

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY

JULY 2004

**PRACTICAL**

# ELECTRONICS

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## EPE PIC MAGNETOMETER

With data logging for  
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Colour CCTV camera, 8mm lens, 12V d.c. 200mA 582x628 Resolution 380 lines Automatic aperture lens Mirror function PAL Back Light Compensation MLR, 100x40x40mm. Ref EE2 £75.90

Built-in Audio 15lux CCD camera 12V d.c. 200mA 480 lines s/n ratio >48db 1V P-P output 110mm x 60mm x 50mm. Ref EE1 £108.90



Metal CCTV camera housings for internal or external use. Made from aluminium and plastic they are suitable for mounting body cameras in. Available in two sizes 1 - 100 x 70 x 170mm and 2 - 100 x 70 x 280mm. Ref EE6 £24.20 EE7 £28.60 multi-position brackets. Ref EE8 £8.80

Excellent quality multi-purpose TV/TFT screen, works as just a LCD colour monitor with any of our CCTV cameras or as a conventional TV. Ideal for use in boats and caravans 49.75MHz-91.75MHz VHF channels 1-5, 168-25MHz-222.75MHz VHF channels 6-12, 471.25MHz-869-75MHz, Cable channels 112-325MHz-166.75MHz Z1-Z7, Cable channels 224-25MHz-446.75MHz Z8-Z35 5" colour screen Audio output 150mW Connections, external aerial, earphone jack, audio/video input, 12V d.c. or mains, Accessories supplied Power supply, Remote control, Cigar lead power supply, Headphone Stand/bracket, 5" model £152.90 Ref EE9, 6" model £163.90 Ref EE10



Self-cocking pistol plcr002 crossbow with metal body. Self-cocking for precise string alignment Aluminium alloy construction High tec fibre glass limbs Automatic safety catch Supplied with three bolts Track style for greater accuracy Adjustable rear sight 50lb drawweight 150ft/sec velocity Break action 17" string 30m range £23.84 Ref PLCR002

Fully cased IR light source suitable for CCTV applications. The unit measures 10 x 10 x 150mm. Is 12V d.c. operated and contains 54 infra-red LEDs. Designed to mount on a standard CCTV camera bracket. The unit also contains a daylight sensor that will only activate the infra-red lamp when the light level drops below a preset level. The infra-red lamp is suitable for indoor or exterior use, typical useage would be to provide additional IR illumination for CCTV cameras. £53.90. Ref EE11



Mains operated and designed to be used with any CCTV camera moving it to scan. The clips can be moved to adjust the scan angle, the motor reversing when it detects a clip. With the clips removed the scanner will rotate constantly at approx 2.3rpm. 75 x 75 x 60mm £25.30. Ref EE12

Colour CCTV Camera measures 60x45mm and has a built-in light level detector and 12 IR LEDs 0.2 lux 12 IR LEDs 12V d.c. Bracket Easy connect leads £75.90. Ref EE15



A high quality external colour CCTV camera with built-in infrared LEDs measuring 60 x 60 x 60mm Easy connect leads colour Waterproof PAL 1/4in. CCD 542 x 588 pixels 420 lines 0.05 lux 3.6mm F2 78 deg lens 12V d.c. 400mA Built-in light level sensor. £108.90. Ref EE13

Colour pinhole CCTV camera module with audio. Compact, just 20x20x20mm, built-in audio and easy connect leads PAL CMOS sensor 6-9V d.c. Effective Pixels 628x582 Illumination 2 lux Definition >240 Signal/noise ratio >40db Power consumption 200mW £38.50. Ref EE21



A small colour CCTV camera measuring just 35 x 28 x 30mm. Supplied complete with bracket, microphone and easy connect leads. Built-in audio. Colour 380 line resolution PAL 0.2 lux +18db sensitivity Effective pixels 628 x 582 Power source 6-12V d.c. Power consumption 200mW £39.60. Ref EE16

Complete wireless CCTV system with video. Kit comprises pinhole colour camera with simple battery connection and a receiver with video output 380 lines colour 2.4GHz 3 lux 6-12V d.c. manual tuning Available in two versions, pinhole and standard. £86.90 (pinhole) Ref EE17, £86.90 (standard). Ref EE18



Small transmitter designed to transmit audio and video signals on 2.4GHz. Unit measures 45 x 35 x 10mm. Ideal for assembly into covert CCTV systems Easy connect leads Audio and video input 12V d.c. Complete with aerial Selectable channel switch £33. Ref EE19



2.4GHz wireless receiver Fully cased audio and video 2.4GHz wireless receiver 190x140x30mm, metal case, 4 channel, 12V d.c. Adjustable time delay. 4s, 8s, 12s, 16s. £49.50. Ref EE20

The smallest PMR446 radios currently available (54x87x37mm) These tiny handheld PMR radios not only look great, but they are user friendly & packed with features including VOX, Scan & Dual Watch. Priced at £64.90 PER PAIR they are excellent value for money. Our new favourite PMR radios! Standby - 35 hours Includes: - 2 x Radios, 2 x Belt Clips & 2 x Carry Strap £64.90 Ref ALAN1 Or supplied with 2 sets of rechargeable batteries and two mains chargers £93.49. Ref Alan2



Beltronics BEL550 Euro radar and GATSO detector Claimed Detection Range: GATSO up to 400m. Radar & Laser guns up to 3 miles. Detects GATSO speed cameras at least 200 metres away, plenty of time to adjust your speed £350.90. Ref BEL550

TheTENS mini Microprocessors offer six types of automatic programme for shoulder pain, backneck pain, aching joints, Rheumatic pain, migraines, headaches, sports injuries, period pain. In fact all over body treatment. Will not interfere with existing medication. Not suitable for anyone with a heart pacemaker. Batteries supplied. £21.95 Ref TEN327 Spare pack of electrodes £6.59. Ref TEN327X



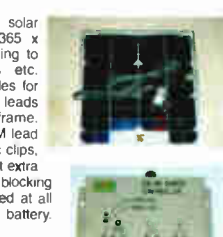
Dummy CCTV cameras These motorised cameras will work either on 2 AA batteries or with a standard DC adapter (not supplied) They have a built-in movement detector that will activate the camera if movement is detected causing the camera to pan Good deterrent. Camera measures 20cm high, supplied with fixing screws. Camera also has a flashing red l.e.d. built in. £10.95. Ref CAMERAB

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 £16.50. Ref IRF2 or a 12" sq for £34.07 IRF2A



GASTON SEALED LEAD-ACID BATTERIES  
1.3AH 12V @ £5.50 REF GT1213  
3.4AH 12V @ £8.80 REF GT1234  
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17AH 12V @ £19.80 REF GT1217  
All new and boxed, bargain prices Good quality sealed lead-acid batteries

SOLAR PANEL 10 watt silicon solar panel, at least 10 year life, 365 x 26mm, waterproof, ideal for fixing to caravans, boat, motorhomes etc. Nicely made unit with fixing holes for secure fittings. Complete with leads and connectors Anodised frame. Supplied with two leads, one 3M lead is used for the clip with two croc clips, the other lead is used to connect extra panels. Panels do NOT require a blocking diode, they can be left connected at all times without discharging the battery. £93.49. REF PAN



High-power modules (80W+) using 125mm square multi-crystal silicon solar cells with bypass diode. Anti-reflection coating and BSF structure to improve cell conversion efficiency: 14%. Using white tempered glass, EVA resin, and a weatherproof film along with an aluminium frame for extended outdoor use. system Lead wire with waterproof connector. Four sizes, 80W 12V dc, 1200 x 530 x 35mm, £315.17. REF NE80, 123W 12V d.c., 1499 x 662 x 46mm, £482.90. REF NDL3, 125W 24V, 1190 x 792 x 46mm, £482.90. REF NEL5 and 165W 24V, 157 x 826 x 46mm, £652.30.

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THE TIDE CLOCK These clocks indicate the state of the tide. Most areas in the world have two high tides and two low tides a day, so the tide clock has been specially designed to rotate twice each lunar day (every 12 hours and 25 minutes) giving you a quick and easy indication of high and low water. The Quartz tide clock will always stay calibrated to the moon. £23.10 REF TIDEC



LINEAR ACTUATORS 12-36V D.C. BUILT-IN ADJUSTABLE LIMIT SWITCHES. POWER COATED 18in. THROW JP TO 1,000lb. THRUST (400lb. RECOMMENDED LOAD). SUPPLIED WITH MOUNTING BRACKETS DESIGNED FOR OUTDOOR USE. These brackets originally made for moving very large satellite dishes are possibly more suitable for closing gates, mechanical machinery, robot wars etc. Our first sale was to a company building solar panels that track the sun! Two sizes available, 12in. and 18in. throw. £32.95. REF ACT12, £38.45 REF ACT18.



POWERSAFE DEEP CYCLE BATTERIES 12V 51AH. NOW ONLY £29.95 EACH YUASA 6V 100AH NOW ONLY £25 + £5 POSTAGE EACH



BRAND NEW MILITARY ISSUE DOSE METERS (radiation detectors) Current NATO issue. Standard emergency services unit. Used by most of the world's military personnel. New and boxed. £75.90. REF SIEM69

NIGHT VISION SYSTEM. Superb hunting rifle sight to fit most rifles, grooved for a telescopic sight. Complete with infra-red illuminator. Magnification 2.7x. Complete with rubber eye shield and case. Opens up a whole new world! Russian made. Can be used as a hand-held or mounted on a rifle. £108.90. REF PN1



These Samarium magnets measure 57mm x 20mm and have a threaded hole (5/16th UNF) in the centre and magnetic strength of 2.2 gauss. We have tested these on a steel beam running through the offices and found that they will take more than 170lb. (77kg) in weight before being pulled off. With keeper. £21.95. REF MAG77.

Peltier Effect heat pump. Semiconductor thermo-electric device which works on the Peltier effect. When supplied with a suitable electric current, can either cool or heat. Also when subject to an externally applied temperature gradient can produce an electric current. Ideal for cooling or controlling the temperature of sub assemblies. Each module is supplied with a comprehensive 18-page Peltier design manual featuring circuit designs, design information etc., etc. The Peltier manual is also available separately. Maximum watts 56.2 40 x 40mm Imax, 5.5A Vmax, 16.7 Tmax (c-dry N2), 72. £32.95 (inc. manual. REF PELT1. Just manual £4.40 REF PELT2

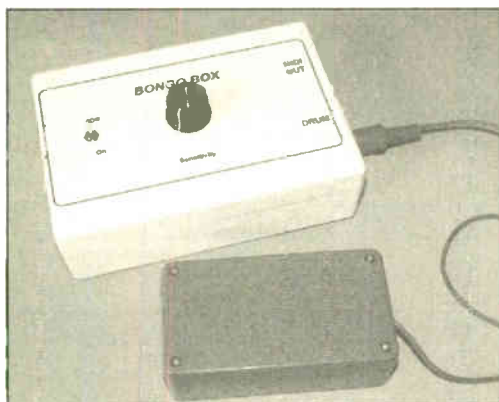
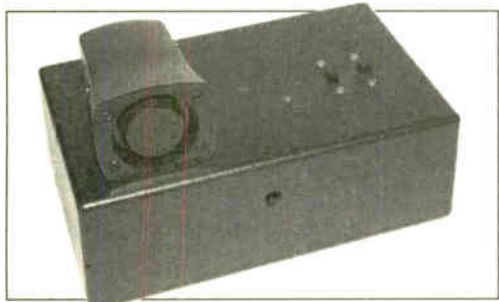
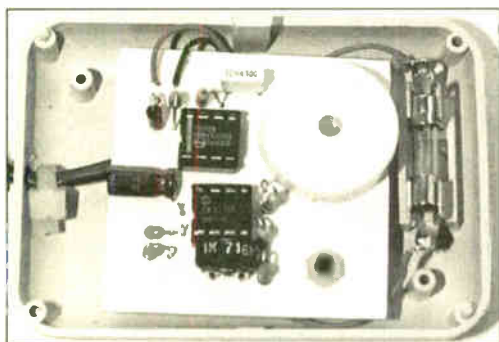
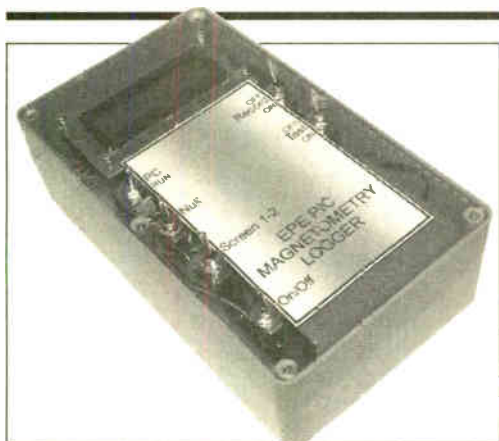


New transmitter, receiver and camera kit £75.90. Kit contains four channel switchable camera with built-in audio, six IR l.e.d.s and transmitter, four channel switchable receiver, 2 power supplies, cables, connectors and mounting bracket. £75.90. Wireless Transmitter, Black and white camera (75 x 50 x 55mm). Built-in 4 channel transmitter (switchable). Audio built-in 6 IR l.e.d.s. Bracket/stand. Power supply 30m range Wireless Receiver 4 channel (switchable). Audio/video leads and scart adapter. Power supply and manual, £75.90. REF COP24.

This miniature Stirling Cycle Engine measures 7in. x 4 1/4in. and comes complete with built-in alcohol burner. Ref flywheels and chassis mounted on a green base, these all-metal beauties silently running at speeds in excess of 1,000 r.p.m. attract attention and create awe wherever displayed. This model comes completely assembled and ready to run. £106.70. REF SOL1



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Our August 2004 issue will be published on Thursday, 8 July 2004. See page 439 for details

## Projects and Circuits

- PORTABLE MINI ALARM** by Andy Flind 448  
Covertly monitor your property and distinguish between loiterers and passers-by
- INGENUITY UNLIMITED – Sharing your ideas with others** 458  
Multiple Range Ammeter; Repeatable Logic Probe; Model Theatre Lighting Dimmer
- BONGO BOX** by David Clark 462  
PIC up the rhythm with our MIDI finger drum!
- EPE PIC MAGNETOMETRY LOGGER – 1** by John Becker 469  
Logging your search for magnetic fields that might reveal hidden artifacts
- HARD DRIVE WARBLER** by Terry de Vaux-Balbirnie 501  
Monitor your PC's hard drive activity from a distance

## Series and Features

- TECHNO TALK** by Andy Emmerson 456  
When it comes to standards, choice is not always a good thing!
- CIRCUIT SURGERY** by Alan Winstanley and Ian Bell 461  
Dual-rail power supplies; Superglue
- TEACH-IN 2004 – 9. Lock and Alarm Systems** by Max Horsey 482  
Continuing our 10-part tutorial and practical series – how to apply electronics meaningfully
- PIC N' MIX** by Andrew Jarvis 494  
"Hello World" for PICs: instruction cycles, masks and clockwork i.e.d.s
- NET WORK – THE INTERNET PAGE** surfed by Alan Winstanley 499  
More on web search engines, plus a look at Gmail
- MAKING FRONT PANEL OVERLAYS** by Andrew Martell 504  
Making low-cost professional-looking front panel overlays using your PC
- PRACTICALLY SPEAKING** by Robert Penfold 506  
A novice's guide to troubleshooting project construction problems

## Regulars and Services

- PIC RESOURCES CD-ROM V2** Invaluable to all PICKers! 442  
A plethora of 20 "hand-PICKed" *EPE* past projects
- EDITORIAL** 447
- NEWS** – Barry Fox highlights technology's leading edge 454  
Plus everyday news from the world of electronics
- SHOPTALK** with David Barrington 467  
The *essential* guide to component buying for *EPE* projects
- READOUT** John Becker addresses general points arising 478
- BACK ISSUE CD-ROMS** Single-source shopping for issues you've missed 480
- BACK ISSUES** Did you miss some issues? 492
- CD-ROMS FOR ELECTRONICS** 496  
A wide range of CD-ROMs for hobbyists, students and engineers
- DIRECT BOOK SERVICE** 508  
A wide range of technical books available by mail order, plus more CD-ROMs
- PRINTED CIRCUIT BOARD AND SOFTWARE SERVICE** 511  
PCBs for *EPE* projects. Plus *EPE* project software
- ELECTRONICS MANUALS** 512  
Essential CD-ROM reference works for hobbyists, students and service engineers
- ADVERTISERS INDEX** 516

Readers Services • Editorial and Advertisement Departments 447

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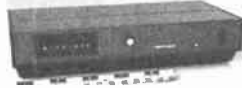
A bulk purchase enables us to bring to you these GIANT 7-segment digital displays at a now affordable price!! The 10" character size gives exceptional readability at long distances and enables a host of applications including, score boards, digital clocks, counters, event timers etc. As the units are a simple electro-mechanical device and operate from 12V DC, simple switching via switches, relays, PIC or PC may be used to control single or multiple digits. Units feature integral 'Zero Power' memory which greatly simplifies design. For an excellent DIY practical article, see the May issue of 'Everyday Practical Electronics' magazine. Ideal School / College construction project. Supplied in good RFE condition, complete with data sheet.



