, where the non-inverting voltage is given by:

Non-inverting input voltage,

$$V+ = +V_S \times \frac{R1}{R1 + R4 + R5}$$

when V_{IN} = 0V and V_{OUT} = high.

Since V_{OUT} is now high, D1 is reverse biased, so V_{C1} is no longer clamped at 700mV and C1 is free to charge via timing resistor R2. As C1 charges, V_{C1} rises until it just exceeds the value of V+ given by the equation above. At this point, the comparator trips again,

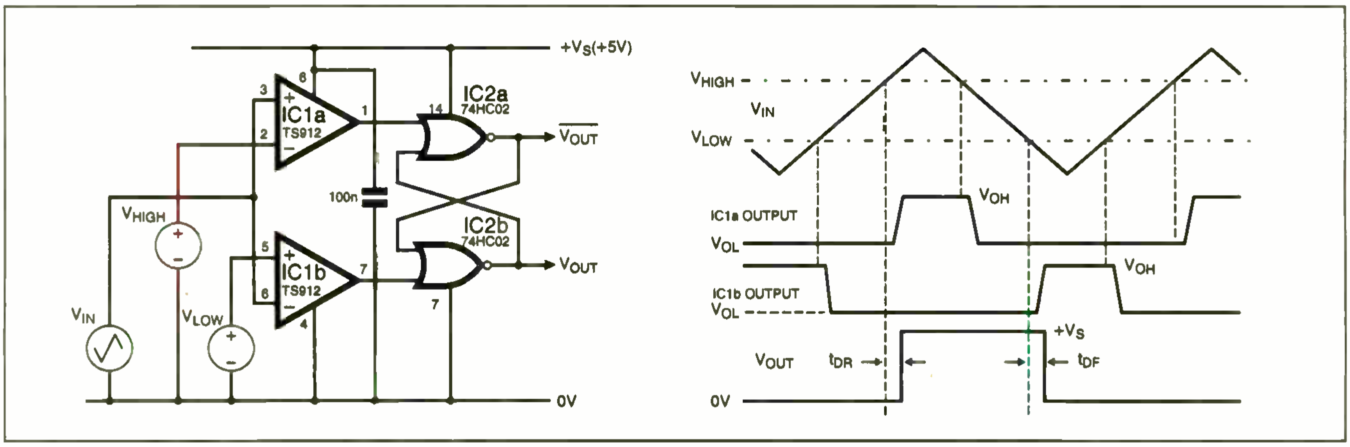


Fig.3.5. Circuit diagram for a precision Schmitt trigger with complementary outputs.

V_{OUT} goes low, and the monostable returns to its stable state. Since D1 is now forward biased, C1 rapidly discharges via R3 which limits the discharge current to a reasonable value.

PULSE STRETCHING

The circuit's waveforms are shown in Fig.3.7, where the voltage on C1 (middle trace) starts to rise as soon as the narrow input pulse (top trace) is applied. With R1 = 33kΩ, R4 = 22kΩ, R5 = 3·3kΩ and $+V_S$ = 5·0V, the value of V+ given by the equation above is 2·83V. V_{C1} can be seen to rise exponentially until it just exceeds 2·83V, at which point the comparator changes state and V_{OUT} immediately goes low.

Although the main timing components are C1 and R2, the values of R1, R4 and R5 also influence the output pulse width since they determine the voltage to which V_{C1} must rise in order to trip the comparator. Also, in the stable state, where V_{OUT} = 0V, R1 and R4 form a potential divider which determines the minimum pulse amplitude, V_P, sufficient to take V+ above 700mV and initiate the output pulse. With R1 = 33kΩ and R4 = 22kΩ, the circuit can be triggered with a pulse amplitude as low as 1·75V.

Note that the monostable in Fig.3.6 is non-inverting and non-retriggerable. "Non-inverting" simply means that the positive-going trigger pulse produces a positive-going output pulse. The term "non-retriggerable" means that once the monostable has been triggered, any further input pulses arriving while the output is high will have no effect on the output pulse; in other words, the output pulse width cannot be "extended" by applying further input pulses.

When using a comparator like the LM311 having an open-collector output, the high level output voltage, V_{OH}, is given by:

High Level Output Voltage,

$$V_{OH} = +V_S \times \frac{R1 + R4}{R1 + R4 + R5} \quad \text{(volts)}$$

Therefore, in order to maximise V_{OH}, the value of pull-up resistor R5 should be much smaller than R1 and R4. For the values given in Fig.3.6, V_{OH} = 4·7V. Clearly, any load connected between the output and 0V will tend to "pull down" V_{OH}, and will also affect the timing by reducing the high level of V+, although "light" loads such as CMOS logic gates will have negligible effect.

To some extent, these problems can be mitigated by replacing the LM311 with a comparator like the dual TLC3702, which has a "push-pull" output stage. Since the output pull-up resistor is no longer required, R5 may be removed from the above equations. As well as simplifying the calculations, this also has the significant benefit of reducing the circuit's power consumption, since an open-collector comparator like the LM311 sinks significant current through its pull-up resistor when V_{OUT} = 0V.

A further disadvantage of bipolar comparators like the LM311 is their relatively large input bias current. When V_{OUT} goes high and C1 starts to charge, the rate of charge should be controlled *only* by the current flowing in timing resistor R2. In practice, the charging current will be affected by the current flowing into (or out of) the comparator's inverting input, which will decrease (or increase) C1's charging current.

With R2 = 47kΩ, the average charging current is around 50μA, and so the LM311's input bias current, which can be as high as 250nA, will have negligible effect on the 5ms output pulse width. However, for long-duration output pulses requiring large values of R2, the input bias current can have a significant and unpredictable effect on pulse width.

Fortunately, these problems can be eliminated by replacing the bipolar comparator with a CMOS device like the TLC3702 (typical input bias current = 5pA). To illustrate how a CMOS comparator can be used to produce very wide output pulses, the comparator in Fig.3.6 was replaced with a TLC3702, R2 changed to 4·7MΩ, and C1 increased to 1μF. The resulting output pulse duration was measured at just over six seconds, some *thirty million* times greater than the 200ns trigger pulse!

READY, SET . . . LATCH

The second member of the multivibrator family, the *bistable* multivibrator, can also be built using a comparator or an op.amp; an example is shown in Fig.3.8.

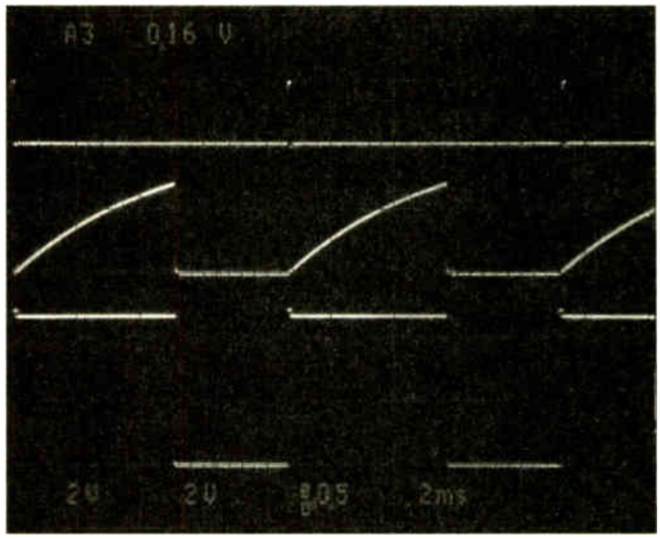


Fig.3.7. Monostable Waveforms. Top Trace: V_{IN} (5V/div.). Middle Trace: Timing Capacitor Voltage, V_{C1} (2V/div.). Bottom Trace: Output Voltage, V_{OUT} (2V/div.). Timebase: 2ms/div.

All Schmitt trigger circuits are effectively "bistable" elements, since their outputs can occupy one of two stable states. However, the circuit in Fig.3.8 is a "proper" bistable in that it has two complementary inputs, SET and RESET. Applying a positive-going pulse to the SET input causes V_{OUT} to go high: the circuit is now "latched" in one of its stable states, and will remain that way until a pulse is applied to the RESET input.

This pulse resets the latch by forcing V_{OUT} low, and the circuit returns to its alternative state. The positive feedback via resistor R4 provides the regenerative switching action necessary to "flip" the circuit rapidly from one state to the other.

Bistables, or "S-R Latches" as they are often called, are familiar circuit elements in digital systems. The function can be implemented with NAND or NOR gates (as in Fig.3.5), or as an integrated function with many variants. Devices like the 4013, 4044, 74HC74 and 74HC112 are just a few of the many devices which implement the S-R latch function in different ways.

However, latches from the 4000 and 74HC CMOS families require logic levels that occupy a specific, narrow range. The circuit of Fig.3.8, on the other hand, offers some flexibility in the magnitude of the pulses needed to set and reset the latch.

IC1 is one half of a dual, micropower, rail-to-rail CMOS comparator. The LMC6762 is not a fast device; its response time is typically around 4μs. Nevertheless, its minuscule input bias current (typically just 0·04pA), rail-to-rail input voltage range, and wide output voltage range (the output swings to within 100mV of the supply rails for light loads) allows us to view it as an "ideal" device when analysing the circuit's behaviour.

If we assume that SET, RESET and V_{OUT} are all at 0V, the potential V− at the inverting input is determined by the R2-R3 potential divider:

Inverting input voltage,

$$V- = +V_S \times \frac{R2}{R2 + R3}$$

when SET, RESET and V_{OUT} = 0V.

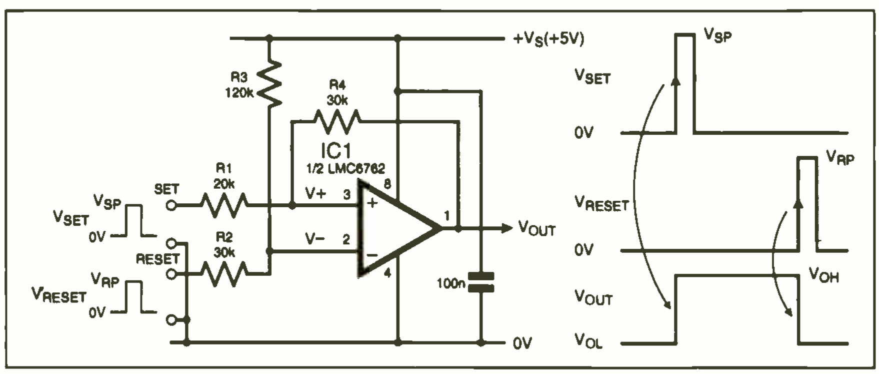


Fig.3.8. Circuit for a bistable multivibrator based on a Schmitt trigger.