7-segment Displays

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## THE AMAZING TELEBOX



TV SOUND & VIDEO TUNER  
CABLE COMPATIBLE

Converts your colour monitor into a QUALITY COLOUR TV!!

The TELEBOX is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors or AV equipment which are fitted with a composite video or SCART input. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers\* (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. TELEBOX MB covers virtually all television frequencies VHF and UHF including the HYPERBAND as used by most cable TV operators. Ideal for desktop computer video systems & PIP (picture in picture) setups. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard. Brand new - fully guaranteed.

TELEBOX ST for composite video input type monitors £36.95  
TELEBOX SL as ST but fitted with integral speaker £39.50  
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner £69.95  
For overseas PAL versions state 5.5 or 6 MHz sound specification.  
\*For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

**NEW** State of the art PAL (UK spec) UHF TV tuner module with composite 1V pp video & NICAM hi fi stereo sound outputs. Micro electronics all on one small PCB only 73 x 160 x 52 mm enable full tuning control via a simple 3 wire link to an IBM pc type computer. Supplied complete with simple working program and documentation. Requires +12V & +5V DC to operate.  
**BRAND NEW - Order as MY00. Only £39.95 code (B)**  
See www.distel.co.uk/data\_my00.htm for picture + full details

## HARD DISK DRIVES 2 1/2" - 14"

2 1/2" TOSHIBA MK1002MAV 1.1Gb laptop (12.5 mm H) New £59.95  
2 1/2" TOSHIBA MK4313MAT 4.3Gb laptop (8.2 mm H) New £105.00  
2 1/2" TOSHIBAMK6409MAV 6.1Gb laptop (12.7 mm H) New £98.00  
2 1/2" TOSHIBA MK1614GAV 18 Gb laptop (12 mm H) New £149.95  
2 1/2" to 3 1/2" conversion kit for Pc's, complete with connectors £15.95  
3 1/2" COMPAQ 313706-B21 (IBM) 9 gb ULT/SCSI-3 New £199.00  
3 1/2" FUJI FK-309-26 20mb MFM I/F RFE £59.95  
3 1/2" CONNER CP3024 20 mb IDE I/F (or equiv.) RFE £59.95  
3 1/2" CONNER CP3044 40 mb IDE I/F (or equiv.) RFE £69.00  
3 1/2" QUANTUM 40S Prodril ve 42mb SCSI I/F, New RFE £49.00  
5 1/4" MINISCRIBE 3425 20mb MFM I/F (or equiv.) RFE £49.95  
5 1/4" SEAGATE ST-238R 30 mb RLL I/F Return £69.95  
5 1/4" CDC 94205-51 40mb H MFM I/F RFE tested £69.95  
5 1/4" HP 97548 850 Mb SCSI RFE tested £99.00  
5 1/4" HP C3010 2 Gbyte SCSI differential RFE tested £195.00  
8" NEC D2246 85 Mb SMD interface. New £99.00  
8" FUJITSU M2322K 160Mb SMD I/F RFE tested £195.00  
8" FUJITSU M2392K 2 Gb SMD I/F RFE tested £345.00  
Many other floppy & H drives, IDE, SCSI, ESDI etc from stock, see website for full stock list. Shipping on all drives is code

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**COMPUTER MONITOR SPECIALS**

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Mitsubishi FA3415ETKL 14" SVGA Multisync colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including IBM PC's in CGA, EGA, VGA & SVGA modes, BBC, COMMODORE (including Amiga 1200), ARCHIMEDES and APPLE. Many features: Etched faceplate, text switching and LOW RADIATION MPR specification. Fully guaranteed, in EXCELLENT like used condition. Tilt & Swivel Base £4.75

VGA cable for IBM PC included. **Only £129 (E)** Order as CG73

External cables for other types of computers available - CALL

**Generic LOW COST SVGA Monitors**  
We choose the make, which includes Compaq, Mitsubishi, IBM, etc. Supplied ready to run with all cables, Standard RTB 90 day guarantee.

14" £59.00	15" £69.00	17" £79.00
---------------	---------------	---------------

Supplied in good used condition. Shipping code (D)

## VIDEO MONITORS

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with both RGB and standard composite 15.625 KHz video inputs via SCART socket and separate phono jacks. Integral audio power amp and speaker for all audio visual uses. Will connect direct to Amiga and Atari BBC computers. Ideal for all video monitoring / security applications with direct connection to most colour cameras. High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed  
**Only £99.00 (E)**  
Dimensions: W14" x H12 1/4" x 15 1/2" D.

PHILIPS HCS31 Ultra compact 9" colour video monitor with standard composite 15.625 KHz video input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13 1/2" D. 240 V AC mains powered.  
**Only £179.00 (D)**

## INDUSTRIAL COMPUTERS

Tiny shoebox sized industrial 40 MHz 386 PC system measuring only (mm) 266 w X 88 h X 272 d. Ideal for dedicated control applications running DOS, Linux or even Windows! Steel case contains 85 to 265 V AC 50 / 60 Hz 70 Watt PSU, a 3 slot ISA passive backplane and a Rocky 318 (PC104) standard, single board computer with 8 MByte NON VOLATILE solid state 'Disk On Chip' RAMDISK. System comprises: Rocky 318 (PC104) SBC ISA card with 40MHz ALI 386SX CPU, 72 pin SIMM slot with 16 Mbyte SIMM, AMI BIOS, battery backed up real time clock. 2 x 9 pin D 16550 serial ports. EPP/ECP printer port, mini DIN keyboard connector, floppy port, IDE port for hard drives up to 528 MByte capacity, watchdog timer and PC/104 bus socket. The 8 MByte solid state 'disk on a chip' has its own BIOS, and can be fdisked, formatted & booted. Supplied BRAND NEW fully tested and guaranteed. For full data see featured item on website. Order as Q006

Typical applications inc: firewalls, routers, robotics etc  
**Only £99.00 (D)**

## TEST EQUIPMENT & SPECIAL INTEREST ITEMS

Unless marked NEW, items in this section are pre owned.

MITSUBISHI FA3445ETKL 14" Ind. spec SVGA monitors £245  
FARNELL 0-60V DC @ 50 Amps, bench Power Supplies £995  
FARNELL AP3080 0-30V DC @ 80 Amps, bench Supply £1850  
KINGSHILL C2403/1 0-50V @ DC 200 Amps - NEW £3950  
1KW to 400 kW - 400 Hz 3 phase power sources - ex stock £POA  
IBM 8230 Type 1, Token ring base unit driver £760  
Wayne Kerr RA200 Audio frequency response analyser £2500  
INFODEC 1U, 24 port, RJ45 network patchpanels, #TH93 £49  
3COM 16670 12 Port Ethernet hub - RJ45 connectors #LD97 £69  
3COM 16671 24 Port Ethernet hub - RJ45 connectors £89  
3COM 16700 8 Port Ethernet hub - RJ45 connectors NEW £39  
IBM 53F5501 Token Ring ICS 20 port lobe modules £POA  
IBM MAU Token ring distribution panel 8228-23-5050N £45  
AIM 501 Low distortion Oscillator 9Hz to 330KHz, IEEE I/O £550  
ALLSON 8360, 11805-1880 MHz hybrid power combiners £2500  
Trend DSA 274 Data Analyser with G703(2M) 64 I/O £POA  
Marconi 6310 Programmable 2 to 22 GHz sweep generator £4500  
Marconi 2022C 10KHz-1GHz RF signal generator £1550  
HP1650B Logic Analyser £3750  
HP3781A Pattern generator & HP3782A Error Detector £POA  
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts £1800  
HP6264 Rack mount variable 0-20V @ 20A metered PSU £475  
HP54121A DC to 22 GHz four channel test set £POA  
HP8130A opt 0.20 300 MHz pulse generator, GPIB etc £7900  
HP A1, A0 8 pen HPGL high speed drum plotters - from £750  
HP DRAFTMASTER 18 pen high speed plotter £750  
EG+G Brookdeal 95035C Precision clock in amp £1800  
Keithley 590 CV capacitor / voltage analyser £POA  
Racal IRC9 dual 40 channel voice recorder system £375C  
Fishers 45KVA 3 ph On Line UPS - New batteries £4500  
Emerson AP130 2.5KVA industrial spec. UPS £1499  
Mann Tally MT645 High speed line printer £2200  
Intel SBC 486/133SE Multibus 486 system, 8Mb Ram £945  
HP6030A 0-200V DC @ 17 Amps bench power supply £1950  
Intel SBC 486/125C08 Enhanced Multibus (MSA) New £1150  
Nikon HFX-11 (Ephiphot) exposure control unit £1450  
PHILIPS PM5518 pro. TV signal generator £1250  
Motorola VME Bus Boards & Components List. SAE / CALL £POA  
Trio 0-18 vdc linear, metered 30 amp bench PSU. New £550  
Fujitsu M3041R 600 LPM high speed band printer £1950  
Fujitsu M3041D 600 LPM printer with network interface £1250  
Siemens 44900 64kb to 140Mb demux analyser £2950  
Perkin Elmer 2298B Infrared spectrophotometer £500  
Perkin Elmer 597 Infrared spectrophotometer £3500  
Veg Electronics 1035 TELETEXT Decoding Margin Meter £3250  
LightBand 60 output high spec 2u rack mount Video VDA's £495  
Sekonic SD 150H 18 channel digital Hybrid chart recorder £1995  
B&K 2633 Microphone pre amp £300  
Taylor Hobson Tallysurp amplifier / recorder £750  
ADC SS200 Carbon dioxide gas detector / monitor £1450  
BBC AM203 PPM Meter (Ernest Turner) + drive electronics £75  
ANRITSU 9654A Optical DC-2.5Gb/w waveform monitor £5650  
ANRITSU ML93A optical power meter £990  
ANRITSU Fibre optic characteristic test set £POA  
R&S FTDZ Dual sound unit £650  
R&S SBU-E1 Vision modulator £775  
WILTRON 6630B 12.4 / 20GHz RF sweep generator £5750  
TEK 2445 150 MHz 4 trace oscilloscope £1250  
TEK 2465 300 MHz 300 MHz oscilloscope rack mount £1955  
TEK TDS380 400MHz digital realtime + disk drive, FFT etc £2900  
TEK TDS524A 500MHz digital realtime + colour display etc £5100  
HP3585A Opt 907 20Hz to 40 MHz spectrum analyser £3950  
PHILIPS PW1730/10 60KV XRAY generator & accessories £POA  
VARIACUS - Large range from stock - call or see our website £325  
CLAUDE LYONS 12A 240V single phase auto. volt. regs

## 19" RACK CABINETS

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## EPE SCORER

This is a versatile PIC-controlled aid for all quizmasters, providing independently adjustable scores for two teams, a countdown stopwatch timer ("You have two minutes on . . .") and "Fingers on the button" function.

Three score buttons can be preprogrammed for each team so that scores can be increased by one, two or four points for each press. There are also buttons to "undo" the last score and take a point off for corrections and penalties.

As well as quizzes, the design could be used to keep track of both time and scores in rugby, football, hockey or other similar sports. An optional extra is a remote slave unit (or two) so that each team can have its own local display if needed.



## PIC TO PS/2 MOUSE AND KEYBOARD INTERFACING

Many circuits based on PIC microcontrollers use switches to set a variety of factors. However, there are instances where some, if not all, of those switches may only be used rarely, except in the initial setting-up process.

So far we have probably all accepted this situation as a fact of life and not considered the expense of seldom-used switches to be of any significance – it's all part of the process of getting a particular design working as we want it.

There are, though, two other options available for minimising or avoiding the use of control switches. Those options can be provided by two items of equipment that the majority of PIC-programming readers will have – the PC's mouse and keyboard. This article describes how the PS/2 versions (the commonest standard) of both these items can be used with a PIC.

## SIMPLE F.M. RADIO

Following the recent Practical Radio Circuits series (June '03 to Jan '04), a number of readers have requested a design for a simple v.h.f. f.m. receiver. Three types of circuit meet the requirement for simplicity. The first two, super-regenerators and synchronous oscillators, can be difficult to set up and operate, and the lack of automatic frequency control causes problems in use.

The third utilises the superhet principle, but adopts a simple resistance/capacitance coupled intermediate frequency amplifier instead of the conventional tuned circuit arrangement. The aerial input is broadly tuned to the f.m. band, and only the oscillator has a variably tuned circuit. This greatly simplifies the construction and setting up of the receiver.

This design sports wide range tone controls and a two-watt output, providing exceptional sound quality for a portable radio. It is easy to construct and to set up.

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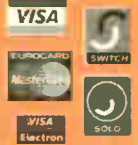
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USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB Plug A-A lead not incl.



Kit Order Code: 3128KT – £29.95

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Will program virtually ALL 8 to 40 pin PICs plus certain ATMEL AVR, SCENIX SX and EEPROM 24C devices. Also supports In System Programming (ISP) for PIC and ATMEL AVRs. Free software. Blank chip auto detect for super fast bulk programming. Requires a 40-pin wide ZIF socket (not included)

Assembled Order Code: AS3144 – £54.95

### ATMEL 89xxx Programmer

Uses serial port and any standard terminal comms program. 4 LEDs display the status. ZIF sockets not included. Supply: 16VDC.



Kit Order Code: 3123KT – £29.95

Assembled Order Code: AS3123 – £34.95

### NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket and USB Plug A-A lead extra. 18VDC.

Kit Order Code: 3149KT – £29.95

Assembled Order Code: AS3149 – £44.95

### Introduction to PIC Programming

Go from a complete PIC beginner to burning your first PIC and writing your own code in no time!

Includes a 49-page step-by-step Tutorial Manual, Programming Hardware (with LED bench testing section), Win 3.11-XP Programming Software (will Program, Read, Verify & Erase), and a rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). Connects to PC parallel port.

Kit Order Code: 3081KT – £14.95

Assembled Order Code: AS3081 – £24.95



### ABC Maxi AVR Development Board

The ABC Maxi board has an open architecture design based on Atmel's AVR AT90S8535 RISC microcontroller and is ideal for developing new designs.