Now, if a voltage pulse, V_{SET}, is applied to the SET input, the potential V+ at the non-inverting input will rise to:

Non-inverting input voltage,

$$V+ = +V_{SET} \times \frac{R4}{R1 + R4}$$

when SET = V_{SET}; RESET and V_{OUT} = 0V.

If this value of V+ is greater than the level of V– given earlier, the comparator will trip and V_{OUT} will go to its high level, V_{OH}: the bistable is now latched. So far, the circuit has behaved like a simple, non-inverting Schmitt trigger with positive feedback provided by resistor R4.

Now, when the pulse at SET returns to zero, the non-inverting input voltage will be:

Non-inverting input voltage,

$$V+ = +V_{OH} \times \frac{R1}{R1 + R4}$$

when $V_{OUT} = V_{OH}$; SET and RESET = 0V.

In order for the bistable to remain latched, this voltage must be greater than the level of V– given earlier. Therefore, provided R1 and R4 are chosen correctly, V_{OUT} will remain high even when SET has returned to 0V. If we now apply a voltage, V_{RESET}, to the RESET input, the inverting input voltage will rise to:

Inverting input voltage,

$$V- = +V_S \times \frac{R2}{R2 + R3} + V_{RESET} \frac{R3}{R2 + R3}$$

when RESET = V_{RESET}.

If this voltage is greater than the value of V+ given above for $V_{OUT} = V_{OH}$, the comparator will trip and the output will return to 0V. Clearly, the resistor values must be chosen carefully to ensure that the circuit will remain latched when the SET pulse has returned to zero, and also to ensure that it can be reset properly when a pulse is applied to RESET.

Also, it is important to select resistor values which will provide adequate noise immunity, such that the circuit can operate correctly even when significant noise voltage is present at SET and RESET.

DESIGN EXAMPLE

The best way to illustrate the design procedure is to work through an example. When SET and RESET are both zero, and V_{OUT} is at its low level, V_{OL}, the non-inverting input voltage, V+, will be a minimum. If we assume, as we did previously, that V_{OL} = 0V, then the minimum value of V+ will also be 0V.

If we know that the inputs may be subject to noise voltage as large as, say, 1V, we must choose R2 and R3 to ensure the quiescent voltage at the inverting input is at least 1V when V_{RESET} = 0V. Values of R2 = 30kΩ and R3 = 120kΩ are suitable.

When V_{OUT} goes high, R1 and R4 should be selected not only to ensure the comparator remains latched, but also to ensure that the difference between the comparator's input voltages is greater than the noise voltage. In other words, the non-inverting input voltage, V+, should be at least 1V higher than the quiescent level of the inverting input voltage, V–.

Since we have chosen the quiescent value of V– to be 1V, we require V+ to be at least 2V. This is satisfied by making R1 = 20kΩ and R4 = 30kΩ, which makes V+ = 2V when V_{OH} = 5V. If the circuit is built using these values, the minimum SET pulse amplitude, V_{SP}, needed to latch the bistable will be around 1·63V, and the minimum RESET pulse amplitude, V_{RP}, required to reset the latch will be around 1·23V.

If necessary, the resistor values could be changed to provide greater noise immunity, although the resulting pulse amplitudes needed to set and reset the latch would also be greater.

In Part Four next month, we'll see how the Schmitt trigger can be adapted to form the third member of the multivibrator family, the *astable* multivibrator, and we'll examine other useful functions which depend upon the Schmitt Trigger's unique behaviour.

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PROJECTS • Interior Lamp Delay • Mains Cable Detector • QWL Loudspeaker System • Micro Power Supply.
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PROJECTS • Acoustic Probe • Vibralarm • Ginormous Stopwatch–1 • Demister One-Shot.
FEATURES • Teach-In 2000–Part 1 • Ingenuity Unlimited • Practically Speaking • Practical Oscillator Designs–5 • Circuit Surgery • New Technology Update • Net Work – The Internet *FREE* Identifying Electronic Components booklet.

DEC '99

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JAN '00

PROJECTS • Scratch Blanker • Versatile Burglar Alarm • Flashing Snowman • Vehicle Frost Box.
FEATURES • Ingenuity Unlimited • Teach-In 2000–Part 3 • Circuit Surgery • Practically Speaking • Tina Pro Review • Net Work – The Internet.

FEB '00 Photostats Only

PROJECTS • PIC Video Cleaner • Voltage Monitor • Easy-Typist Tape Controller • Find It – Don't Lose It!
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MAR '00

PROJECTS • EPE ICEbreaker • High Performance Regenerative Receiver–1 • Parking Warning System • Automatic Train Signal.
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APRIL '00

PROJECTS • Flash Slave • Garage Link • Micro-PICscope • High Performance Regenerative Receiver–2.
FEATURES • Teach-In 2000–Part 6 • Ingenuity Unlimited • Technology Timelines–3 • Circuit Surgery • Interface • Telcan Home Video • Net Work – The Internet.

MAY '00

PROJECTS • Versatile Mic/Audio Preamplifier • PIR Light Checker • Low-Cost Capacitance Meter • Multi-Channel Transmission System–1.
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PROJECTS • Atmospheric Electricity Detector–1 • Canute Tide Predictor • Multi-Channel Transmission System–2 • Automatic Nightlight.
FEATURES • Teach-In 2000 – Part 8 • Technology Timelines–5 • Circuit Surgery • Interface • New Technology Update • Ingenuity Unlimited • Net Work – The Internet.

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PROJECTS • g-Meter • Camera Shutter Timer PIC-Gen Frequency Generator/Counter • Atmospheric Electricity Detector–2.
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AUG '00

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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

OLD HANDS at electronic project construction can look at practically any component and know whether or not it has to be connected a certain way around, and if so, which way around. For the beginner it can take a while to become familiar with the components and their characteristics.

Capacitors are potentially a source of confusion since some have to be connected the right way round, but most do not. The lower values of about less than about 1μF are mostly non-polarised, but components having a value of about 1μF or more are nearly all polarised.

Electrolytics

By far the most common type of polarised capacitor is the ***electrolytic*** type. An ordinary capacitor is basically just two metal plates with a layer of insulation in between.

Practical components are almost invariably in the form of two pieces of metal foil. The insulation is often in the form of plastic foils or a plastic coating on the metal foils, but other materials can be used. The insulating layer is called the *dielectric*.

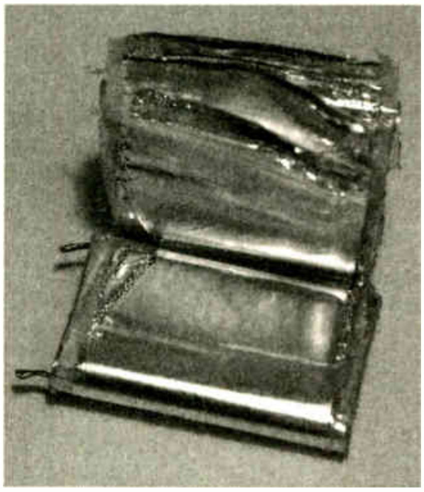

Fig.1. Ultra-thin metal foil is used in most types of capacitor.

The pieces of foil are placed one on top of the other and then rolled up or folded in some way so as to give a large plate area (and capacitance) in a small physical volume. Fig.1 shows a defunct capacitor that has been cut open, and some of the numerous layers of foil can be clearly seen.

Electrolytic capacitors take a similar form, but thin layers of an absorbent material impregnated with an electrolyte replace the plastic foils. This enables extremely high values to be obtained from tiny components, but at least a small d.c. potential of the correct polarity is needed for this type of capacitor to work properly.

Unfortunately, if an electrolytic capacitor is connected the wrong way round the electrolyte will provide a low resistance path. In the case of a capacitor connected across the supply lines this can result in a large current flow, rapid overheating and the component bursting with a loud "crack". If the capacitor is used in a low current part of a circuit it is unlikely that anything will be damaged if its polarity is incorrect, but the high leakage current will almost certainly prevent the circuit from working properly.

Beads

Electrolytics are not the only type of polarised capacitor, but they are probably the only type you will normally use. ***Tantalum*** capacitors are the only possible exception, and these are sometimes used where an electrolytic capacitor is inadequate.

Electrolytic capacitors combine very high values with small physical dimensions, but that is about all that they have going for them. Their value changes significantly with variations in temperature and over a period of time. The tolerances of these components are quite high at plus and minus 20 per cent or more.

The leakage currents also tend to be relatively high. Also, they do not work well at high frequencies, although this is often unimportant. Ordinary electrolytic capacitors are only suitable for undemanding applications.

Tantalum capacitors are often referred to as tantalum "*beads*", due to their almost spherical, bead-like shape. They provide very high values together with small physical size, but they are superior to normal electrolytics in most if not all respects. Their price, of course, tends to be relatively high, so there is no point in using a tantalum capacitor if an electrolytic will do. Tantalums are perhaps used rather less than was once the case, due to the various superior grades of electrolytic that are now available. These offer similar characteristics to tantalum capacitors, and can be found in any of the larger component catalogues.

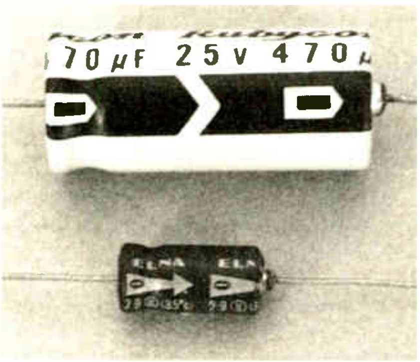

Fig.2. Axial electrolytics have polarity markings, but the ridge indicates the positive end of these components.

Being Superior

Where a project requires a superior grade electrolytic or tantalum capacitor, the components list and (or) the text should point out exactly what is required and why. Usually a superior grade component is needed for a timing circuit or for a switch-mode power supply.

In a timing circuit it is a closer tolerance and lower leakage level that are needed. Using a lower grade component will give poor timing accuracy or will simply result in the circuit failing to operate at all.

In the case of switch mode power supplies it is usually the high frequency performance that is of prime importance. A "bog standard" component can result in damage to a switch-mode circuit, so do not go in for "penny pinching" with this type of project.