#### Features:

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- Output buffers can sink 20mA current (direct I.e.d. drive) • 4 x 12A open drain MOSFET outputs • RS485 network connector • 2-16 LCD Connector
- 3.5mm Speaker Phone Jack
- Supply: 9-12VDC.

The ABC Maxi STARTER PACK includes one assembled Maxi Board, parallel and serial cables, and Windows software CD-ROM featuring an Assembler, BASIC compiler and in-system programmer.

Order Code ABCMAXISP – £79.95

The ABC Maxi boards only can also be purchased separately at £59.95 each.

## Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU345 – £9.95

### Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security.

4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx can be learned by one Rx (kit includes one Tx but more available separately). 4 indicator LEDs.

Rx: PCB 77x85mm, 12VDC/6mA (standby).

Two & Ten Channel versions also available.

Kit Order Code: 3180KIT – £41.95

Assembled Order Code: AS3180 – £49.95



### Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered

by PC. Includes one DS1820 sensor and four header cables.

Kit Order Code: 3145KT – £19.95

Assembled Order Code: AS3145 – £26.95

Additional DS1820 Sensors – £3.95 each



### NEW! DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired.



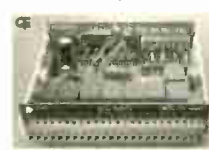
User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm.

Power: 12VDC.

Kit Order Code: 3140KT – £39.95

Assembled Order Code: AS3140 – £49.95

### Serial Port Isolated I/O Module



Computer controlled 8-channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch

states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130 x 100 x 30mm. Power: 12VDC/500mA.

Kit Order Code: 3108KT – £54.95

Assembled Order Code: AS3108 – £64.95

### Infra-red RC 12-Channel Relay Board



Control 12 on-board relays with included infra-red remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm.

Supply: 12VDC/0.5A.

Kit Order Code: 3142KT – £41.95

Assembled Order Code: AS3142 – £51.95

### PC Data Acquisition & Control Unit

Monitor and log a mixture of analogue and digital inputs and control external devices via the analogue and digital outputs. Monitor pressure, tempera-



ture, light intensity, weight, switch state, movement, relays, etc. with the appropriate sensors (not supplied). Data can be processed, stored and the results used to control devices such as motors, sirens, relays, servo motors (up to 11) and two stepper motors.

#### Features

- 11 Analogue Inputs – 0-5V, 10 bit (5mV/step)
- 16 Digital Inputs – 20V max. Protection 1K in series, 5-1V Zener
- 1 Analogue Output – 0-2.5V or 0-10V. 8 bit (20mV/step)
- 8 Digital Outputs – Open collector, 500mA, 33V max
- Custom box (140 x 110 x 35mm) with printed front & rear panels
- Windows software utilities (3-1 to XP) and programming examples
- Supply: 12V DC (Order Code PSU203)

Kit Order Code: 3093KT – £69.95

Assembled Order Code: AS3093 – £99.95

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

## Cool New Kits This Winter!

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

### NEW! EPE Ultrasonic Wind Speed Meter



Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need

calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

#### Specifications

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

Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see web site for full details). Power: 9VDC (PP3 battery or Order Code PSU345).

Main PCB: 50 x 83mm.

Kit Order Code: 3168KT – £34.95

### NEW! Audio DTMF Decoder and Display



Detects DTMF tones via an on-board electret microphone or direct from the phone lines through the onboard audio transformer. The

numbers are displayed on a 16-character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based.

Supply: 9-12V DC (Order Code PSU345).

Main PCB: 55 x 95mm.

Kit Order Code: 3153KT – £17.95

Assembled Order Code: AS3153 – £29.95

### NEW! EPE PIC Controlled LED Flasher



This versatile PIC-based LED or filament bulb flasher can be used to flash from 1 to 160

LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 superbright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher by Steve Challinor, EPE Magazine Dec '02. See website for full details. Board Supply: 9-12V DC. LED supply: 9-45V DC (depending on number of LED used). PCB: 43 x 54mm. Kit Order Code: 3169KT – £10.95

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

## FM Bugs & Transmitters

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

### MMTX' Micro-Miniature 9V FM Room Bug



Our best selling bug! Good performance. Just 25 x 15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere.

Operates at the 'less busy' part

end of the commercial FM waveband and also up into the more private Air band.

Range: 500m. Supply: PP3 battery.

Kit Order Code: 3051KT – £8.95

Assembled Order Code: AS3051 – £14.95

### HPTX' High Power FM Room Bug

Our most powerful room bug.



Very Impressive performance. Clear and stable output signal thanks to the extra circuitry employed.

Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip supplied). 70 x 15mm.

Kit Order Code: 3032KT – £9.95

Assembled Order Code: AS3032 – £17.95

### MTTX' Miniature Telephone Transmitter



Attach anywhere along phone line. Tune a radio into the signal and hear

exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire – uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20 x 45mm.

Kit Order Code: 3016KT – £7.95

Assembled Order Code: AS3016 – £13.95

### 3 Watt FM Transmitter



Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 3 watts of RF power. Can be used with the electret

microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45 x 145mm.

Kit Order Code: 1028KT – £22.95

Assembled Order Code: AS1028 – £34.95

### 25 Watt FM Transmitter

Four transistor based stages with a Philips BLY89 (or equivalent) in the final stage. Delivers a mighty 25 Watts of RF power. Accepts any line level audio source (input sensitivity is adjustable). Antenna can be an open dipole, ground plane, 5/8, J, or YAGI configuration. Supply 12-14V DC, 5A. Supplied fully assembled and aligned – just connect the aerial, power and audio input. 70 x 220mm.

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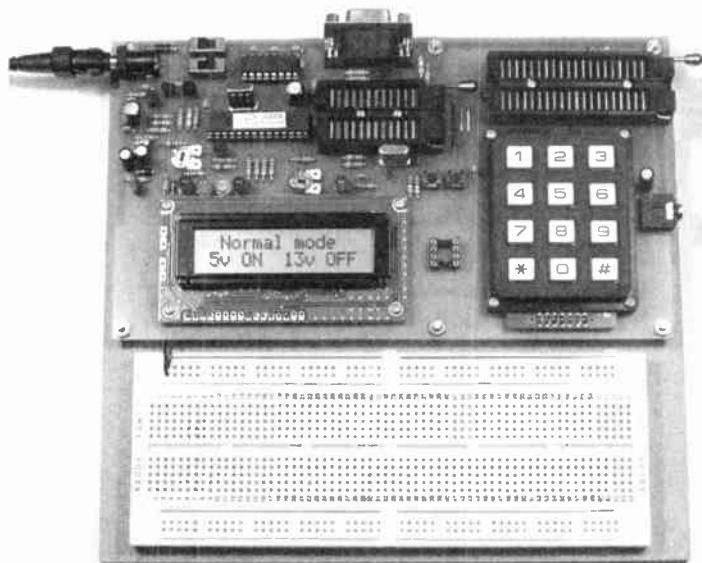
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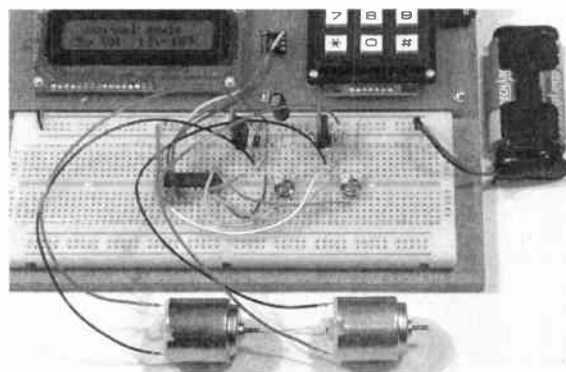
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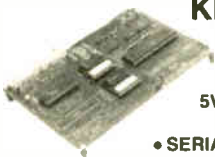
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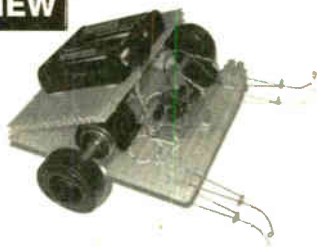
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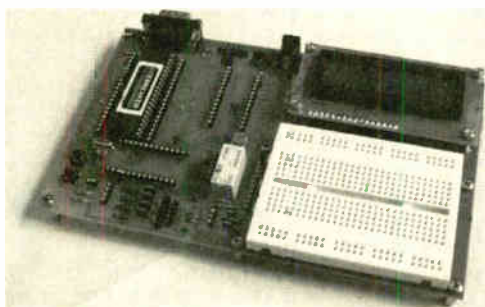
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# EVERYDAY PRACTICAL ELECTRONICS

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 33 No. 7

JULY 2004

## Ghostly Electrics

It's the intermittent faults that are the hardest to find! Fay's car takes on a life of its own when the warm weather comes – it seems to lie relatively dormant in the winter, just twitching occasionally, but come a hot day and it positively jumps about. Well actually what happens is that a ghost inside the car wakes up and starts turning the central locking on and off at random, no matter if the car is being driven or just parked up. The ghost often locks her in as she drives or unlocks the car while it's parked in the sun, then locks it, then unlocks it, then . . . well you get the picture.

She has taken it to the local main dealer who tell her they cannot find anything wrong. It seems to me to be a bad connection or a dodgy switch somewhere, but finding it is the problem when the ghost does not want to co-operate! We can, of course, disconnect it but that is rather defeatist. As I said, it is the intermittent faults that are the hardest to find, so I have a great deal of sympathy with anyone trying to trace such a fault in a complex piece of electronics.


## Bugs

Bugs in software are similarly often hard to locate, particularly when you have written the code yourself. How do the little vermin get in there and how do they manage to hide so well that you simply cannot see them?

It's like that with checking the magazine content. Once you have made a mistake it's very hard to see it when you check things – I reckon it's Fay's ghost hiding them!

Sharp-eyed readers will have noticed that last month's *Advertisers' Index*, on the last page of the issue, is in fact the one from the previous month and not the correct one – sorry. We did produce the correct one and check it carefully but the ghost must have switched it in the computer at the last minute so we never noticed.

Just don't know why or how he/she does it!



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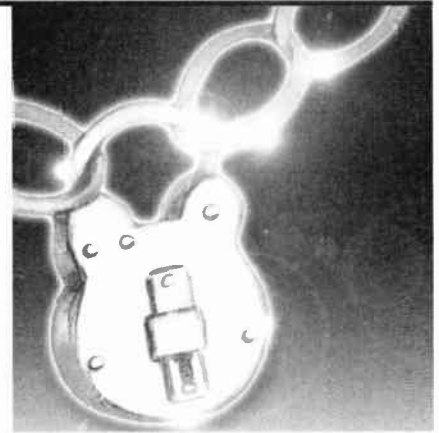
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# Portable Mini Alarm

Andy Flind



*Covertly monitor your property and distinguish between loiterers and passers-by*

**T**HIS is a unit that should find many applications within home and business security. Battery powered and about the size of a small brick, it can be simply placed at the area to be protected, switched on and left. Intruders entering the area will trigger a siren that is loud enough to alert anyone nearby.

The circuit features "pulse counting" that enables it to distinguish between passers by and someone loitering, perhaps with "intent", in the protected area. The count can be adjusted by the user for the desired degree of immunity from false alarms. The battery life will depend upon the number of detections and alarms, but the circuit is a micro-power design and is capable of remaining "on guard" for periods well in excess of a year.

Simple construction means that several can be built if needed, the author has three! There are various ways in which the circuit can be modified for individual requirements and a few suggestions will be given later.

## Sensible Concept

The Sensor circuit, shown in Fig.1, uses a passive infrared (PIR) sensor, IC1, in this case without a lens. The sensor provides a

very inconspicuous unit as it "looks out" through a small hole in the case. A schematic view of it is shown in Fig.2.

In Fig.1, resistor R1 and capacitor C1 decouple the supply for the sensor. These sensors have an output voltage that varies slightly when a warm body passes in front of them and tends to drift back to the quiescent value when the input remains steady.

Two amplification stages are used, IC2 and IC3. The sensor is d.c. coupled to IC2,

which in turn is a.c. coupled to IC3. Together, IC2 and IC3 exhibit a band-pass characteristic having a centre frequency of about 0.5Hz, which is optimal for this application. IC4 and IC5 form a "window comparator" where one or other of the outputs will go positive regardless of which way the input signal deviates from quiescent.

The outputs are combined in IC6, a 40107 dual NAND gate buffer/driver with open-collector outputs. This device is a lesser-known member of the 4000 series CMOS family (see 40107 Dual NAND Gate panel). A positive signal from either IC4 or IC5 will cause the outputs to turn on and sink current to ground.

## Power Considerations

The original test circuit was found to be very sensitive to supply voltage fluctuations, so much so that even if fed by a regulator from a battery supply, any alteration of battery current drain could cause false triggering. The solution to this was to use a separate 6V battery and design the circuit to take a constant supply current. This dispenses with the need for a regulator and its associated supply current.

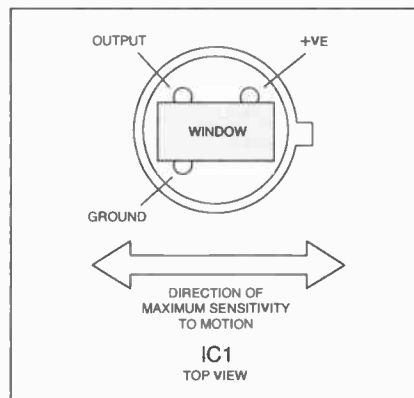


Fig.2. Sensor pinout and sensitivity details.

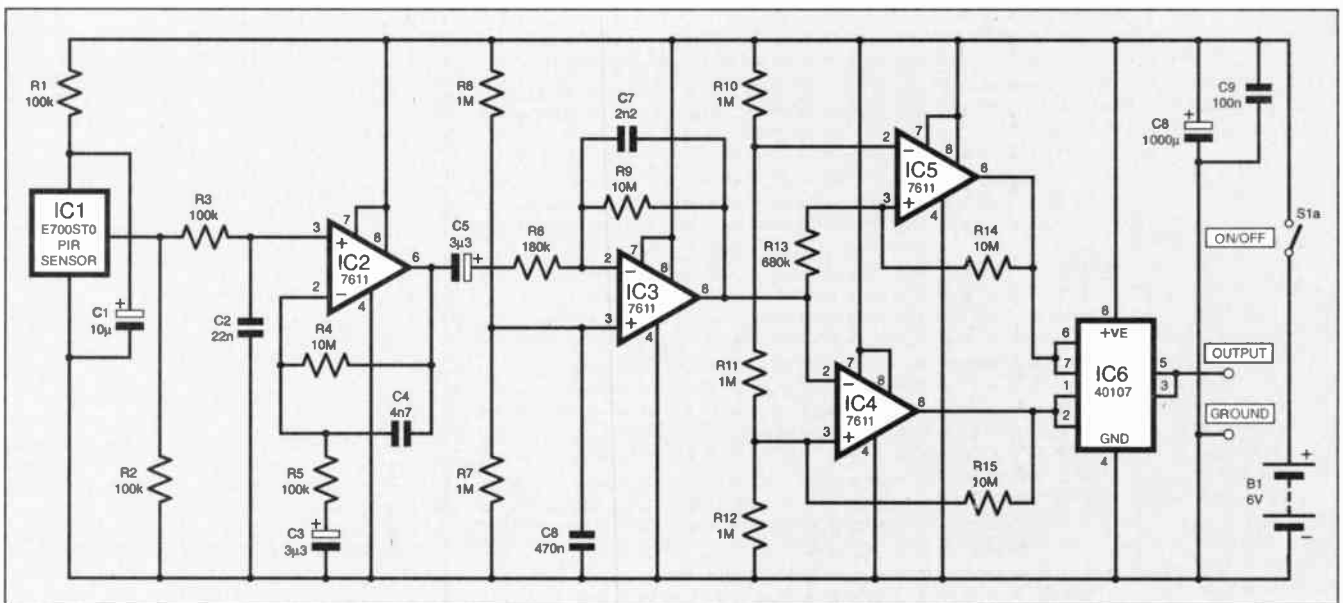


Fig.1. Circuit diagram for the Sensor section of the Portable Mini Alarm.