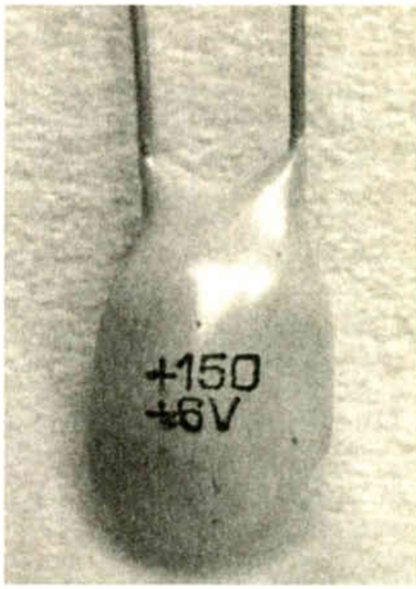

Fig.3. Modern tantalum capacitors have normal value and polarity markings.

Getting It Right

Printed circuit mounting capacitors, which are also known as "radial" capacitors, have the polarity indicated by "+" and "–" signs on their bodies, near the leadout wires. Actually, most modern components only have the "–" sign, but provided at least one of the leads is clearly marked there is no excuse for getting it wrong.

In days gone by axial lead electrolytics had their polarities marked using "+" and "–" signs, but these days it is more common for them to have more fancy markings with "–" signs and arrows pointing to the negative lead, see Fig.2. These markings are not strictly necessary anyway, since there is always a narrowing of the body near the positive leadout wire. The polarity is always readily apparent at a glance, even if the markings are badly worn or have rubbed off altogether.

Early tantalum capacitors used a system of colour coding to indicate the value and polarity. This system is now long obsolete, and any components of this type should now have the polarity and value marked on the body in much the same way as a radial electrolytic, see Fig.3.

As pointed out previously, getting a polarised capacitor connected the wrong way round can result in its destruction in some circumstances. It is also worth pointing out that relatively small reverse voltages and current flows can damage some polarised capacitors.

There will not be any sign of external damage, but the component will provide substandard performance if it is now used in the circuit the correct way round. Tantalum capacitors and some high-grade electrolytics are the most at risk from reverse voltages.

One-way Only

The only other common two-lead polarised component is the ***diode***. A diode is a sort of electronic equivalent to a mechanical valve, and it only allows a current to flow in *one* direction. Connect a diode with the wrong polarity and it will block currents it should allow to pass, and permit current flows that it should block.

With small diodes this is unlikely to cause any damage, but it can do so in the case of something like a protection diode across a relay coil. Instead of the relay being switched on, the diode would instead be fed with a high current.

With high power diodes (called *rectifiers*) there is a high risk of something being damaged if the polarity is wrong. It is definitely a good idea to check and double-check that diodes and rectifiers are connected correctly.

Most diodes and rectifiers have their polarity indicated by a band around the end of the body that carries the cathode (k) leadout wire. There are a few variations on this, but the only common one is a narrowing of the body at the cathode end of the component. This method is now used quite a lot for higher power rectifiers.

A few years ago it was quite common for some diodes to have several coloured bands, which made it necessary to take a careful look at the component in order to identify the cathode leadout. The idea of the coloured bands was to indicate the type number using a system of colour coding based on resistor colour codes. This meant having three or four bands instead of one.

These days most diodes have a single band and the type number marked using text characters. Due to the small size of modern diodes you will probably need a magnifier to read the type numbers. The system of colour coding may make it easy to read the type number, but it also makes it far easier to fit the diodes the wrong way round.

Diodes of this type have become less common in recent years, but they are by no means extinct. The polarity of multi-band diodes is indicated by having the band nearest the cathode lead wider than the other two or three bands. Unfortunately, the difference in width is often something less than obvious, so it is essential to look carefully at these diodes before fitting them onto a circuit board.

L.E.D. Astray

Light emitting diodes (l.e.d.s) are undoubtedly the type of diode that gives the most problems. This situation occurred due to a lack of standardisation when these components were first introduced. It has been sustained and even amplified by the enormous range of different shapes, sizes, and types of l.e.d. that have evolved over the years.

By far the most common method of indicating the polarity is to have the cathode (k) lead slightly shorter than the anode (a) lead. More often than not the leads of an l.e.d. have to be trimmed prior to connecting the component into circuit. It is, therefore, a good idea to keep the cathode lead fractionally shorter even after trimming so that you still know which lead is which.

Unfortunately, a few l.e.d.s seem to be supplied with two leads of equal length. In these cases the cathode is normally indicated by the case being flattened slightly next to the cathode lead. This "flat" is often present in addition to the shorter cathode lead, but it is not the universal feature that it once was.

So how do you determine the polarity of a l.e.d. if the flat is absent, and either the leads were originally the same length or you have trimmed them to the same length? A method used by many is to look at the two electrodes inside the case. These are usually different sizes and shapes (Fig.4), and the larger electrode *usually* connects to the cathode (k) lead.

Although this method works very well with "run of the mill" l.e.d.s, it is far from 100 per cent reliable with the more exotic types. The "jumbo" high-brightness l.e.d. shown in Fig.4 proves this point, and has its *anode* lead connected to the larger electrode.

In Reverse

The only sure way is the "suck it and see" approach. If connecting an l.e.d. one way round does not give the desired result, simply reverse the connections and it should work fine.

Readers sometimes point out to me that connecting an l.e.d. around the wrong way will result in it receiving a potential that is in excess of its reverse breakdown voltage, and that it could be "zapped". It is true that the reverse breakdown voltage of l.e.d.s is quite low, at typically about five to seven volts. It is also true that even marginally exceeding the maximum voltage ratings of semiconductors can often have dire results.

However, exceeding some voltage ratings does not in itself cause any damage. The reverse breakdown voltage of an l.e.d. and the base-to-emitter breakdown voltage of a transistor are two examples of this. In both cases the component acts a bit like a low voltage Zener diode.

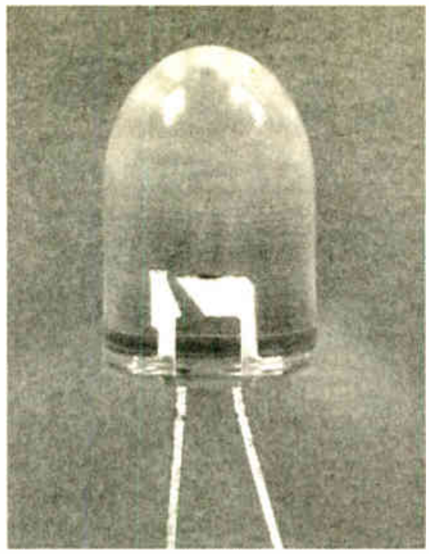

Fig.4. The larger electrode of an l.e.d. usually connects to the cathode, but not in the case of this "jumbo" l.e.d., where it connects to the anode.

Provided the current flow is limited to a safe level no damage will result. The resistor that limits the forward current to a safe level will continue to do so if the l.e.d. is connected the wrong way around.

In some instances it will be difficult to alter the connections to an l.e.d. if it is connected with the wrong polarity, or there may simply be too many l.e.d.s to make the "suck it and see" approach viable. Most multimeters have a facility to test diodes and find their polarity, but not all of these operate with l.e.d.s due to their high forward threshold voltage of about 1·8V or more.

This is about three times higher than that of an ordinary silicon diode. If it comes to it, the simple test set up of Fig.5 can be used to check the polarity of l.e.d.s that produce light in the visible part of the spectrum.

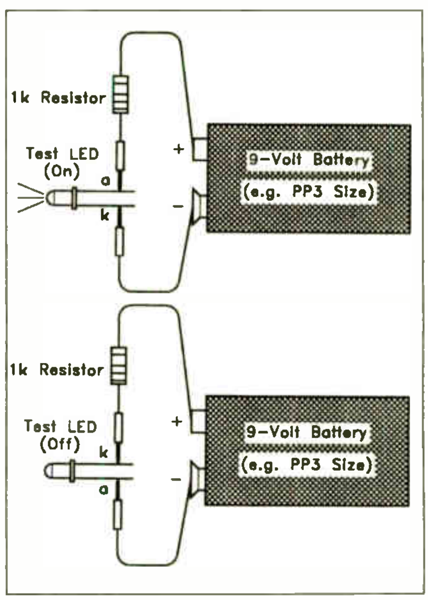

Fig.5. Simple test set-up for checking the polarity of l.e.d.s that produce light in the visible spectrum.

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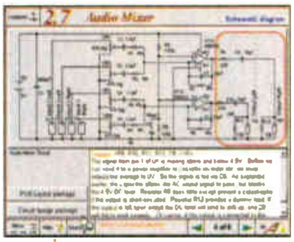
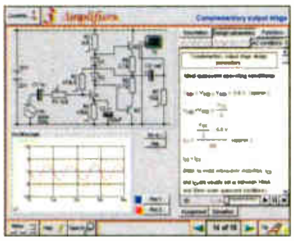


Audio Mixer circuit description

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture, circuit simulation** and **p.c.b. design** software is included.

The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ANALOGUE ELECTRONICS



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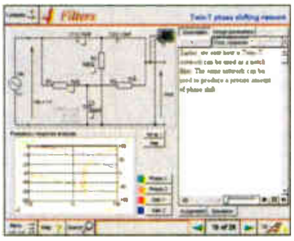
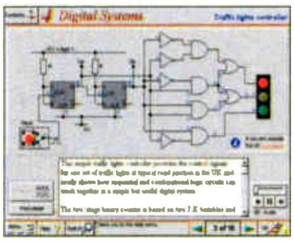


Twin-T phase shifting network

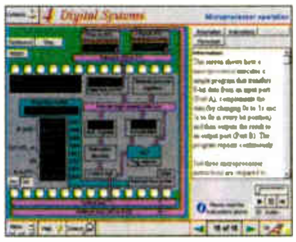
Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

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

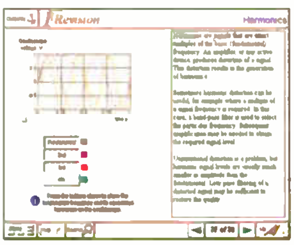


Microprocessor

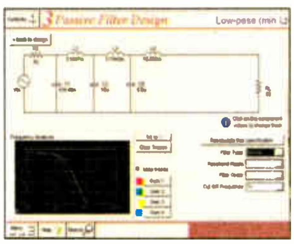
Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.

Covers binary and hexadecimal numbering systems, ASCII, basic logic gates and their operation, 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 and their parameters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.