## THE 40107 DUAL NAND GATE

The author has never seen a 40107 dual NAND gate used in an amateur design and suspects this may be because it does not appear in Don Lancaster's *CMOS Cookbook*, which is probably the bible for most users of this logic. Whatever the reason, it is a pity because it has characteristics that are practically unique within the CMOS 4000 series, some of which are extremely useful.

The first and most obvious difference is that the d.i.l. version is housed in an 8-pin package whereas all the others use a minimum of 14 pins.

The other main difference concerns the device outputs. It contains two 2-input NAND gates in which, as usual, if both inputs are high the output goes low. However, the outputs in this case are open-drain *n*-channel MOSFETs, not bipolar (high and low) as with most other logic gates. This means that they can sink current to ground, but are unable to source it from a positive supply.

Where the output would normally be high, for the 40107 it is effectively open-circuit. For normal logic use this would require a pull-up resistor which would incur extra operating current. However, this has advantages. Because the output is an open drain, it can be connected to a voltage source that is different to the chip's power supply. Consequently, it can be used to interface a logic circuit operating from, say, 5V to another circuit section with a 12V supply.

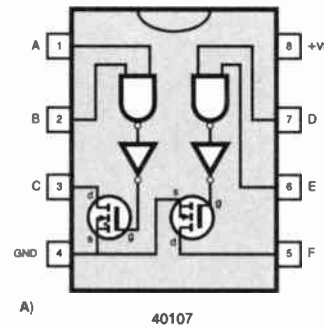
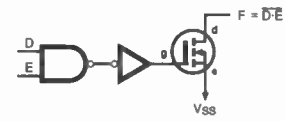
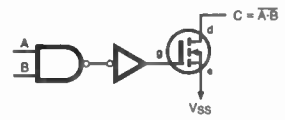
In fact, the voltage rating for the drain is higher than that of most CMOS devices. It is rated for use with a 20V supply, with an absolute maximum of 22V.

Another difference concerns the amount of current the outputs of the 40107 can sink. Most CMOS 4000 series outputs can only sink or source a few milliamps and have difficulty driving a single

i.e.d. Not so with the 40107. Its current sinking capability depends upon the supply voltage, but at 5V it can typically sink 32mA, and with a 10V supply this rises to a whopping 136mA!

The datasheet ([www.us.st.com/stonline/books/pdf/docs/2018.pdf](http://www.us.st.com/stonline/books/pdf/docs/2018.pdf)) shows example circuits driving 12V 2-2W incandescent lamps and even a motor. And of course, it's excellent for discharging timing capacitors!

There must be many other interesting applications for this device, so hopefully some more will be appearing in *EPE* before too long.



A	B	C
L	L	*H
H	L	*H
L	H	*H
H	H	L

\*WITH EXTERNAL PULL-UP RESISTOR  
\*WITHOUT PULL-UP RESISTOR (3-STATE)

its output turns on and discharges C3, which causes the output of IC1d to go high and turn on output transistor TR1, to activate whatever load is connected to it, in this instance a siren or piezo sounder is suggested (WD1).

The output remains active for at least as long as the time taken by C3 to recharge, which commences only when the input pulse ends. Further input pulses occurring before C2 has had time to recharge will restart the output period immediately and discharge C2 again, so the circuit responds immediately to further input pulses until a sufficient period has elapsed for C2 to recharge and reset IC3.

An active output is indicated by the 2mA red i.e.d. D3. A separate switch, S2, is provided for the output warning device. This allows the unit to be set up and tested without deafening everyone, and for it to be temporarily disabled without turning off the sensor circuit, because this takes about thirty seconds to settle after power up. Clear as mud? Probably!

### Effective Discrimination

The outcome is a circuit that counts pulses and only triggers once a certain number have occurred with less than ten seconds between any of them. Once triggered, it will keep on re-triggering immediately until a ten-second gap has occurred. This is highly effective in discriminating between a body merely passing and one remaining within the sensing area, and also in encouraging said body to depart from the area.

As a matter of interest, if all the links between IC3 and IC4 are set to Off, the output will be triggered immediately by the leading edge of the first pulse. It is therefore easy to see the links as setting the output to be triggered by the first leading edge (0), or the second (1), the third (2) and so on, up to the 33rd (all). The count is set as a binary value, e.g. a count often would

## COMPONENTS

Approx. Cost  
Guidance Only

£35

excl. case & batts

### Sensor Board

**Resistors**  
R1 to R3, R5 100k (4 off)  
R4, R9, R14, R15 10M (4 off)  
R6, R7, R10 to R12 1M (5 off)  
R8 180k  
R13 680k  
All 0-6W 1% metal film

**Capacitors**  
C1 10µ radial elect. 10V  
C2 22n polyester film, 5mm pitch  
C3, C5 3µ3 radial elect. 10V (2 off)  
C4 4n7 polyester film, 5mm pitch  
C6 470n polyester film, 5mm pitch  
C7 2n2 polyester film, 5mm pitch  
C8 1000µ radial elect. 16V  
C9 100n polyester film, 5mm pitch

**Semiconductors**  
IC1 IRA-E700STO PIR sensor  
IC2 to IC5 ICL7611 op.amp (4 off)  
IC6 40107 CMOS dual 2-input NAND gate, open-drain output

**Miscellaneous**  
S1 see Counter board

Printed circuit board, available from the *EPE PCB Service*, code 452 (Sensor); 8-pin d.i.l. socket (5 off); battery holder for 4 x AAA cells; connector clip for battery holder.

See  
**SHOP  
TALK**  
page

### Counter Board

**Resistors**  
R1 10k  
R2, R7 1k (2 off)  
R3 100k  
R4 10M  
R5 1M  
R6 100Ω  
All 0-6W 1% metal film.

**Capacitors**  
C1 1n polyester, 5mm pitch  
C2, C3 1µ polyester, 5mm pitch (2 off)  
C4, C6 1000µ radial elect. 16V (2 off)  
C5 100n polyester, 5mm pitch

**Semiconductors**  
D1 yellow i.e.d., 2mA  
D2, D4 1N4001 rectifier diode (2 off)  
D3 red i.e.d., 2mA  
TR1 1RF520 power MOSFET  
IC1 4093B quad Schmitt NAND gate  
IC2 40107 dual 2-input NAND gate, open-drain output  
IC3 4024B 7-stage ripple counter  
IC4 4068B 8-input NAND gate

**Miscellaneous**  
S1, S2 sub-min d.p.d.t. slide switch (2 off) (see text)  
WD1 piezo sounder, 12V (see text)

Printed circuit board, available from the *EPE PCB Service*, code 453 (Counter); 8-pin d.i.l. socket; 14-pin d.i.l. socket (3 off); 0-1in pitch pin strip (3 x 5 pins); 0-1in pitch connector links (5 off); battery holder for 6 x AA cells; connector clip for battery holder; ABS plastic case, 158mm x 95mm x 54mm; connecting wire; solder, etc.



require links 2(2) and 4(8) to be on, as shown in Fig.4.

Power for this part of the circuit is supplied by a separate 9V battery pack of six AA cells that can supply adequate current for the siren used. Diode D2, resistor R6 and capacitor C4 reduce the effect of output current demands on the controlling part of the circuit. The overall power used depends on frequency of input and output activation, but the standby current is virtually zero since this is an all-CMOS circuit.

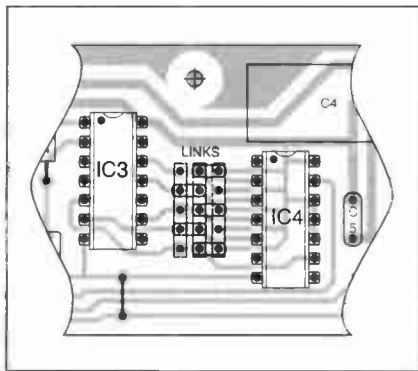


Fig.4. Setting the "count" using the bridging links

### Practical Considerations

The first of the author's prototype units used two small printed circuit boards, which were mounted on aluminium plates cut to fit the moulded slots in the preferred case. Whilst successful, this led to a lot of cutting and drilling and untidy wiring, which was time consuming to carry out and made access to the pulse count links awkward.

For the two subsequent units, one of the boards was made wide enough to fit directly into moulded slots in the case and the

second was attached to it. They were placed "back-to-back" with their copper sides facing each other. The connections between the boards were made with wires soldered to pads on the copper sides, and the connections for the sensor circuit battery were "carried through" the pulse counter board so that all the connections were made to the rear of the assembly. This made for simple construction with tidier wiring, which in turn makes link adjustment easier.

### Construction

Component positioning and track layout details for the two printed circuit boards (p.c.b.s) for the Portable Mini Alarm are shown in Fig.5 (Sensor) and Fig.6 (Counter). These boards are available from the *EPE PCB Service*, codes 452 and 453 respectively.

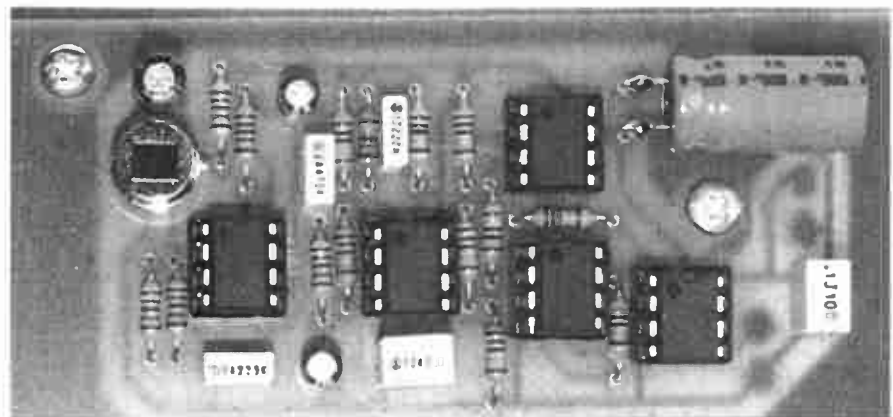
Starting construction with the Sensor board, it may be advisable to first use this as an aid to mark the position for the case

hole through which the sensor will "look". Note that, circuit-wise, both boards have some very high impedance areas, so it is essential to keep them clean during the construction process. A good surgical-style hand scrubbing before starting is probably advisable.

Next, all the components can be fitted as shown, preferably using dual-in-line (d.i.l.) sockets for IC2 to IC5. Care should be taken with the polarities of the three electrolytic capacitors. Capacitor C8 is laid flat on the board to give a low profile and a drop of adhesive will help to keep it in place.

The four external connections are taken from solder pads on the copper side of the board, although constructors wishing to use this design in other projects may drill holes through these pads for leads or solder pins if they wish.

Sensor IC1 is fitted so that its top is about 10mm from the side of the case when the board is in place.



Sensor board component layout. Note the electrolytic capacitor is mounted on its side.

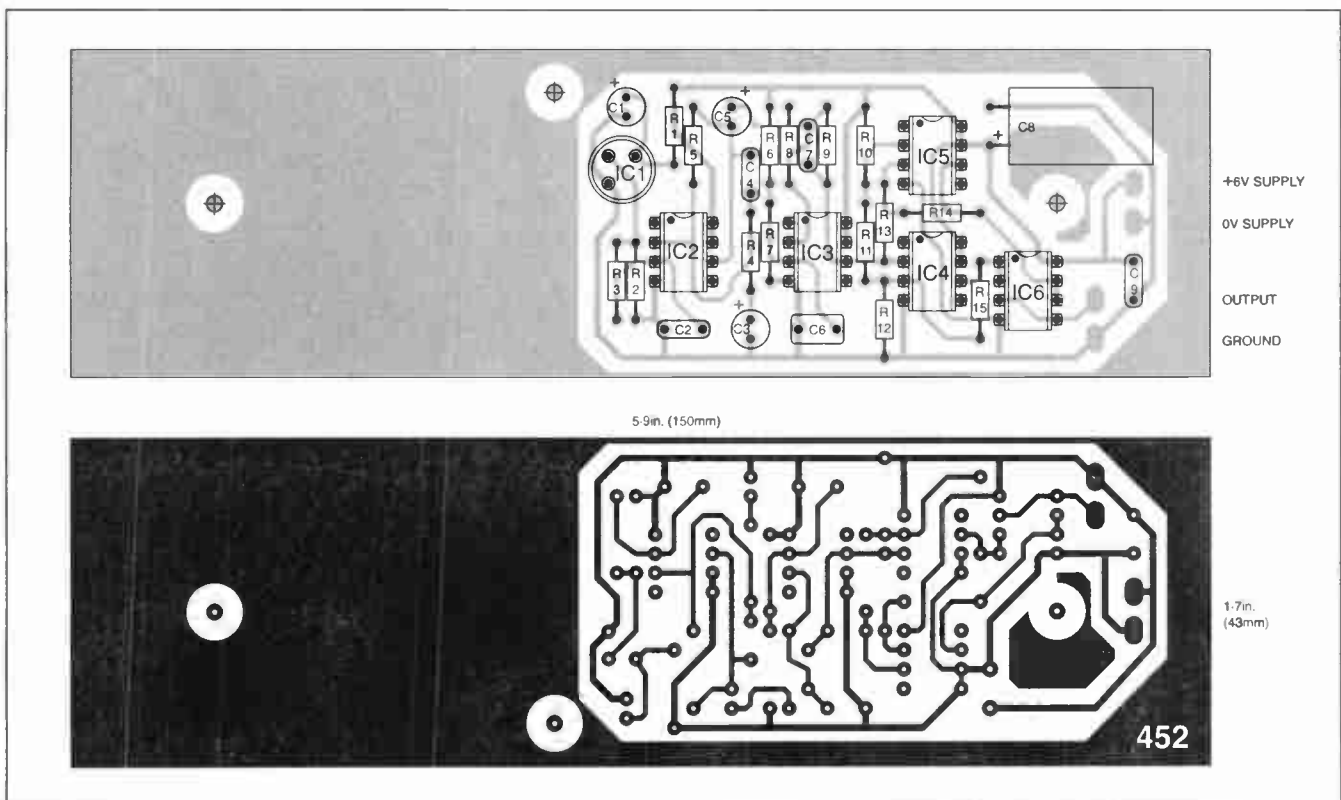


Fig.5. Printed circuit board component layout and full-size underside copper foil master for the Sensor section of the Portable Mini Alarm.

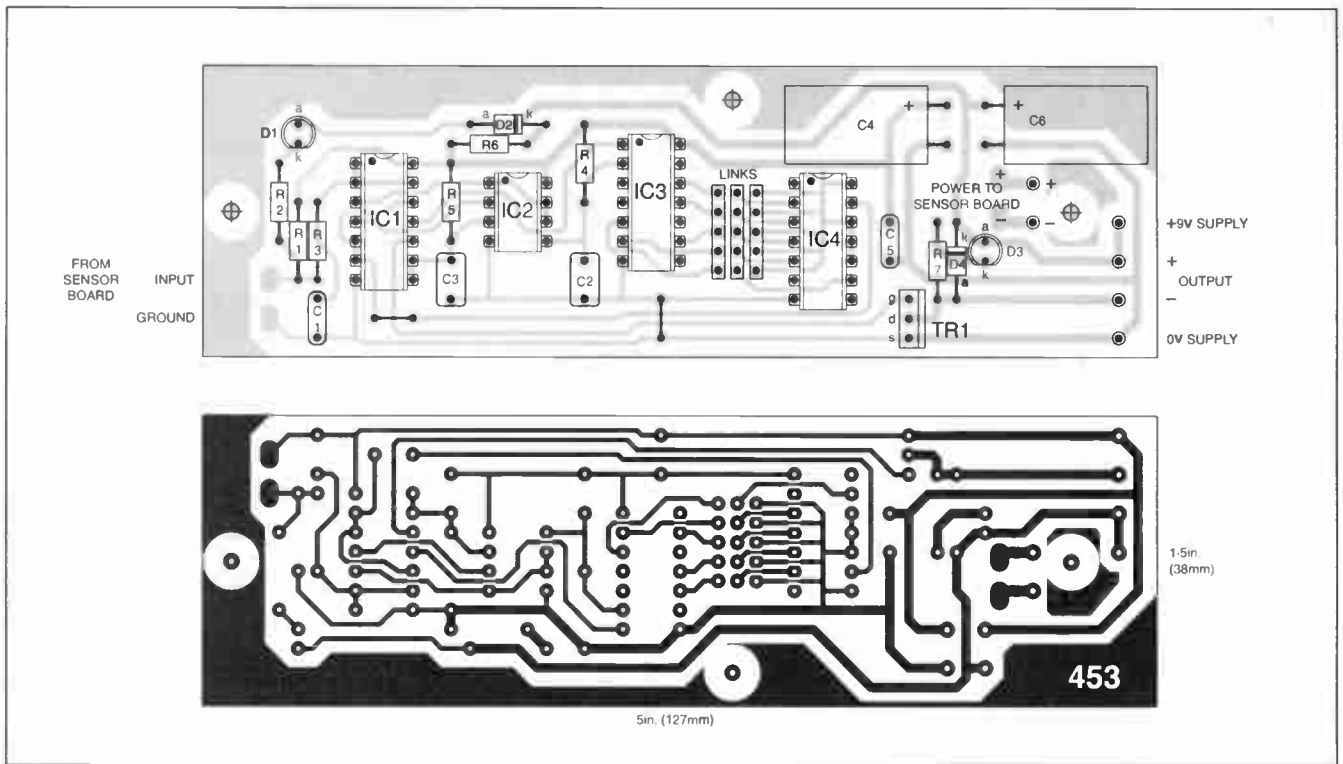


Fig. 6. Pulse Counter printed circuit board component layout and full-size underside copper foil track master pattern for the Portable Mini Alarm. The completed Pulse Counter board is shown below bolted to the Sensor p.c.b.

### Counter Board

The Counter board can be constructed in a similar way. Before starting it would be as well to ensure that it fits into the slots in the intended case. Some filing may be required for a good fit.

There are two links on this board and it has six solder pins for the external connections. The two l.e.d.s (D1 and D3) are shown as mounted on the board for clarity, but in the prototype they are connected by short leads so that they can be fitted to the case. As before, d.i.l. sockets are recommended for the i.c.s, and the two large electrolytic capacitors C4 and C6 are positioned horizontally to reduce the height profile.

The pins for the count selection links are supplied in strips that are cut to length before fitting. They fit into place quite firmly so there should be no alignment problems. Soldering them should be done with extra care, however, as track clearances here are small.

The suggested piezo sounder draws less than a couple of hundred milliamps so output transistor TR1 is not fitted with a heat-sink. As it is either fully on or off it should dissipate very little heat anyway.

Treat all the i.c.s as CMOS devices and discharge static electricity from your body by touching a grounded (earthed) item of equipment before handling them.

### Testing

To test the Sensor board, a supply of 6V should be applied, with a separate supply powering an output indicator as shown in Fig. 7. Sensor IC1 must be shielded in some way to limit its "field of vision" or it will probably never settle into the quiescent state. A short piece of opaque tubing can be placed over it and a hand waved in front of this to check operation.



When switched on, it is likely that the output will remain active continuously for about 30 seconds as capacitors C3 and C5 charge and the circuit settles to its quiescent state. Thereafter, if a hand waved in front of sensor IC1 produces output pulses it is probably working properly.

The output of IC2 should settle to a low voltage equal to the output from IC1. IC3's output should settle to half the supply voltage and when quiescent the outputs of IC4 and IC5 should both be low.

The supply voltage for this circuit must be exceptionally stable so it may be best to use a 6V battery to test it. The supply drain current should be about 50µA to 60µA.

### Test Count

To test the Counter board, the links must be fitted first. The count is in binary, with the least significant bit at the top. If a link is fitted on the left (on) at the fourth position down, and all the others to the right (off), this should trigger the output after eight input pulses.

A microswitch can be used to impulse the circuit, using normally open contacts connected directly across the input. If it appears to trigger prematurely this may be due to switch bounce so should not be taken too seriously.

If this circuit appears faulty, it might be worth setting all the links to Off. This will put some of the outputs into a known state, e.g. IC4 output should be low so IC1c and IC1b outputs should be high. An input pulse should then take IC1a output high, so the output of IC1d should go high and the

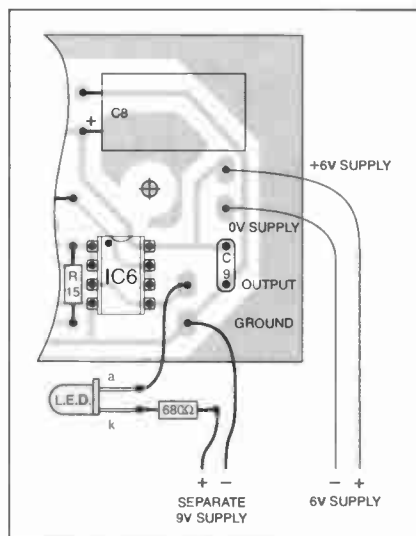


Fig. 7. Testing the Sensor board using two separate power supplies.

final output at transistor TR1 should become active.

Unfortunately, it is difficult to monitor the voltages across capacitors C2 and C3 due to the very high values of resistors R4 and R5. Even a digital voltmeter (DVM) tends to load these points to some extent.

### Interconnection

Connections between and to the two boards are shown in Fig.8. After making the four connections between them on the copper side and attaching the l.e.d. leads, the two boards are bolted together using M3 screws with a couple of nuts on each between the boards to act as spacers. A final test of the completed two-board assembly might be advisable at this point.

The remaining external connections are then all made to the Counter board, from where they can be easily routed to their destinations. The wires should be long enough to allow the boards to be lifted up for link adjustment.

Two small slide switches were used in the prototype. Switch S1 turns the power to both boards on and off. Switch S2 disables the sounder during setting up and testing.

Some care is required to ensure everything fits together without fouling. A single aluminium plate forms a battery compartment to hold both battery packs, a 6V pack of AAA cells for the Sensor board and a 9V pack of AA cells for the Counter board.

The hole for the sensor to "look" through should be drilled carefully in the case. Its diameter will set the approximate field of view, the wider it is, the wider the angle it will cover. It might even be possible to use a horizontal oval hole to provide fan-shaped coverage, though this has not been tried. The holes on the prototypes are all around 8mm in diameter.

Some plastic foam stops the battery packs from moving when the case cover is screwed into place and a small strip of foam presses the boards into place to maintain alignment of the sensor with its hole.

### Warning Device

There are various piezo sirens available that can be used with this project. Most are for 12V operation but make plenty of noise from 6V upwards, and the racket produced is quite stunning for their size.

The horn-shaped type seen in the photos comes with a small mounting bracket. This was discarded, and the front of the unit was prised off after removing four screws. It does not come off completely as it is attached to a small inner circuit board by two leads.

However, with care, the unit could then be bolted firmly to the case with a couple of M2.5 screws before replacing the front. It would be easier to use one of the cube-shaped sirens with two mounting lugs, but it has to be said that the units look good with the little black horns on top!

### Further Options

Options for the construction and use of this project are many. The pulse counter is not essential; if it is not required, other output circuits may easily be used with the sensor.

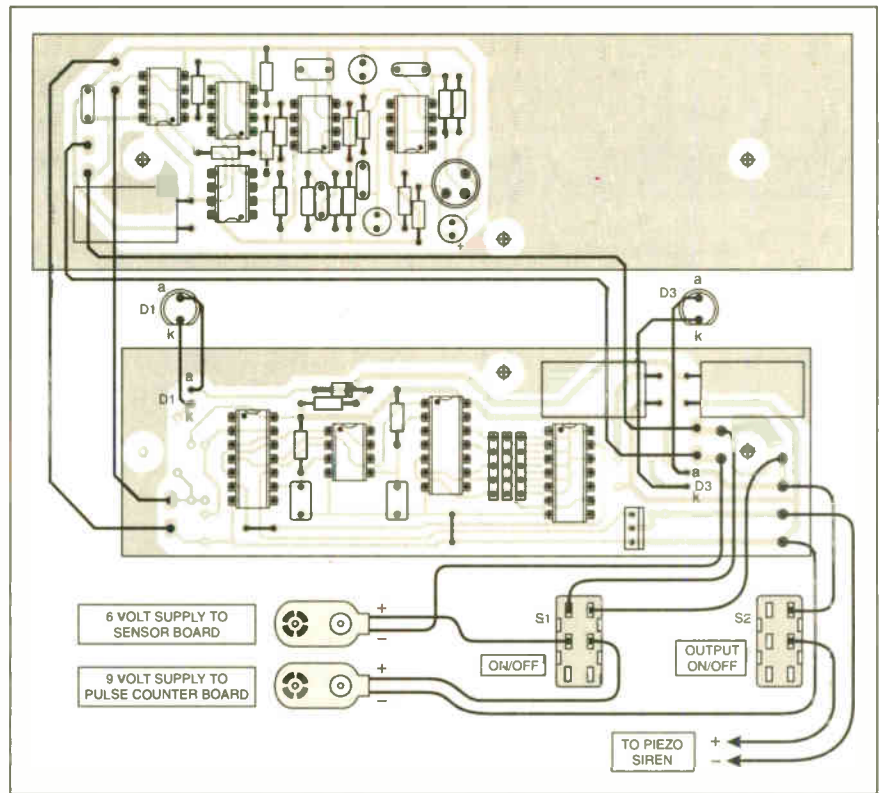


Fig.8. Interwiring between the Sensor and Counter p.c.b.s and off-board components. All wires should be long enough to allow the Counter board to be raised from its case slots to give easy link adjustment.

The alarm period can be adjusted by changing the value of resistor R5, up to the period set by R4 and C2, which could also be lengthened or shortened by changing the value of R4. The l.e.d.s may be omitted for more covert applications.

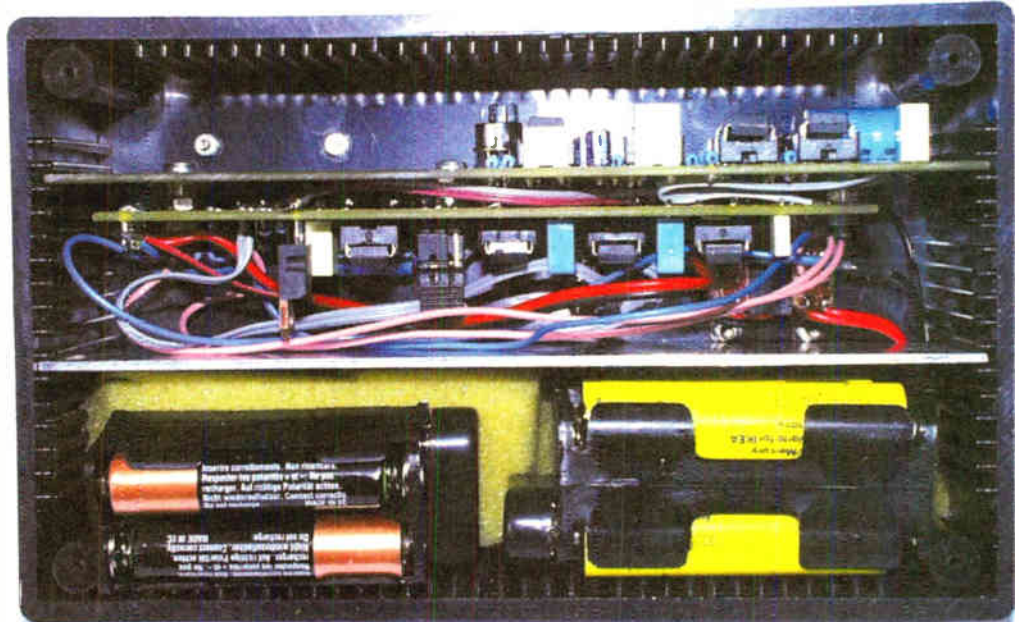
Just about any form of case may be used. How about building one into a box file, with the sensor behind the hole in the rear that some of these files have? Or an imitation book, or video cassette case? The possibilities are endless.

The long-term operation from batteries makes it ideal for protecting outbuildings where mains power is not available. A higher-powered siren could be used, perhaps

with a beacon, or it could switch on a battery powered radio link to alert someone in a nearby house. For higher-powered outputs the pulse counter can have a 12V supply.

The pulse counting is particularly useful in situations where there may be innocent passers-by. The author has used a similar circuit for some years to protect a garage door facing onto a footpath.

Another possible use is in pet training. One of the author's cats is occasionally a little reluctant to go outside to use toilet facilities provided, and one of these units placed by spots used for such misbehaviour has proved an effective reminder – especially when someone is around to hear it! □



The circuit boards and battery "compartment" panel slotted into the plastic case. Some foam stops the battery pack from moving when the lid is screwed into place.

## TETRA AT BAPCO SHOW

**There's a distinct lack of communication about the Essential Services TETRA system, as Barry Fox recently found at the BAPCO exhibition.**

**B**APCO – the British Public Safety Communications exhibition – held at the Islington Design Centre in late April might more accurately have been billed as the TETRA Show.

TETRA, Terrestrial Trunked Radio, is the communication system developed as an international standard for the “blue light” emergency services – police, ambulance and fire brigades. TETRA works like a GSM cellphone network, but at different frequencies close to the UHF TV band. Because the network is being built by the Airwave division of O<sub>2</sub> under government contract, a fair degree of secrecy shrouds the project. Much of this secrecy is unnecessary because the TETRA standards are public.

Motorola, which is providing the infrastructure, refers any awkward question to Airwave. So does Nokia which, along with Motorola, is providing the handsets. But Airwave makes little attempt at proactive communication with the general press and public, and is evasive. This has created a fertile breeding ground for conspiracy theories on TETRA's proven and unproven side-effects.

### TV Interference

It is proven fact that TETRA can cause interference to any TV system that uses an amplifier, because non-linearity causes inter-modulation and dumps spurious signals into the TV band. The Radio-communications Agency, now part of Ofcom, has published a damning report but done nothing to publicise it. Neither have Airwave or Motorola. Transmitters are switched on without announcement. So viewers who suffer mysterious, sudden interference do not identify the cause as a new TETRA transmitter, and do not know the cure is a band-pass filter upstream of any amplifier.

The new base stations needed for TETRA upset environmental groups on purely aesthetic grounds.

TETRA uses a 17-65Hz modulation pattern which has led anti-TETRA groups to accuse the system of using potentially dangerous pulsed r.f. This has stirred health concerns among the public and the emergency service officers who will be carrying and using the handsets.