FILTERS



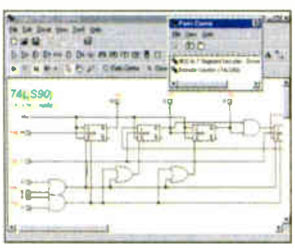
Filter Theory



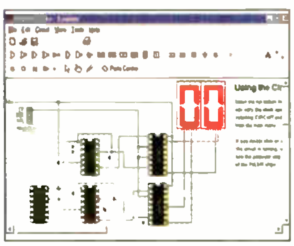
Active filter synthesis

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



Macro screen



Counter project

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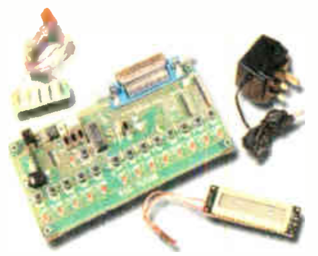

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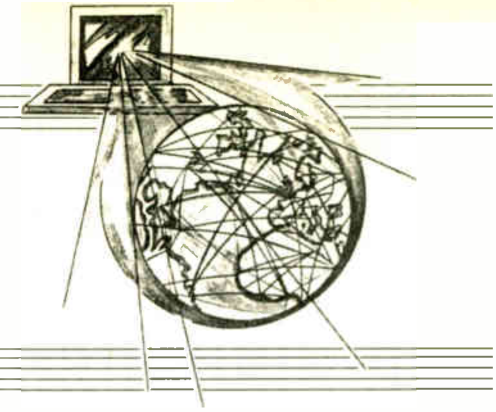


NET WORK

ALAN WINSTANLEY

Happy Christmas to you too

A STUDENT acquaintance recently graduated from University, but only just in the nick of time: her entire computer system together with her entire course work were stolen. It contained fours years of hard work but no backup disks were kept "off site", and the heartless thieves ignored her plea just to return the disks if nothing else. It is now an accepted fact of life that University student "digs" can be rich pickings for thieves, as they can be a prime source for a variety of computer hardware.

With new computer equipment presently being purchased for Christmas, it's worth reminding school pupils, students and home users to take some sensible precautions to guard equipment and the important data it may contain. Removable disks, especially CD-ROMs, are a good idea.

However, even if you have accumulated many years of work and retained it on disk, the Internet now offers more secure ways of backing up important data "off site". Furthermore, you can use special Internet access software to help identify modem calls made when a career criminal uses a stolen computer to dial into the Internet.

There are a few fundamental things you can do to guard against computer theft. Obvious precautions include the use of anti-theft devices that lock into the oval keyhole slots located on many computers and laptops for this purpose: mail order and retail sources (e.g. Inmac, see **www.inmac.co.uk**) provide a full range that enable you to secure hardware in place to frustrate the would-be thief.

ET Phone Home

A couple of "E.T." software products are also available, so called because they "phone home" when a thief connects a stolen computer (yours) to a phone line and tries to dial out. The modem will actually make a phone call to your selected number, affording you an opportunity to obtain the caller's phone number using Caller Line ID (if enabled). One such product is Phone Home Millennium Edition by UK Software (**www.uk-software.com/phonehome/**) who say that this invisible software device will, at a user-defined time, dial a number of your choice, e.g. your own phone number.

Another package is E.T. Version 3.3 by Kestrel Software Systems (**www.ksoft.demon.co.uk**) – your computer could, when stolen, dial say your mobile phone, either at a preset time or whenever the PC is booted! A demo is available from their web site.

There are certain obvious drawbacks to using these systems which make them less than foolproof, but they may help to foil an unsophisticated thief, always assuming you can enlist the support of the Police. Neither software package has been tested or endorsed by the writer.

Back Up or Else

Everyone knows the importance of keeping a backup to guard against disasters such as theft, fire or total hard disk failure. As my student friend discovered, even if you *do* back up four years' worth of University coursework onto removable disks, it's no good if the disks are themselves stolen. Storing a copy safely off-site is the best protection, hence a number of web sites which have sprung up that enable you to back up your files remotely onto the Internet. The University student would have saved herself considerable grief if one of these web disk space providers had been used.

One example is Driveway (**www.driveway.com**). This web-based file storage service is easy to set up and is reasonably fast, and it enables you to categorise your data into folders. You're given 25MB of space for free (a fuel gauge shows how much is left), and this is yours for archiving, backing up or for sharing data amongst friends or colleagues. You can E-mail an invitation to other users to access or share your drive space using a password, and it has several Windows-like features which make the job easier.

Each Driveway customer is provided with a username and password for security, although the system can never be totally impregnable. Any sensitive files are best password-protected as well: consider zipping files together, adding a password and then upload them to your Driveway space. You can delete files using drag and drop, and can also upload a number of files in small batches (see screenshot) – a progress meter is provided.

Readers in the UK might consider The Elephant (**www.elephant365.co.uk**) backup web site which uses its own free software and provides 50MB free, claiming to be secure. More space is available for a small monthly cost.

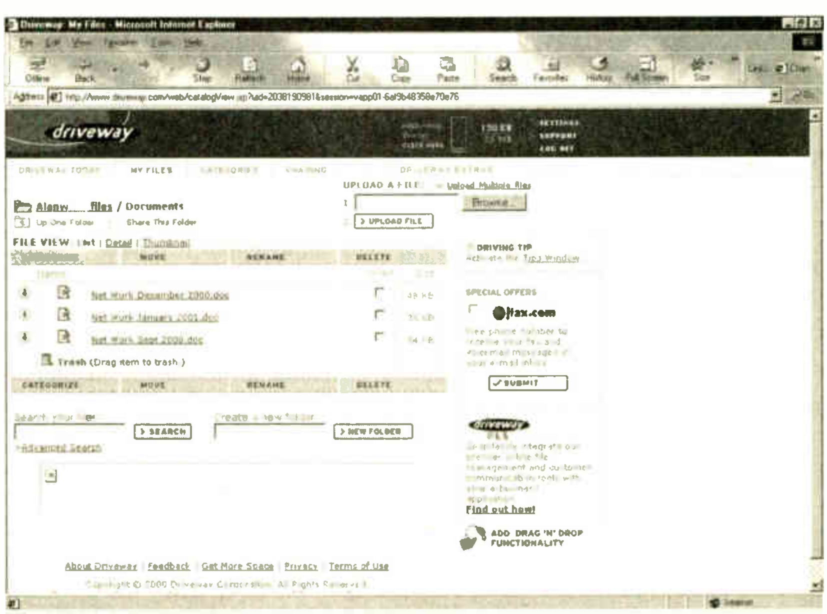
Furthermore, in the event of total system data loss, The Elephant offers to send you a CD of your archived data in the post for a fee. Now even if your computer hardware is pinched, at least you stand a chance of recovering data from the Internet afterwards.

Unwilling Partners

Last month I complained that my line speed had dropped drastically, due to BT "partnering" my modem line with another, using a DACS (Digital Access Carrier Service) box. There is hope yet: up the telegraph pole once again I spotted two BT engineers, who confirmed that they were un-DACSing my line as requested and finding another "partner" instead.

So, if DACSing happens to you, and you suddenly suffer slow speeds or difficult modem negotiations regardless of which ISP you use, complain long and hard, or threaten to close the account. Before going to war, though, have BT check the line gain, and maybe get it turned up.

That wraps up the year 2000. I wish readers around the world a peaceful Christmas and a Happy New Year. (You can E-mail me at **alan@epemag.demon.co.uk**.)



You can back up your files on the Internet using services such as Driveway.

PIC-MONITORED DUAL PSU

JOHN BECKER

Part Two

LAST month the principle of operation for this dual power supply (PSU) was discussed and details of the circuit and printed circuit boards were given. We now describe the completion of the unit, discuss shortened versions of it, and tell you about running the software.

WIRING-UP

Before wiring up is commenced, thoroughly check all the soldered connections and component positions on the p.c.b.s. Use a magnifying glass to check for short circuits and missed soldering joints.

Details for the mains power connections are shown in Fig.11. Once they have been satisfactorily made, completely surround them with heavy duty insulating tape or heatshrink sleeving. Solder the mains Earth lead to an eyelet tag mounted via one of the bolts securing the transformer to the base of the case.

There is at least one occasion on which you might need to make an adjustment inside the case when the power is switched on – when adjusting the l.c.d. contrast preset VR3 (but see later). You may also need to take voltage readings should any trouble-shooting be required (unlikely if you've assembled it all correctly, but still possible).

The insulating tape is intended to prevent inadvertent contact with any mains powered connections. As a further safety precaution, always work with one hand in your pocket when making adjustments or measurements inside mains powered equipment. This will minimise the risk of mains power passing from one hand to the other via your heart. This and the hand-to-foot routes are probably the most dangerous in an electrical shock situation.

Connections between the boards and the panel mounted components are shown in Fig.12. All connection points are numbered. Like-numbers should be connected together, other connections should be made according to the table in the monitor p.c.b. diagram of Fig.10 in Part 1. Numbers prefixed by A or B indicate connection to power supply board A or B as indicated.

Preferably leave wiring longer than is really necessary until full checking of the unit has been satisfactorily completed. When that has been done, the wiring can be suitably shortened and grouped into several harnesses using cable ties.

DO NOT make *any* wiring connection between the circuits inside the case and the mains earth. As will be seen later, *external* circuit connections *can* be made to earth, depending on what configuration of outputs is used, especially in the series connection mode. Any *internal* earthed connection could cause large short circuit currents to flow.