Although the British network is nearly half finished, there is still no agreement on providing cover on the London Underground by the installation of leaky feeders down the tunnel walls. So TETRA radios will not work underground and any police, fire or ambulance operation on the Tube must wait for Underground staff to be ready with their

own radios. So TETRA has already got a bad name and it is getting worse, with uninformed reporting.

### Rejoicing in Rejection

The *West Sussex Observer* recently reported local rejoicing because an Airwave mast had been installed and then switched off after protests. The paper stated as uncontested fact that “49 people were suffering symptoms and headaches and nosebleeds that stopped on the day”!

The BAPCO show gave a taste of the message that Airwave could and should be getting across; but BAPCO also showed there is still no coherent strategy to inform the press and public about the real practical benefits of the new system. The most down-to-earth information came from police officers visiting the exhibition to catch up on new developments.

Three-quarters of all the UK's fifty-plus police forces are now signed up to use TETRA. Negotiations are in place to put leaky feeders through underground tunnels, but no-one can yet agree who will foot the bill. The Metropolitan Police have just ordered 30,000 handsets, costing between £400 and £500 each.

### Encryption

Encryption stops criminals eavesdropping on police calls. “Until now we have been using UHF and VHF radios”, a senior ranking police officer told me. “Anyone can buy a scanner and listen in, or more likely they throw a brick through a shop window and grab one. We know they are listening to us because when they raid phone boxes to steal the cash, they follow a clear road route – until we radio ahead to catch them. Then they change route. When there is a robbery, someone just listens to our radio traffic with a scanner so they know how long they have got to get clear”.

“When people protest about the installation of a TETRA mast, they don't realise that if we haven't got radio cover, we can't send a police officer into a crime scene. If there's a man wielding an axe in a pub, would you want to go in on your own, without a radio to call for back-up? More and more, police on the beat are relying on cellphones to keep in touch because their police radios don't work as well”.

Under new health and safety regulations the emergency services are no longer immune from prosecution if they put staff at unnecessary risk.

The TETRA handset can be used like a cell phone, to make ordinary calls to a

fixed phone. But more often, the TETRA handsets are set up to make “group calls”, which are like conference calls on a cell phone, but involving up to thirty officers. Once the group call is set up, all members of the group simply press to talk, with everyone able to hear each other, but with no fear of eavesdropping.

Some of the latest phones have a GPS chip built in so that the officer's location can be automatically tracked.

When a member of the public makes a 999 call, the public phone system automatically over-rides any block the subscriber has put on CLI (calling line identification) and this is displayed on a screen, to speed the dispatch of a TETRA-equipped fire engine, ambulance or squad car.

### Picture Messaging

The latest TETRA handsets look like slightly chunky cell phones with picture messaging screens. This lets a police station transmit mug shots of criminals to officers on the beat; it also allows police on the beat to send pictures of suspects back to the station, so that identities can be checked, without the need for arrest, and the consequent risk of legal action for wrongful arrest.

TETRA puts a 36Kbps data stream on each frequency channel, known in TETRA parlance as a “base radio”. Total transmission power per base radio channel is 25 watts.

The base radio stream is divided into four 9Kbps time slots; one is a control channel and three are used for speech or data. Each time slot can be used for speech or data, or a mixture of both. This means that data transmission is slow, at best 9Kbps, and at BAPCO Motorola's demonstration of a 130 × 130 pixel picture file of around 11K bytes, took 28 seconds to transmit.

“But that's a lot quicker than going back to the police station to pick up a photo print”, reminded a police officer.

### Omenous?

Will O<sub>2</sub> Airwave now be more proactive at telling the public what TETRA can mean for the man in the street – and proactively warning about TV interference so that homes which suddenly suffer analogue herring bone patterns or digital break-up will know what is causing it?

The omens are not good.

Airwave still has no plans to proactively warn the public over TV interference – or to educate the public on what they stand to gain from TETRA.

# Clever Power Saving

By Barry Fox

AS the screens on mobile phones and PDAs get bigger and more colourful, they soak up more power and flatten batteries quicker. Matsushita (Panasonic) has a startlingly simple solution (patent GB 2 384 400). Current screens emulate paper by switching on most of the l.c.d. pixels to give a white background, and switching off a few pixels to overlay black text.

But, as Panasonic point out, when people are talking with a phone to their ear, they are not looking at the display. So Panasonic reverses the display, like a photographic negative, when the user is talking. A few white "on" pixels display text on an "off" black background. So power is saved. Reversal is automatic when a call connects, or an infra-red sensor detects when the phone is held to an ear.

## ICEPIC3

R.F. SOLUTIONS have introduced ICEPIC3, a universal in-circuit emulator for PIC microcontrollers. The system provides full-speed, up 40MHz, low voltage emulation for the PIC18, PIC16 and PIC12 series. Sophisticated, unlimited, precision breakpoints allow problems to be resolved quickly and efficiently.

ICEPIC3 operates within MPLAB and is Microchip Assembler and C compatible. It comprises a main board, PC software, user manual, power supply and USB cable for connection to laptop and desktop PCs. Optional plug-in trace boards are available to provide real-time analysis.

For more information contact R.F. Solutions, Dept EPE, Unit 21, Cliffe Industrial Estate, South Street, Lewes, E.Sussex BN8 6JL. Tel 01273 898000. Fax: 01273 480661.

Email: [sales@rfsolutions.co.uk](mailto:sales@rfsolutions.co.uk)

Web: [www.rfsolutions.co.uk](http://www.rfsolutions.co.uk)

## SPOT-ON VALUE

THE Precision Resistor Company is introducing a packaged group of seven selected resistor values for use in the verification and adjustment of the resistance function of digital multimeters. Undoubtedly they will also find beneficial use in many other applications too where precision is required. The resistance values are 1, 10, 100, 1k, 10k, 100k and 1M ohms, with a rated tolerance of 0.01% for values above 10 ohms and 0.02% for the 1 ohm and 10 ohm units. For convenience, the resistors are contained in a plastic case with leads extending through the sides. The quoted price is US\$63.90.

For more information, contact Precision Resistors Company, 10601 75th Street North, Largo, FL 33777-1421, USA.

Tel: 727 541 5771. Fax 727 546 9515.

Email: [prc@precisionresistor.com](mailto:prc@precisionresistor.com)

Web: [precisionresistor.com](http://precisionresistor.com)

## AUDIO ON ICE

DENSION Audio Systems launched their ice>Link:iPod in-car interface at the recent *Sunday Times* Motor Show 2004. The interface enables owners of the Apple iPod to control their iPod from their car audio systems, working in place of a traditional in-car CD changer and vastly expanding the amount of music that car owners have available to them.

Lee Harris, Head of Business Development at Dension commented: "Mass storage MP3 devices are the future of in-car entertainment. In producing the iPod, Apple has created a product that is as big a change to the audio industry as the Sony Walkman was in the 1970s. The ice>Link:iPod spreads this change to the car audio market by making the Apple iPod easy to integrate to the vehicle entertainment environment.

The ice>Link:iPod is priced from £79.99 for aftermarket car audio systems and £129.99 for factory-fit systems. It is available from car audio specialists and iPod accessory retailers.

For more information browse [www.dension.com](http://www.dension.com) and [www.progressiveAV.com](http://www.progressiveAV.com).

## Matrixed E-Blocks

MATRIX Multimedia, whose excellent PIC-related CD ROMs we sell, have introduced a new E-blocks range which provides rapid developments of electronic systems.

The new range consists of more than 50 individual hardware and software items which are designed to save development time. At the core of this range is a suite of 17 circuit blocks which snap together to form complete electronic systems.

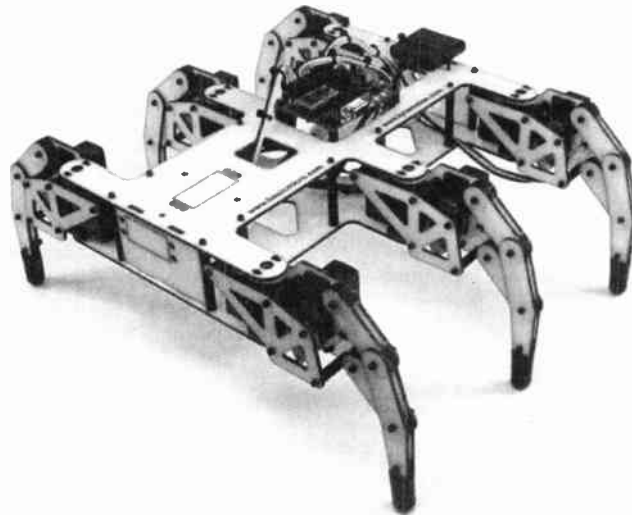
Accompanying high-level software includes routines to control each block and the resulting combination makes product development extremely rapid and extremely easy.

Matrix Multimedia was founded 10 years ago with the aim of providing high quality educational resources that make education easier. The company provides technical education resources to schools, colleges and universities all over the world.

For more information contact Matrix Multimedia Ltd, Dept EPE, The Factory, 23 Emscote Street South, Halifax HX1 3AN. Tel: 0870 700 1831.

Web: [www.matrixmultimedia.co.uk](http://www.matrixmultimedia.co.uk)

## Robots and Movies



TOTAL ROBOTS is a company specialising in all sorts of aspects to do with robotics. Their latest press release highlights a couple of such products.

The Extreme Hexapod Walker 2 looks as though it offers splendid entertainment. The EH2 Walker Kit is a 12-servo hexapod featuring two degrees of freedom (DOF) per leg. The robot can walk forwards or backwards and turn on-the-spot left or right with variable speed; it can even do gradual turns!

The advanced leg design features low power consumption when the legs are standing. The combo kits include everything needed to make an operational robot, although the chassis and servos are available separately for those who want to use their own electronics. There are video clips of the EH2 in action, via the website given below.

Also of interest is the new CAMT5 wireless CMOS "pin-hole" colour video camera, which offers excellent image quality from a unit measuring only 30mm x 30mm x 27mm. The camera transmits at 2.4GHz and is ideal for remote robots, including the EH2, model cars and boats, kites and model airships, and video surveillance systems etc.

Image resolution is 512 x 628 pixels. Small d.i.l. switches allow for the selection of up to eight different frequency levels which, combined with the antennae on the p.c.b., enables data transmission to a range of approximately 150m when in open ground with no obstacles. The CAMT5 is PAL and CMH-110 compliant.

For further information on these two products, and others available, contact Total Robots, either via 0208 823 9220 or [www.totalrobots.com](http://www.totalrobots.com).

## Unstandardised Standards

**When it comes to standards, choice is not always a good thing.  
Andy Emmerson examines the confusion surrounding digital television.**

**W**HERE digital video is concerned, everybody's in favour of standards. So popular are standards that the attitude is the more the merrier, which is precisely not what we want. If the present free-for-all continues consumers will be the loser, having to pay for multiple decoders to watch video programming from differing sources – or opting to stuff the idea altogether.

### Battle of the Eyeballs

There are two problems, a battle royal for setting standards of the next-generation of streaming video watched on computer screens, and the risk that the next digital TV you buy will not receive all broadcast services. As usual, vested commercial interests are fighting it out over the "battle of the eyeballs" and whoever wins out, you and I will be the losers. Let's examine the two issues separately.

Once upon a time computers were computers and televisions were televisions. These days the distinction is less clear, with Bill Gates and others trying to persuade us to accept a "media center" PC in the living room as a universal entertainment device. Equipped with cards that tune in terrestrial radio and television, handle cable and satellite signals and also pump in video-on-demand from the Internet, these media-enhanced PCs will hook up to hi-fi speakers and large-screen video displays to become the focal point of the living room. That's the notion anyway.

It stands a chance of succeeding of course. Just as electronic programme guides made it easier to select your viewing choices, the Online Spotlight feature of Windows XP Media Center computers will give users an easy way to find a vast range of programming from a vast and diverse number of content providers. How other flavours of computer will see this content is less clear.

### Uncopyable

Shoving vast amounts of data across the Internet calls for more efficient means of encoding and decoding (using clever compression systems) and two standards are being proposed for distributing content in this way. Microsoft offers its Windows Media Video 9 solution (WM9 for short), which was launched in early 2003 after a development binge costing an estimated \$500 million.

Microsoft has invested heavily in digital rights management (DRM) technology, making programming viewable but theoretically uncopyable, to the delight of copyright owners. For this and other reasons Microsoft has won a lot of friends among rights owners.

WM9 is a proprietary offering, however, and proponents of open standards prefer the rival solution of AVC. AVC, standing for Advanced Video Coding, is also known as MPEG-4/part 10 or H.264.

It builds on the experience gained from video broadcasting over telephone lines and local area networks, and like WM9 offers something like three times the compression efficiency of current MPEG-2 coding. As an open standard, AVC appeals to broadcasters and military users far more than the proprietary WM9 solution.

### Global Dominance

Which will predominate is far from clear, although it's obvious the question has nothing to do with which solution is technically better. Being an open standard, AVC makes best sense for us users, but the ability to keep tight control over what users do with material they download will appeal to content providers. Factor in also the global dominance of Microsoft Windows and you can guess which standard I think will win. I'm not convinced it's good news for users, though.

Coding standards for streaming digital content across networks are one thing but what about the other digital divide, digital television reception? The government is doing its damndest to convince us digital television (terrestrial and satellite) is good for us, but thanks to the regulatory body Ofcom's "light touch" style of regulation, is doing nothing to make sure we can watch the new digital programmes. To receive certain free-to-air programming from the *Astra* satellite you need a reception card for your set-top box that is no longer available; instead you are forced to subscribe to one of the Sky packages.

Terrestrial digital television is in a mess too: although its name Freeview implies there is no charge for viewing, the regulator has allowed a company called TopUp TV to offer paid-for programmes that very few people can watch. Unless your set-top box has a viewing card slot (very few do), you will be unable to pay for (and hence see) the programmes. Worse, shoehorning these new channels into the electronic programme guide has forced some of the established channels out of the menu on existing customers' boxes, blocking them from viewing them. Is this joined up thinking?

### Television Without Frontiers?

According to Philip Laven, Technical Director of the European Broadcasting Union, this is only a minor symptom of a far worse muddle, however. Digital television in Europe offered a real opportunity to adopt a single system and avoid the penalties of multiple standards.

Consumers, manufacturers and broadcasters all stood to gain from this vision of "television without frontiers". But has it happened? Of course not. There are now more than 2,000 digital satellite TV services using fully agreed Digital Video Broadcasting (DVB) standards in Europe, plus many more planned via satellite, cable and terrestrial, he states. That's the good news.

"Regrettably, to receive all 2,000 satellite services, you would need many different digital TV set-top boxes. The reality is that there is a serious problem with interoperability. How could this happen when the 1995 Directive on TV Standards insists on common transmission standards for digital television?" he asks.

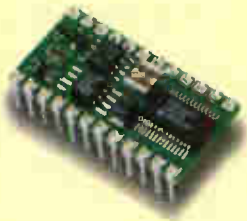
Although Article 2 of Directive 95/47/EC states that all television services transmitted to viewers in the Community, whether by cable, satellite or terrestrial means shall . . . if they are fully digital, use a transmission system which has been standardized by a recognized European standardisation body, this does not guarantee that consumers will be able to buy digital TV receivers that will be able to receive all broadcast services. This is because the Directive's narrow definition of "transmission system" excludes many other important elements, such as Conditional Access, Electronic Programme Guides and Applications Programming Interfaces.

### Incompatible

A significant portion of the blame is for pay-TV operators, some of which choose to use incompatible proprietary standards to lock in their customers and prevent them from changing to competing services. Regulators around Europe chose not to intervene for fear of discouraging investment in digital television through "over-regulation" of a fledgling industry.