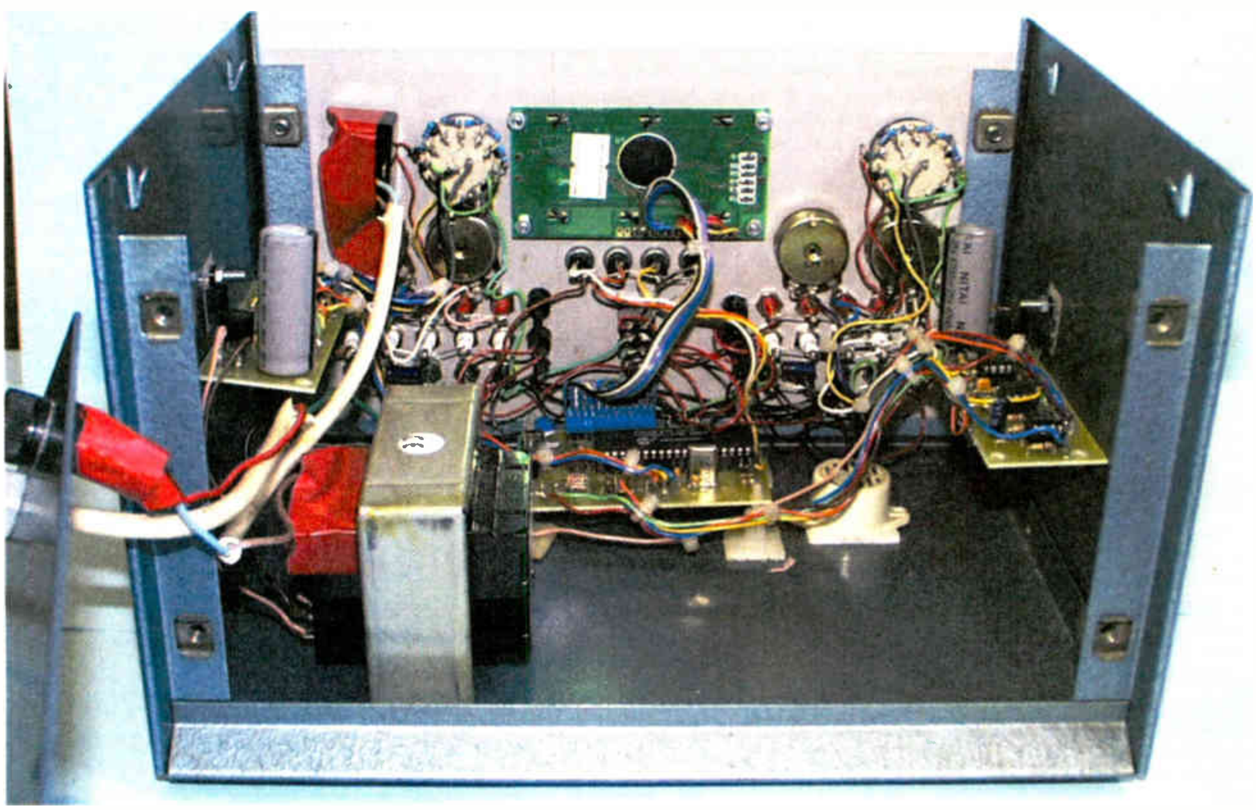
CHECKING OUT

It is recommended that if an existing power supply is available, it should be used to perform preliminary checking of the low voltage circuits before mains connections are made.

Should any fault become apparent during checking, immediately switch off, disconnect from the mains or other power supply and recheck your assembly.

Do not insert the PIC or l.c.d. yet.

Rotate all controls fully anti-clockwise, setting the switched outputs for 5V, and the



variable outputs to 0V. Set switch S7 to Parallel mode.

If you have to check the circuits using the mains power supply, immediately at switch-on check the voltage present on both power supply boards at terminal point 3 (junction of capacitor C1 and the positive output of rectifier REC1).

There should be a voltage of at least 20V d.c. at this point, probably nearer to 22V d.c.

Then check that 5V is present at the output of regulator IC1 on both power supply boards, and at the output of regulator IC5 on the monitor board.

Once the monitor's 5V has been proved, the l.c.d. module can be connected and its contrast adjusted using preset VR3 (although you will only see the top line until the PIC is inserted and running).

Next check that switches S2 select between the six voltage output options (listed earlier) for both channels. Also check that the variable output voltages can be changed by both VR1 potentiometers. The voltage available should be variable between just over 0V (0·2V in the prototype) and about 1V below the fixed voltage selected by switches S2.

With your voltmeter's common (0V) probe connected to the common output (0V) of Channel A, switch on S7, observe that l.e.d. D7 turns on, and that the output voltages from Channel B are raised by the same amount as selected for the fixed voltage of Channel A.

For example, if output 1 (Channel A) is at 5V and output 3 (Channel B) is selected for 5V, then the voltage between output 3 and the 0V sockets of Channel A should read as 10V. Check the situation for all settings of both channels. The maximum voltage available from output 3 with reference to Channel A's common output should be about 36V.

When in series mode, the voltage at Channel B's common output sockets should be the same as that at Channel A's switched output sockets.

The block diagrams in Fig.13 illustrate the three maximum output voltages obtainable with parallel and series connection.

SOFTWARE

The software for this design was written in TASM and is available from the Editorial office on 3·5-inch disk, for which a nominal handling charge applies. It is also available *free* via the *EPE* web site. For details on both options see this month's *Shoptalk* page, which also gives details on obtaining pre-programmed PICs.

The PIC16F877's configuration must be set according to Table 5. The settings are the same as the default values in the *PIC Toolkit Mk2* programmer.

Table 5

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

With one exception, there is nothing significantly different about the program routines compared to many of the author's recent PIC designs.

The exception is the binary-to-decimal routine, which was kindly sent to the author by *EPE* reader Peter Hemsley.

It is shorter than the author's original "library" routine, fast and 24-bit but easily modified to 16 or 32-bit. Execution time is

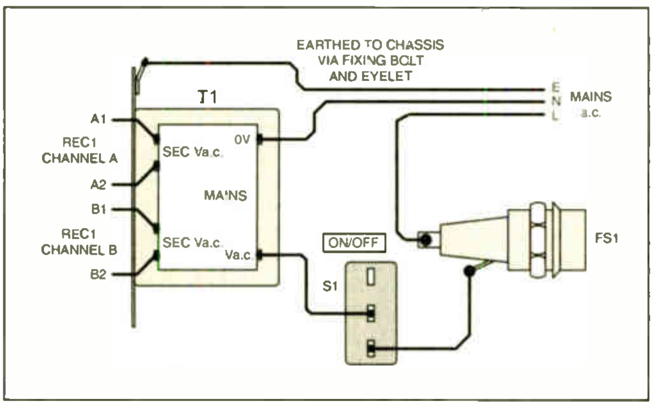


Fig.11. Mains power connections.

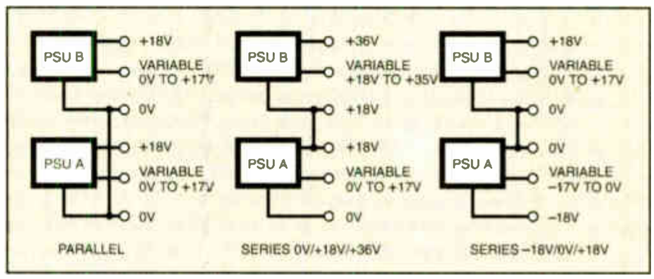


Fig.13. Maximum output voltages obtainable with parallel and series connection.

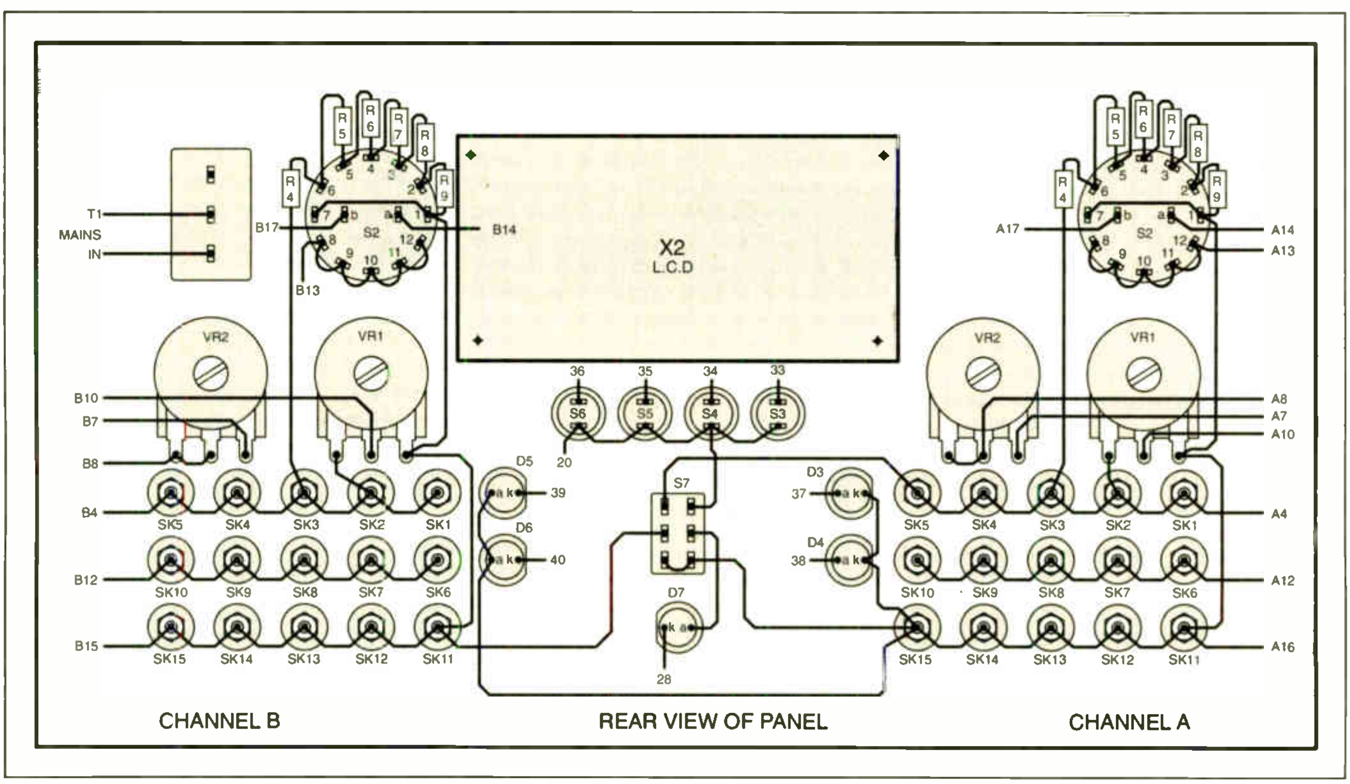
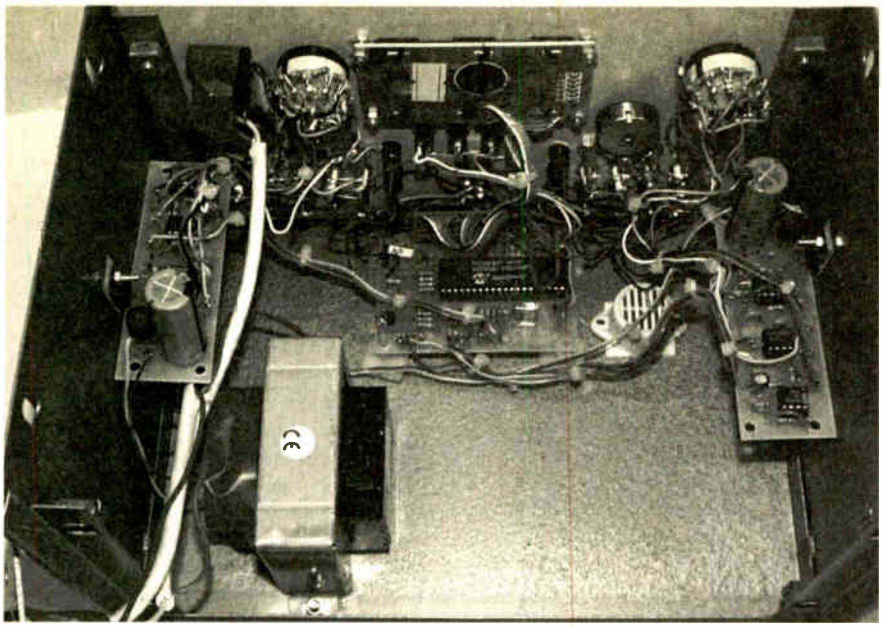


Fig.12. Front panel wiring details, viewed from inside.



constant and so can be used where timing is critical. Thank you Peter (and to all readers who contributed to the *Readout* discussion).

PIC CHECK

Once voltages have been checked, the PIC microcontroller (IC6) can be inserted.

If you wish to program your own PIC, it can be done *in situ* on the Monitor board using the *PIC Toolkit Mk2* programmer. The connection points are at terminal pin block TB2, in the same order as for the author's recent PIC designs. *Toolkit* can be powered at 9V via the Power Supply's Channel A Output 1 sockets.

When the programmed PIC is running, the first thing the program does is to recall the current limit values from the EEPROM data memory. On the first occasion the PIC is run, these values could be any random number from 0 to 255.

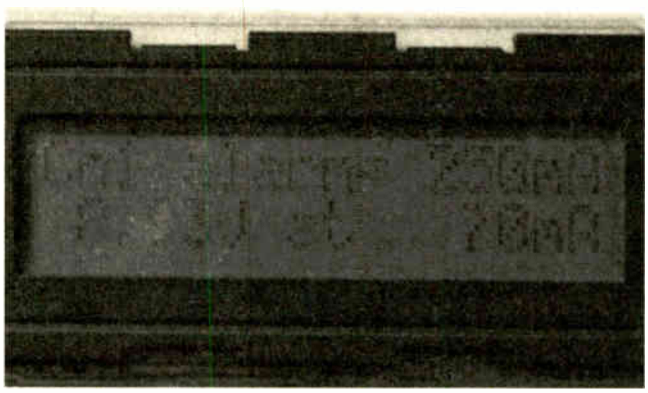
If the program finds that a value is zero it sets it for a 10mA limit. If a value is greater than 100 then the limit is set at 1000mA. To set different current limits use switches S3 to S5 as described in Part 1 (Control Switches). The new values are automatically stored in the EEPROM.

On this first occasion, again perform all the checks outlined earlier, observing the l.c.d. screen results. You may need to readjust VR3 to optimise the l.c.d. screen contrast.

If all is well, the power supply is ready for the final checks. These simply entail connecting varying loads to each of the outputs and checking that the current values are shown and that the alarm l.e.d.s are turned on if the current drawn is greater than the preset output limit.

If possible, briefly load the outputs so that more than 1A is drawn, in which case the buzzer should sound. Do not sustain this condition, which could cause some components to overheat.

Once all the checks have been completed, the panel can be calibrated around VR1, VR2 and switch S2.



Typical display when monitoring a single output.

HEATSINKING

This power supply can cause a considerable amount of heat to be generated across regulators IC1 and op.amp IC3. As an example, if IC1 supplies 5V to a 1A load, it can have a voltage drop across it of at least 15V, representing a heating power of 15W. The 7805 data sheet quotes a maximum power dissipation of about 2W without a heatsink and the device internally shuts down if it gets too hot.

Although both IC1 regulators are bolted to the case, which acts as a heatsink, 15W is a large amount of heat to dissipate. If you intend to use the power supply for prolonged periods at such levels, external finned heatsinks should be bolted to the case in the region of the regulators. An example of this technique is shown in Andy Flind's *Moodloop Power Supply* of September '00.

It might also be worth considering gluing a small finned heatsink to each rectifier. Drilling ventilation holes in the case could be useful as well.

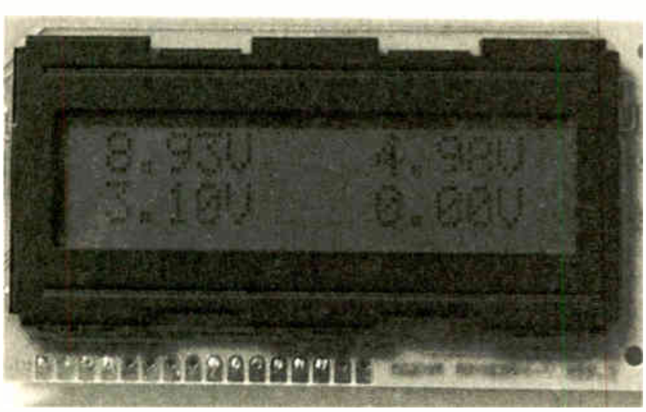
Op.amp IC3 could also be overheated at higher currents when a low voltage is being output. If you need to use the variable voltage outputs at low voltages and higher currents, switch IC1 so that it supplies IC3 with a lower voltage.

The maximum power that the L272 (IC3) can dissipate is 5W, and it too features thermal shutdown. Should you find that it does become overheated, consider gluing a small finned heatsink to it, as is suggested for the rectifiers.

It is for heatsinking reasons that the specifications given in Part 1 quote normal operational current values well below 1A.

To expand further on this, the suggested maximum currents versus output voltages from the 7805 regulator are given in Table 6. The values are calculated on the assumption that the rectified voltage is 20V d.c. and that the case probably dissipates about 5W. Note that the 7805 feeds the L272 op.amp and its output current must therefore be taken into account as well.

For the L272, the maximum output current is limited to about 350mA due to the action of the circuit around IC4a. However, be wary of powering it at 18V when the output voltage is set below about 6V, since the op.amp's wattage rating could be exceeded even at modest currents.



Typical display when monitoring voltage at all four outputs.

Typical display when monitoring current at all four outputs.

Table 6. Maximum output current versus voltage for 7805.

5V	450mA
6V	500mA
9V	630mA
12V	875mA
15V	1A
18V	1A

Apart from testing the power supply at higher currents, the author has not had practical experience of using it for supplying high-current loads in "active service". Most circuits published in *EPE* these days (including this author's designs) only require small supply currents. Feedback from readers on using this power supply at higher currents would be appreciated, addressed to the Editorial office, for possible inclusion in *Readout*.

SIMPLE POWER SUPPLY

It was said in Part 1 that a simplified version of a single power supply channel could be constructed according to Fig.3.

For this version, which is intended to supply either a fixed 5V or a variable supply of approximately 6V to just over 9V, it is suggested that a transformer having a single secondary of 9V a.c. is used, rated at about 250mA maximum. For this supply the working voltage of capacitor C1 can be reduced to 25V, the rectified voltage being about 9V a.c. × 1·414 – 1.4V = 11·3V.

The amended p.c.b. component layout and wiring details are shown in Fig.14. Note that the regulator is bolted to the case, as is done with the full power supply design.

Once constructed and thoroughly checked for assembly errors, simply check with your voltmeter that the correct voltages are available at the output socket. It is suggested that you calibrate the front panel around potentiometer VR1, showing the settings for different voltages.

OTHER VERSIONS

If a single channel version of the PIC-monitored supply is preferred, use Channel A. Channel B's inputs on the monitor p.c.b. can have their attenuation resistors omitted, but the associated PIC inputs should be linked to 0V (via positions R30 to R33).

A lower voltage and/or current version can be constructed, single or dual channel. However, if a lower voltage version is built, note that switch S2's divider resistor chain should remain as shown and discussed, or recalculated for fewer resistors.

If current monitoring is not required, the unused PIC inputs (RA1, RA3, RE0, RE2) should be linked to their voltage input partners (RA1 to RA0, RA3 to RA2, RE0 to RA5, RE2 to RE1). The l.c.d. screen will show that zero current is being drawn. □

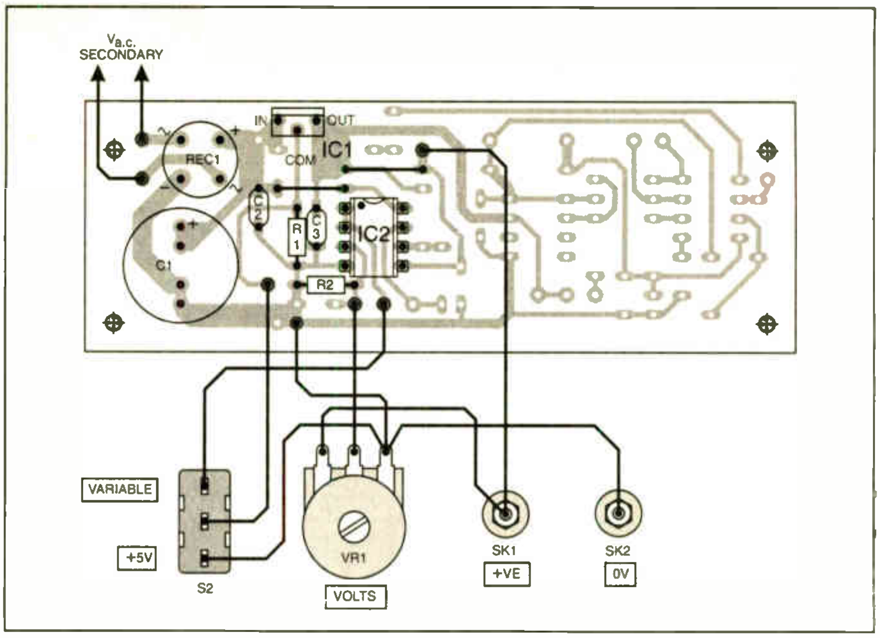


Fig.14. Component layout and wiring details for the suggested simple power supply.