What Laven calls the noble concept of "television without frontiers" has been hampered by equipment specified by a particular service provider that typically cannot be used to receive services from other sources. Regulators are cautious about imposing standards and the EC is reluctant to get involved, preferring to encourage players to come to voluntary agreements, even though there's no evidence to suggest that self-regulation will be successful".

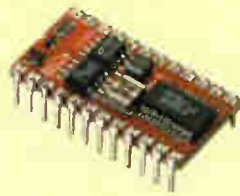
The moral is obvious: open markets benefit everybody and broadcasters should compete on the basis of their services, rather than using technological barriers to limit consumers' freedom of choice. Laven sums up: "Digital television is far too important to be left solely to the uncertainties of the market forces. Regulators in Europe must ensure that the benefits of digital TV are available to all consumers."



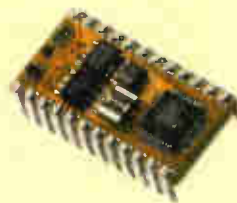
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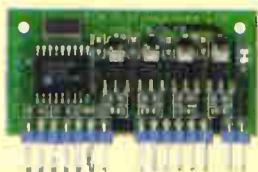


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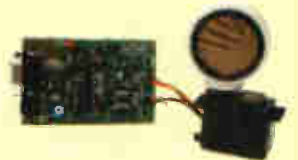
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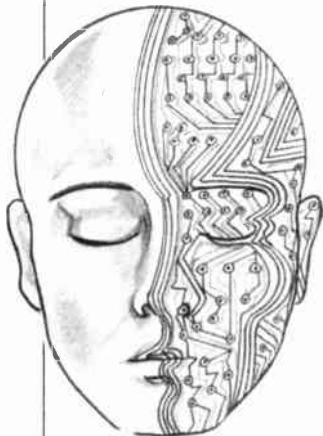


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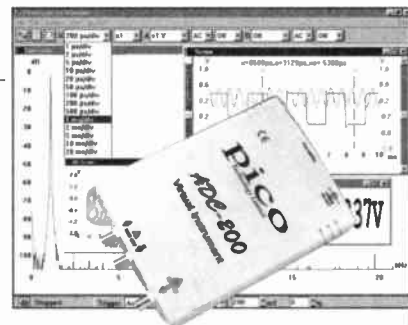
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## Multiple Range Ammeter – Current Affairs

A SINGLE shunt is used in this ammeter, whose circuit diagram is shown in Fig.1. It uses a 50mV = 50A shunt (1mV = 1A). Meter ME2 is a 50mV full scale voltmeter with an internal resistance of 50kΩ. This meter measures the millivolt output of IC1. Meter ME1 simply keeps track of the input supply voltage.

When the 20A range is used with 20A applied from a power supply to an appropriate load, there will be a 20mV drop across the shunt, R8. Thus 20mV is applied to R4, a 1kΩ resistor.

Since IC1 pin 2 is at virtual ground, 20μA of current will flow through R4 on the non-inverting input at pin 2. This causes an equal but opposing current from the output at IC1 pin 6 to flow through resistor R5 and back to pin 2. This current results in a voltage drop across R5 of 50mV (20μA × 2500Ω). This causes meter ME2 to read 50mV full scale, representing 20A. Thus 10A on this range would read half scale, or 25mV.

When switch S1 is set to the 5A range, a current flow of 5A would result in a 5mV voltage drop, causing 5μA to flow through R4 and an equal but opposite current through R6, causing a voltage of 50mV full scale deflection on meter ME2.

For 1A on this range the meter would read 10mV (1μA × 10000Ω). On the 2A range, when 2A is applied, 2mV is dropped across the shunt, causing a current of 2μA to flow through R4, and an opposing but equal current through R7, resulting in a 50mV reading on ME2 for full scale (2μA × 25000Ω). A current of 1A on this range would show as half scale or 25mV on ME2.

### Offset

An offset circuit is provided to zero meter ME2 after each range change. It comprises resistors R2 and R3, and adjustment potentiometer VR1, with its wiper connected to the -12V supply rail.

The circuit was developed to be placed in series between a Ham radio transceiver and a 13.6V meter-less test supply, as an aid to troubleshooting the gear. Both voltage and current were monitored using the power supply as a temporary battery replacement.

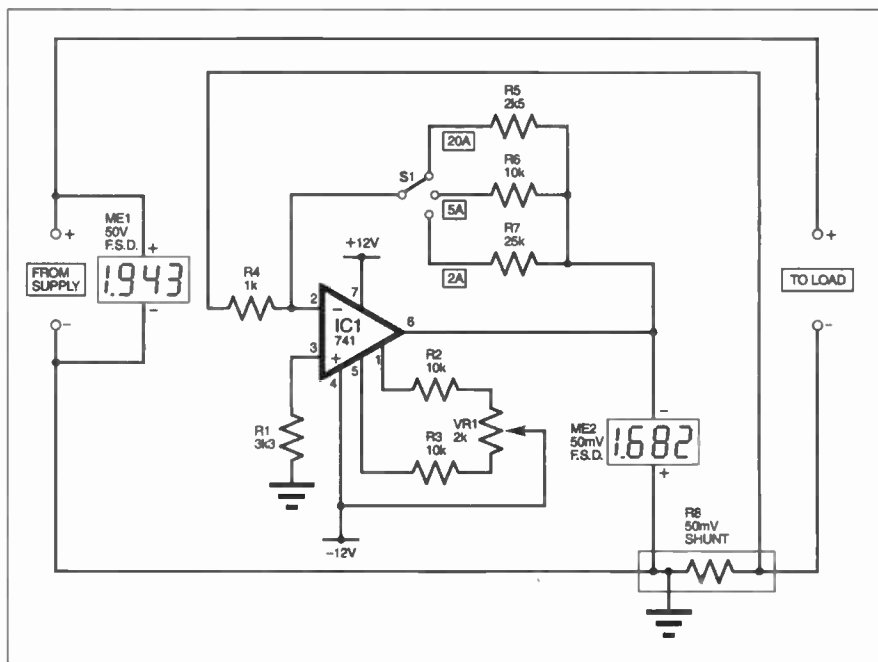


Fig.1. Circuit diagram for the Multiple Range Ammeter.

### Modification

To improve the usefulness of the offset, an s.p.d.t. normally-closed momentary switch, S2, could be added as shown in Fig.2. The switch allows meter ME2 to be zeroed during a current measurement, or after range change while measuring current (millivolts per amp).

To use the offset circuit with this addition, push switch S2 from the normally-closed position to the normally open position, use offset pot VR1 (main circuit) to zero the meter, then release S2. This momentary change of S2 to the open position will ground the input to R4, so that shunt current will not interfere with the offset adjustments.

Duane W. Clairmont,  
Conway, USA

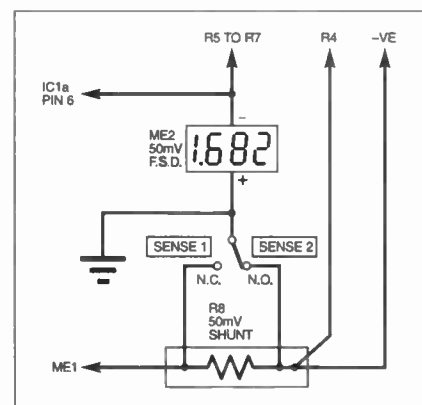


Fig.2. Offset meter ME2 zero circuit modification.



## Repeatable Logic Probe - Colourful Hi-Los

THE circuit in Fig.3 shows a way in which the output of a logic circuit can be monitored using a bicolour l.e.d., D1, with one colour indicating high logic and the other low logic. It does not load the source circuit, and it provides adequate power and controllability for matched intensities.

Several copies of this circuit were used by the author to monitor the logic output levels in a complex digital project. All were powered by the same 5V supply as used for the circuit under test.

The l.e.d. D1 has one end "suspended" half-way between the power rails by power op.amp IC1. Usually, potentiometer VR1 would be left as close to its mid-travel position as possible. In this instance, IC1 output pin 3 would, therefore, be providing a buffered half-rail supply voltage of about 2.5V which can source or sink current through the l.e.d. Although not used in the prototype, resistor R1 may be needed to limit the current through the l.e.d.s in D1 if their voltage limits are lower than the output from IC1.

The other end of the l.e.d.s is connected to the output of IC2, which swings high or low depending on the logic level at its input pin 3. IC2 is used in open-loop comparator mode. It is one section of an LMC6484 quad op.amp, a device chosen for its rail-to-rail capability.

The author thinks he first made this chip's acquaintance in something that John Becker designed (probably PICronos. Ed) and realised that the same device could be applied here. This was after trying and rejecting alternatives such as the CMOS 4050 buffer, which has insufficient output current available to satisfactorily drive an l.e.d.

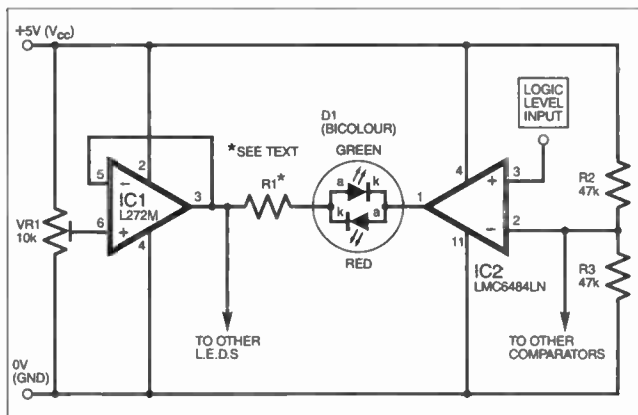


Fig.3. Repeatable Logic Probe circuit diagram.

Op.amp IC2 compares the logic level being sensed by using a mid-rail fixed voltage from the potential divider formed by resistors R2 and R3. The high impedance inputs of IC2 mean that it will not load the logic output to which it is attached, so full fan-out is still available. It is more complex and costly than a simple buffer, but the benefit of adequate l.e.d. light emission was thought to be worth it.

The l.e.d. is connected such that its red anode (a) goes to IC2 output at pin 1, giving red light when the input logic level is

high and pin 1 is thus also high. When the input logic level is low, the converse applies and the green half of the l.e.d. glows, its cathode (k) being attached to pin 1. A good glow is achieved by both of the l.e.d.s, thanks to the rail-to-rail output of IC2.

Many copies of this circuit can be implemented with just one copy of power op.amp IC1 (which can typically supply about 1A), and one copy of the reference level divider, R2 and R3. It is only necessary to have one rail-to-rail amplifier and one bicolour l.e.d. for each channel.

Note that IC1 is one half of a dual power amp, and IC2 is one quarter of a quad rail-to-rail op.amp. The unused sections of both i.c.s. may be similarly used.

The author's project for which this probe circuit was developed has 29 separate logic outputs, each with true and complement, 58 l.e.d.s in total (although this doesn't beat John's record for the most l.e.d.s, which is held by his PICronos L.E.D. Wall Clock of June/July '03, which had 174!). Power op.amp IC1 actually provides two amplifiers in one package and each half supplies 29 of the l.e.d.s. It just gets warm.

Due to circuit tolerances, there may be slight differences between red and green l.e.d.s. Preset VR1 may be tweaked slightly off-centre until the red and the green glows appear equally bright.

## Model Theatre Lighting Dimmer - A Shining Act

THE circuit diagram in Fig.4 shows the basis for the dimmers in a model theatre lighting system which uses torch bulbs as the light source. It is based around a 555 timer, IC1, driving a triac, SCR1.

All the dimmers share the one power supply and zero-crossing detector. Transformer T1 isolates the circuit from the a.c. mains and outputs approximately 12V a.c. This is rectified by diode D1 and smoothed by capacitors C1 and C2.

Transistors TR1 to TR3 comprise a zero-crossing detector whose output is inverted into a negative-going pulse by TR4. This pulse is fed to the trigger input of the 555 timer, IC1, which then starts its timing period at the beginning of each mains half cycle.

The length of this period is set by capacitor C3 and resistor R6, in conjunction with the

resistance provided by the two variable controls, VR1 and VR2.

The output from the timer is connected via current limiting resistor R7 to the base (b) of TR5, which inverts the pulses to trigger the triac via resistor R8. When the timing period is short, the triac is turned on early in each half cycle and the lights are bright. Conversely, when the timing period is longer, the lights are dim or turned off.

The main dimmer control is potentiometer VR1. Trimpot VR2 is used to set the range of VR1. With VR1 set for maximum resistance, VR2 is adjusted until the lights are just turned off. The lights should then be able to be faded over the full range by VR1.

Barry Freeman,  
Morphett Vale, Australia

Godfrey Manning,  
Edgware, Middx

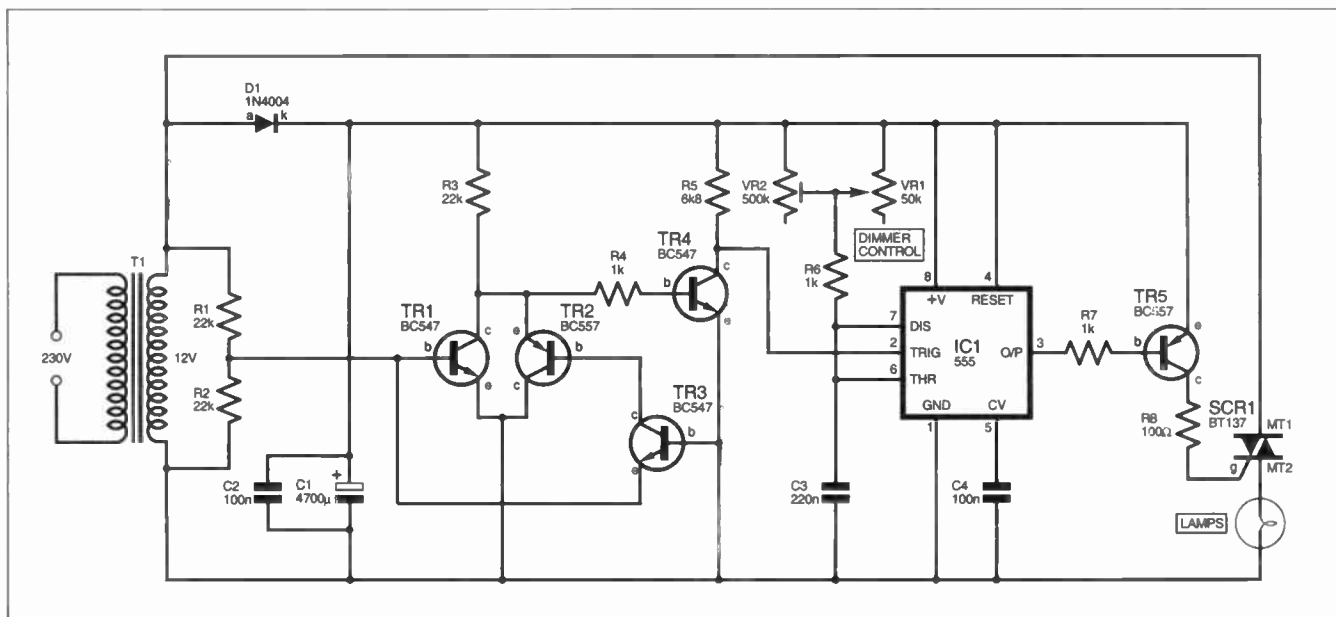


Fig.4. Circuit diagram for a Model Theatre Lighting Dimmer.