COMPONENTS

Approx. Cost Guidance Only **£15** *excluding case*

SIMPLE PSU

Resistor
R1 1k 0·25W 5%

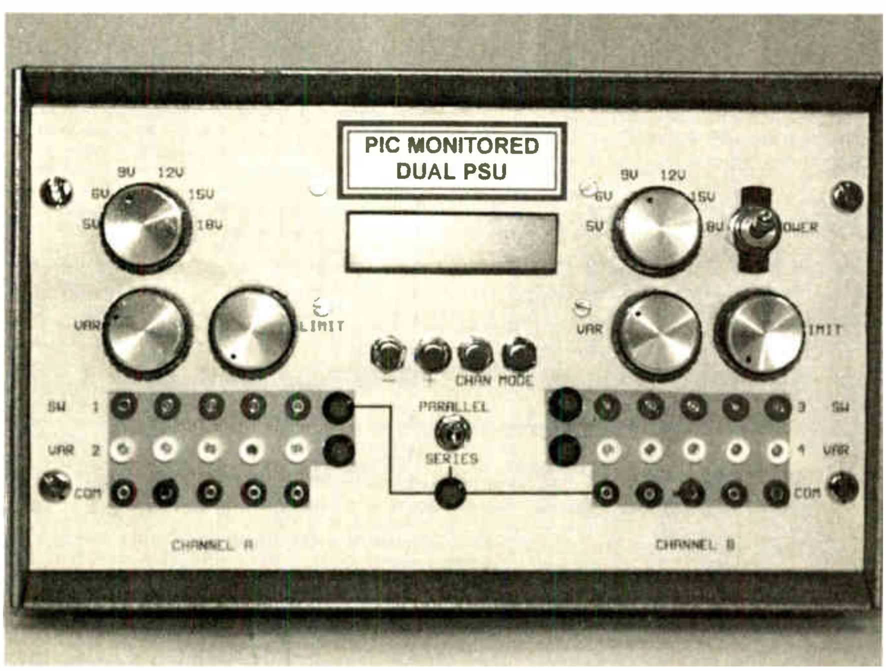
Potentiometer
VR1 10k rotary carbon, lin

Capacitors
C1 4700μF radial elect. (see text)
C2 220n ceramic disc, 5mm pitch
C3 100n ceramic disc, 5mm pitch

Semiconductors
IC1 7805 +5V 1A voltage regulator
IC2 LM358 dual op.amp

Miscellaneous
FS1 20mm fuseholder, panel mounting, with 1A 20mm fuse, slow blow
REC1 W005 50V 1A bridge rectifier, or similar
S1 s.p.d.t. switch, mains rated
S2 min. s.p.s.t. toggle switch
SK1 2mm socket, red (see text)
SK2 2mm socket, black (see text)
T1 mains transformer, 9V secondary, 250mA (see text)

Printed circuit board, available from the *EPE PCB Service* code 280 (power supply); knob; TO220 insulating washer kit for IC1; 8-pin d.i.l. socket; metal case to suit (see text); heatsink compound (see text); eyelet tag; mains cable clamping grommet; nuts and bolts for mounting transformer (2 off each); cable ties; 1mm terminal pins; 3-core mains cable, 5A; connecting wire; solder, etc.



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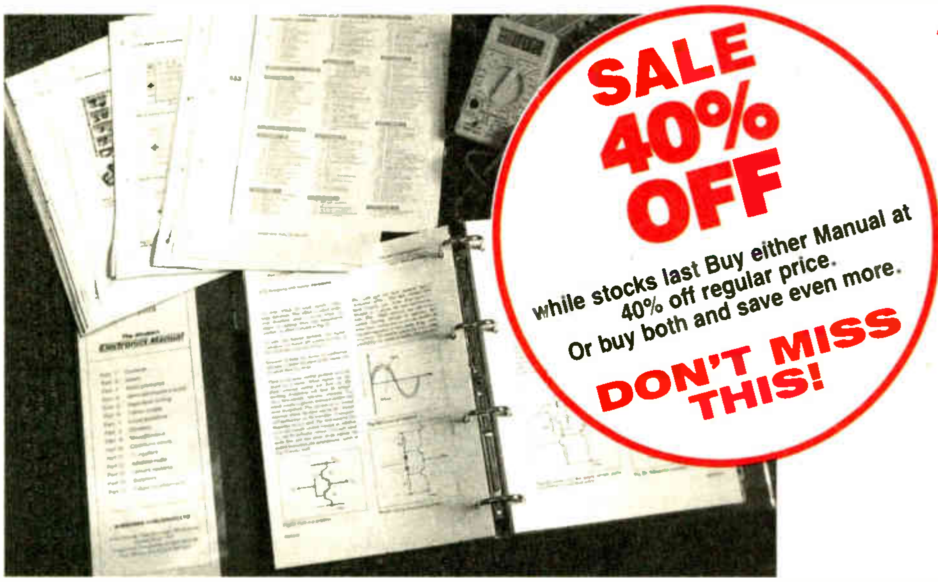

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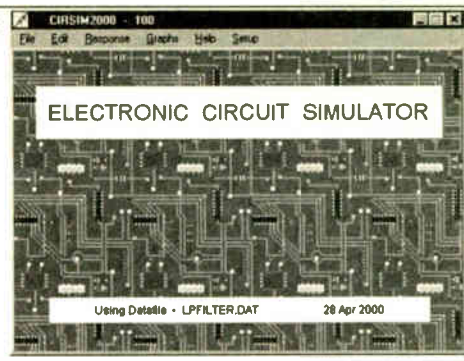
Special Review

CIRSIM SHAREWARE



COLIN SLOAN

A Circuit Simulation Program for the PC.

COMPUTER-BASED circuit simulation programs are now used extensively as an aid to circuit design. These programs do not actually design circuits but save time by enabling engineers to try out ideas by simulation before actually constructing hardware. There are some quite sophisticated packages on the market, such as Analyser III, MicroCap-V, Electronics Workbench and Tina Pro. The latter was reviewed in *EPE* last year.

These more expensive programs, which range in price from £100 upwards, are used in industry and by colleges for teaching purposes. They can handle a mixture of both analogue and digital circuits and even allow one to connect virtual instruments, such as an oscilloscope with appropriate controls, to view waveforms. A much cheaper but quite powerful simulation program called CIRSIM, which can analyse any linear analogue circuit, is now available and is the subject of this review.

ON ADMITTANCE

How do these programs work? Well, linear circuit analysis programs, such as CIRSIM, function by setting up a matrix of admittance values for each frequency at which the circuit response is required, these being derived from the component values defined for the circuit. It is essential to work with admittances rather than impedances (admittance is the reciprocal of impedance), as if there is no connection between two nodes of a circuit then the admittance of the path is zero, whereas the impedance would be infinity – a difficult value for computers to handle!

This matrix is known as the "indefinite admittance matrix" and relates the total current at any node in the circuit to the voltages at the nodes. The matrix is easy to set up as it exhibits a great deal of symmetry and would be of size $n \times n$ for a circuit containing n nodes. For three and four terminal components (such as transistors, op.amps and transformers), their own individual admittance matrices are derived and then added in to the main matrix – this is justified by the principle of superposition.

Having been set up, the complete matrix is then reduced to a 2×2 matrix representing the two-port blackbox equivalent network of the circuit, from which the usual parameters may easily be derived; i.e., gain, phase shift, input and output impedances. For more details of the theory see the articles given in refs. 1, 2 and 3.

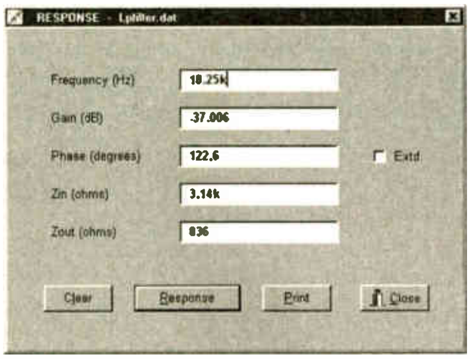


Fig.1. Results of analysis at a single frequency.

CIRSIM

CIRSIM itself is written in Pascal, using Borland Delphi, employing 32-bit code which will run under Windows 95, 98 and NT. It is capable of analysing circuits with up to 100 nodes and containing any mixture of resistors, capacitors, inductors, mutual inductors, transistors (both bipolar and f.e.t.), op.amps and thermionic valves. The high frequency parameters of both transistors and op.amps can be defined and there is no restriction on the total number of components.

In use a number is allocated to each nodal connection point on the circuit diagram (including earth) and then the component details and nodal connection numbers are input to the program. A simple text editor, with the usual cut and paste facilities, is incorporated in the program for this purpose. One can also add comments and circuit diagrams by using standard text characters, a facility which will be enhanced with appropriate circuit symbols in proposed later editions.

IN RESPONSE

Having defined the circuit, the simulator can calculate the response at any frequency. To do this, choose the appropriate menu item and type in the required frequency value. The screen will then display the gain in dB, the phase shift in degrees between input and output nodes, the input impedance and the output impedance at the specified frequency, as shown in Fig.1. With the 'Extd' box ticked, the results are displayed with much greater precision in floating point format.

The circuit definition is stored on disk so the analysis can be repeated at other frequencies or you can return to the editor to make circuit changes, adding or deleting components, to see how these affect the response. You can also change the input or output nodes so the response can be calculated at any intermediate point in the circuit. A listing of the component values and the results of the analysis can be output to the printer at any time.

It is possible to determine the stability criteria of oscillators by breaking the circuit loop at an appropriate point and finding that frequency at which there is zero phase shift between input and output. Provided the gain is greater than unity at this frequency, the circuit will oscillate when the loop is closed.

The simulator can plot the amplitude response of your circuit over a defined frequency range. Some 50 preset frequency scales are provided, ranging from 0·03Hz to 3GHz with each spanning 1, 2, 3 or 5 decades. A user-defined frequency scale is also available covering any range you care to define.

Progress is indicated by a horizontal bargraph while the results are being computed. On completion, another menu allows you to set the amplitude scale appropriately, after which the response is displayed on the screen in a 640×480 format.

After examining the result, you can return to the amplitude setting menu, revise the scale if required, and then display again. If you want a hard copy of the plot, a printer setup menu is provided which makes it possible to position the graph on the paper and to scale the plot. A typical result, Fig.2, shows the response of a low pass Chebyschev filter, and Fig.3 shows the response of a mutually coupled tuned circuit (as might be used in an i.f. amplifier) with various degrees of coupling; namely, undercoupled, critically coupled and overcoupled.

One unique feature of this program is that plots can be superimposed – a facility often not found in more expensive packages. Thus, one can plot and save a response, return to the editor to make circuit changes, and then superimpose the revised response on the first – repeating this as many times as required.

The impressive result in Fig.4 shows the response of a seven-band graphic equaliser circuit. The various boost/cut potentiometers (sliders) were set to flat and the response plotted. The response was then plotted with each in turn set first to maximum and then to minimum positions. The resultant 15 plots were superimposed on one graph as shown.

It can also calculate the squarewave response of a circuit at any given frequency. This can be rather time consuming so to speed things up, with a slight loss of accuracy, one can restrict the number of harmonics used in the calculation. The squarewave response of the low pass Chebyschev filter plotted on the printer in the same way as the amplitude response is shown in Fig.5.

IN USE

CIRSIM is easy to install and use. It is robust, it doesn't crash if you type in silly values, and it appears to be accurate. The program designer claims to have compared the results obtained from CIRSIM with those using PCSPICE analysing the same circuit and found there was exact agreement.

It is very fast in operation with smaller circuits but slows up rapidly as the number of nodes increases. To analyse a circuit containing 100 nodes (which is quite large) takes about one second using a, now fairly ancient, 100MHz Pentium. As you would expect, graphs take longer to compute since 400 data points are involved.

Detailed documentation is provided which can be displayed on the screen using a simple menu system and more than 20 circuit examples are included in the package. These include simple active and passive filters, a loudspeaker crossover network, a cascode circuit, various audio amplifiers (including a valve amplifier), a Baxandall tone control, a gyrator and a 47-section transmission line.

The simulator is very useful for analysing linear circuits and can save a lot of time by resolving problems before actually building any hardware. At lower frequencies, up to about 10MHz, circuits perform as predicted by CIRSIM within the limits of experimental accuracy. At higher frequencies there are some discrepancies which are probably caused by inaccurate modelling of components – more especially stray capacitance and inductance not being included in the simulated circuit.

SUMMING UP

To sum up, in terms of accuracy and speed CIRSIM is as good as other more expensive programs designed to simulate linear analogue circuits while the graphical output is well presented with the advantage of superposition. It is also capable of analysing circuits containing thermionic valves, which is a bonus.

The program does have its limitations – it does not have all the bells and whistles of its more expensive counterparts, there are no facilities to import component data from files and it cannot handle logic circuits. However, for the price, just £10, it represents excellent value for money and is a good low-cost introduction to the art of linear circuit simulation.

A free evaluation version of the software, providing all the facilities of the program but handling a limited number of nodes, can be downloaded from the website **http://www.bells-hill.freeserve.co.uk**. This downloaded file contains full documentation and examples. The purchase price of £10 applies only to the version of the program handling the full number of nodes.

CIRSIM can be obtained from:

Peter Montgomery, Downings, Bells Hill, Stoke Poges, Slough SL2 4EG.

Tel: 01753 643384.

E-mail: cirsim@bells-hill.freeserve.co.uk ☐

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1. Network Analysis and Synthesis by F. F. Kuo – J. Wiley and Sons.
2. Semiconductor Device Modeling for Computer-Aided Design by G. A. Herskowitz and R. B. Schilling – McGraw-Hill.
3. Computer Circuit Simulation by W. Blume – Byte July 1986.

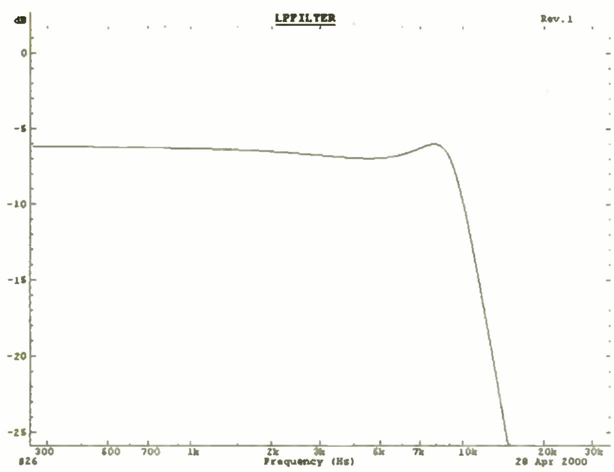

Fig.2. Amplitude response of a low pass filter.

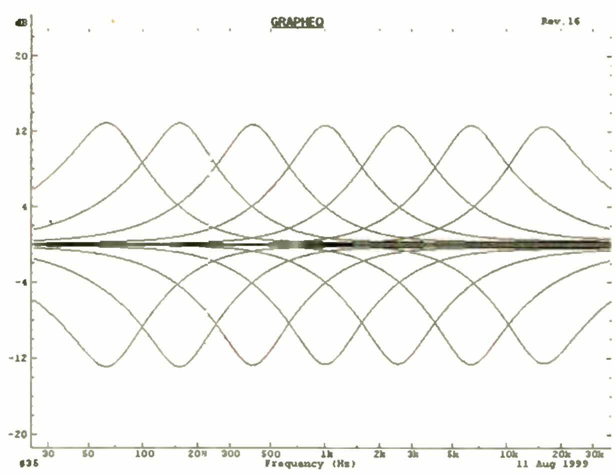

Fig.4. Amplitude response of a seven-band graphic equaliser circuit.

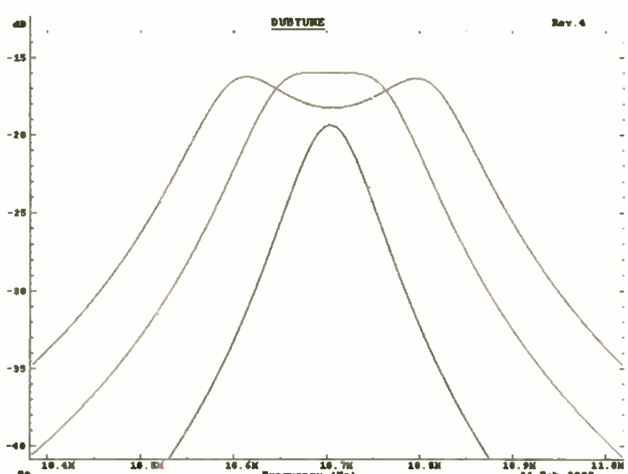

Fig.3. Response of mutually coupled tuned circuits.

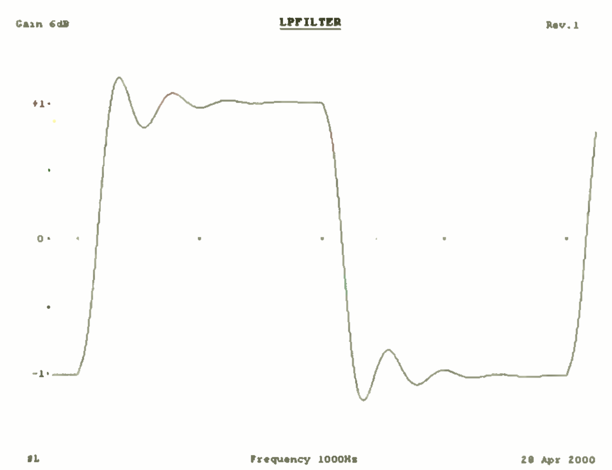

Fig.5. Squarewave response of the low pass filter, showing ringing around the cut-off frequency.

Everyday Practical Electronics Books

TEACH-IN No. 7
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For a further selection of books see the next two issues of *EPE*.

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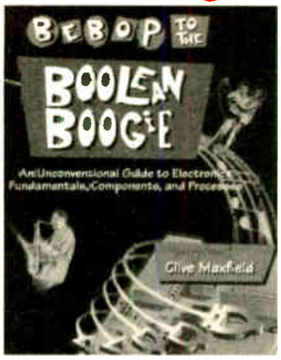
Theory and Reference

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

Specially imported by *EPE* – *Excellent value*

An Unconventional Guide to Electronics Fundamentals, Components and Processes



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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250 pages **Order code NE28** £16.99

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FREE CD-ROM

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Music, Audio and Video

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN

V. Capel

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148 pages **Temporarily out of print**

ELECTRONIC MUSIC AND MIDI PROJECTS

R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing in this respect.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

138 pages **Order code PC116** £9.95

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

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R. A. Penfold

Computers are playing an increasingly important part in the world of music, and the days when computerised music was strictly for the fanatical few are long gone.

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This book will help you learn the basics of computing, running applications programs, wiring up a MIDI system and using the system to good effect, in fact just about everything you need to know about hardware and the programs, with no previous knowledge of computing needed or assumed. This book will help you to choose the right components for a system to suit your personal needs, and equip you to exploit that system fully.

174 pages **Temporarily out of print**

THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN

Robert Charles Alexander

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Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first electronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

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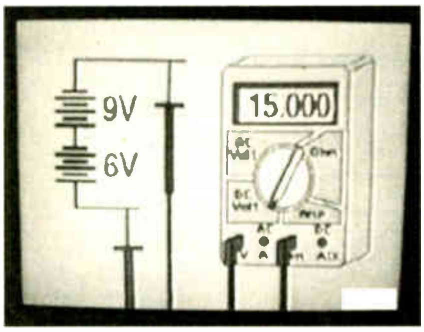

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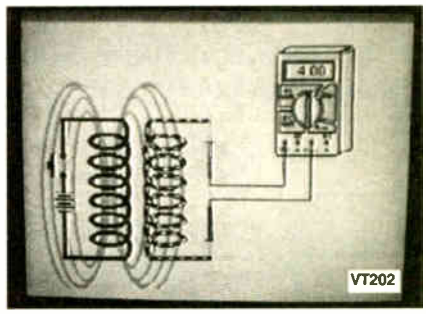

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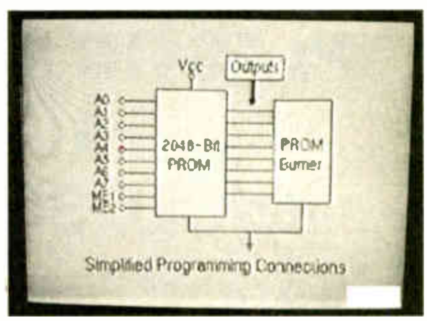

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Published on approximately the second Thursday of each month by Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. Printed in England by Apple Web Offset Ltd., Warrington, WA1 4RW. Distributed by COMAG Magazine Marketing, 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.