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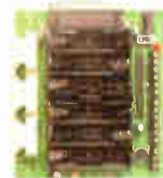
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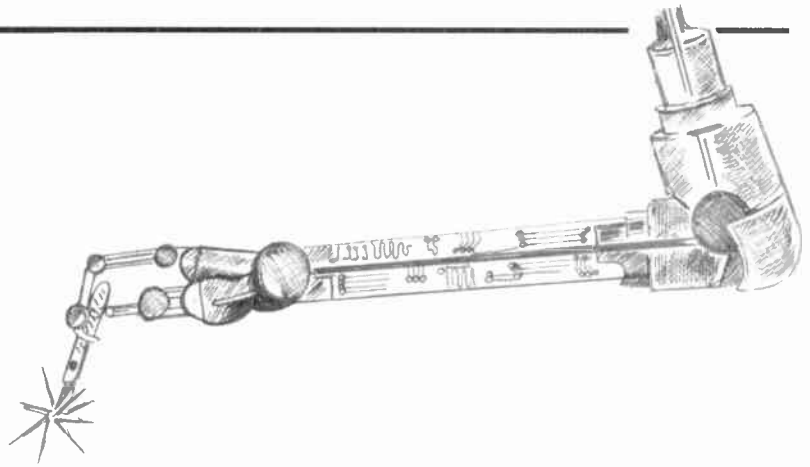
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# Circuit Surgery

Alan Winstanley and Ian Bell



This month, our brainstorming surgeons look at dual-rail power supplies and a reader's superglue experience

## Dual-Rails

*As a beginner in electronics, am I right in assuming that the expression "dual-rail power supply" (as used in Teach-In 2004 Part 3) can be translated as a "dual wire power supply" or is it more complicated? Thanks from Peter (posted in the EPE Chat Zone message board at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk))*

Supply voltages cause a lot of confusion amongst beginners in electronics. If you take a look at a typical car battery, for example, you will see that its terminals are usually marked as +12V and -12V.

However, as any young school student will know, the mathematical difference between the two values is in fact 24, so technically speaking 12V car batteries are marked incorrectly: they should be marked as "+12V" and "0V" for the positive and "negative" terminals, to give a correct value of 12V "potential difference" between the two terminals.

A dual-rail supply usually has both positive and a negative supply lines or "rails". This configuration is very common when op.amps are used, because the op.amp's output will often swing between positive and negative values, as demonstrated in the *Teach-In '04* series. Some op.amp devices are optimised for single supply rail use though.

The *Teach-In* article (January 2004 issue) showed how a simple dual-rail supply could be constructed from two 9V batteries. This arrangement is shown in Fig. 1.

Two 9V batteries are connected in series with terminals designated as A, B and C. If the junction of the two (B) is said to be 0V, then the dual-rail voltages are +9V (A) and -9V (C), so it is a  $\pm 9V$  supply. Cost is a key factor that makes the use of batteries for dual supplies somewhat impractical though.

## Brainstorm

It is always a matter of measuring voltages with respect to a reference point, and nearly always that reference point is the 0V rail. If we had a brainstorm and decided to call point A 0V instead, then B would be -9V and C would be -18V.

If we use a multimeter to take some test readings, then the readings would show the correct positive or negative voltages only if we connected the negative lead to the relevant reference point. It is the custom to measure circuit voltages with reference to 0V, except when measuring the voltage drop across a component.

Split supplies are rather rare amongst the project pages of *EPE* as many projects just require a simple d.c. supply, but looking back through some previous issues, I saw that the *Earth Resistivity Logger* (April and May '03) used a 9V battery to drive a +5V regulator, followed by a 7660 i.c. to create a -5V rail as well; I have just assembled a PC which has a power supply offering +12V, +5V, +3.3V, -5V and -12V so it has two dual rails and a 3.3V rail too. A.R.W.

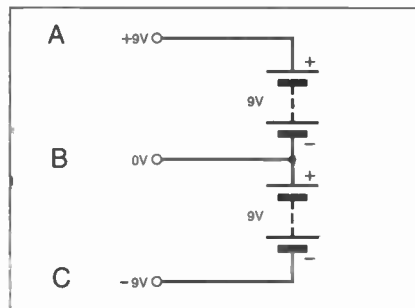


Fig. 1. Example of a dual-rail power supply.

## Super Glued

*I was a little concerned about some advice you gave in April's Circuit Surgery. You suggested that lifted p.c.b. tracks could be repaired with superglue.*

*A friend of mine (an electronic engineer) repaired a board that unknown to him had such a fix. He only became aware of it when he began choking. Apparently superglue at soldering iron temperatures may release dangerous quantities of cyanide gas.*

*I don't claim to know enough about chemistry to confirm it, but you might want to look into it. Boris Burke by email.*

In my humble but illustrious career, I found myself working for the country's

largest filler of tubes (as in. tubes of adhesive etc.) and the company used to fill superglue into small tubes for the retail market. (You haven't lived until you have seen a filling machine grind to a halt, having gone rock solid internally.) I checked the Material Data Sheet of a typical cyanoacrylate adhesive, but I couldn't find any reference to toxic gases being released when heating the (cured) adhesive. It is perhaps possible that other products (e.g. p.c.b. lacquers and fluxes) combined and caused your friend to suffer some ill effects.

It is true that superglue has a pungent odour until cured, and if heated the fumes given off may have caused severe discomfort in an enclosed space, especially when you are very close to the work. Police forensic scientists use the fumes emitted by large pots of superglue to react with and reveal fingerprints on murder weapons etc.

Some other general-interest pointers about cyanoacrylate adhesive that most users don't appreciate: it polymerises (hardens) almost instantly in contact with water, and a suitable solvent to help clean accidental spills is acetone (e.g. nail varnish remover). Sometimes, it is best to let the product just harden and then deal with the after effects, as in the case of accidental skin contact which is often harmless but annoying.

## Medical Attention

If superglue ever gets in your eyes, don't panic: irrigate the eye thoroughly with water for at least 15 minutes, taking care not to wash adhesive from one eye to another. If an eye is bonded shut, don't force it open but cover it with a wet pad soaked in warm water. You should get prompt medical attention, in case solid particles of cured adhesive become trapped behind the eye and cause abrasive damage.

The Data Sheet advises to keep the eye covered with a wet pad until de-bonding is complete, usually within 1 to 3 days. If any reader would like to know more, please email me ([alan@epemag.demon.co.uk](mailto:alan@epemag.demon.co.uk)) and ask for a data sheet. A.R.W.

# Bongo Box

David Clark

PIC up the rhythm with our MIDI finger drum!



**T**HE Bongo Box is for budding drummers everywhere who like to tap out a rhythm with their finger ends on any available surface. This project is guaranteed to make such individuals even more annoying to any partner, parent or pet in the vicinity!

In fact, the Bongo Box could be of serious use to anyone involved in playing or recording music using MIDI (Musical Instrument Digital Interface) controlled instruments. Any box or enclosure can be turned into an electronic drum by placing this design inside it. The response of the device is rapid, and drumming your fingers on the box causes a series of drum sounds to be played in quick succession.

This is a great improvement over the usual situation where a MIDI keyboard is used to trigger sounds – normally it is not possible with a keyboard to mimic the quick “rolls” that drummers play. The Bongo Box makes this technique possible,

without having to go to the expense of buying an electronic drum kit!

The Bongo Box is designed to be connected to a computer that has a MIDI input and is running software that can send MIDI information to a sound module or a sound card, or has in-built sound facilities. Most computers now have this ability; a MIDI interface is normally accessible via the joystick or game ports. For even greater flexibility, the Bongo Box can also be connected to the MIDI input of a dedicated drum machine.

## Circuit Description

The block diagram for the Bongo Box is shown in Fig.1. With the exception of the PIC microcontroller, the functional blocks are all formed around simple analogue circuits. The complete circuit diagram for the Bongo Box is shown in Fig.2.

The microphone insert, MIC1, has an in-built amplifier and was found to give a peak

output of several hundred millivolts. The output from the microphone is first applied to a voltage follower stage provided by op.amp IC1a, which buffers the signal prior to it being amplified by the  $\times 6$  gain stage around IC1b. This ensures that the signal is as large as possible without clipping at the initial “hit”.

The next stage consists of an active full-wave rectifier formed around IC2a, IC2b and IC2c. The rectification converts the bipolar output of the microphone to the unipolar output necessary for the digital (PIC) part of the circuit.

Using full-wave rectification, rather than half-wave, has two advantages here. Firstly, none of the “energy” of the signal is discarded as it would be in half-wave rectification, and secondly it speeds up the response of the circuit to a “hit” if the initial output from the microphone is negative-going. This can potentially save around half a millisecond at a signal frequency of 1kHz.

Op.amps IC2a and IC2b each only pass the positive and negative half-cycles respectively, due to diodes D1 and D2, and these are recombined by the differential amplifier IC2c. An active rectifier is, of course, more complex than a simple diode bridge rectifier, but it has the quality necessary in this application of not “losing” the 600mV (or so) needed to overcome a diode’s forward voltage drop.

## Trigger

From IC2c, the signal is routed in two directions. First, it is sent to the stage around IC1c. This determines the level of signal that will trigger an interrupt in the PIC (IC3). IC1c is configured as a comparator whose trigger level is adjustable by potentiometer VR1. Diode D3 acts as clamp to prevent any negative voltage reaching, and damaging, the PIC. A Schottky diode is used as this has a forward voltage drop of around 0.2V instead of the usual 0.7V for a silicon diode. Resistor R13 limits the current through the diode when clamping.

The output from the active rectifier that will ultimately be used by the PIC to determine the volume level is derived via the second signal path, through IC2d. This op.amp is basically used as a buffer, but has also been given some gain to compensate

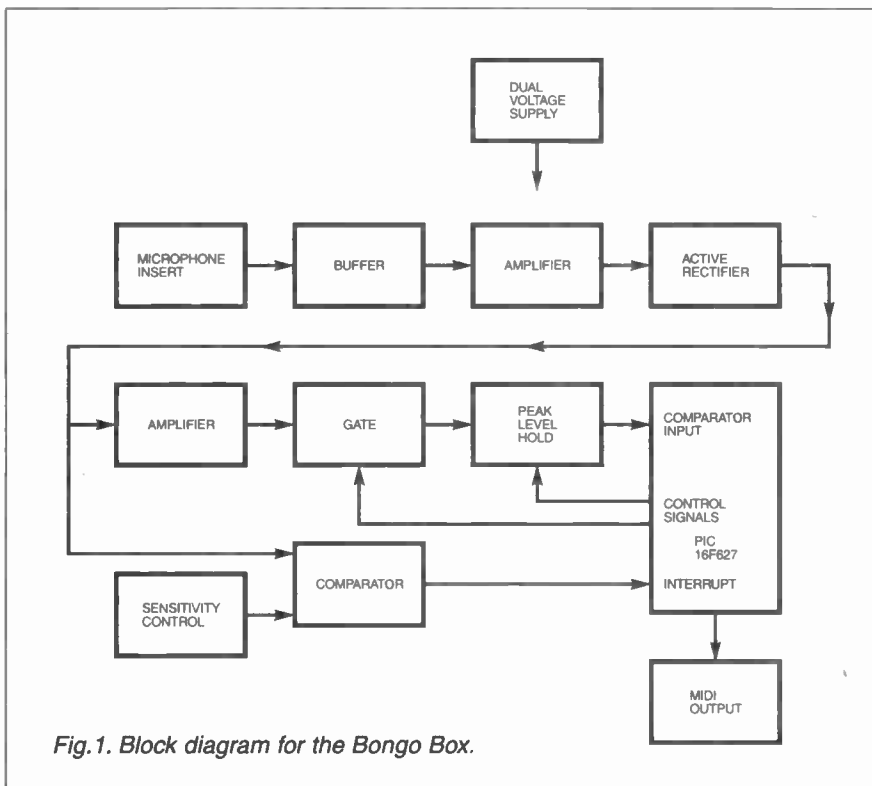


Fig.1. Block diagram for the Bongo Box.

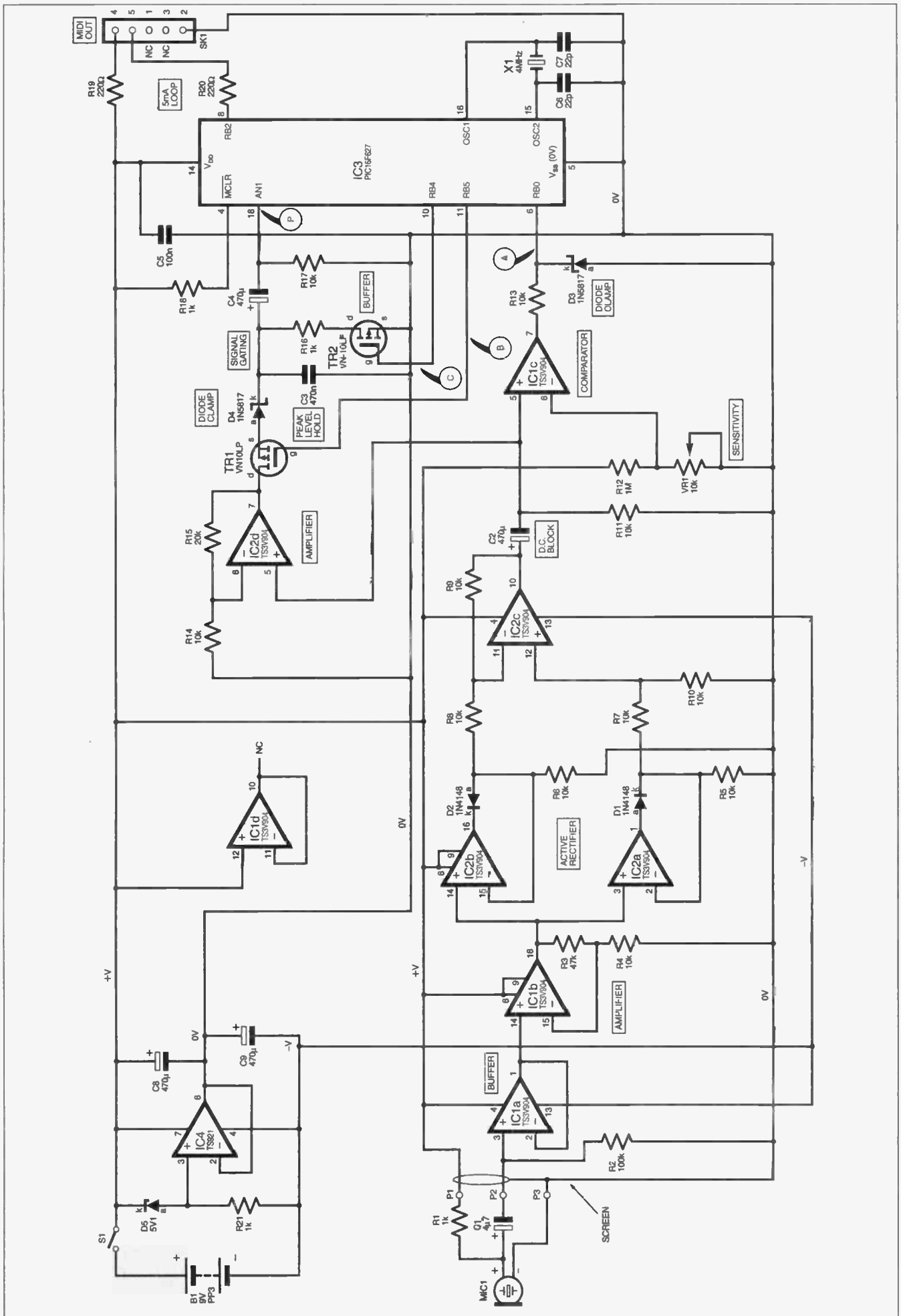
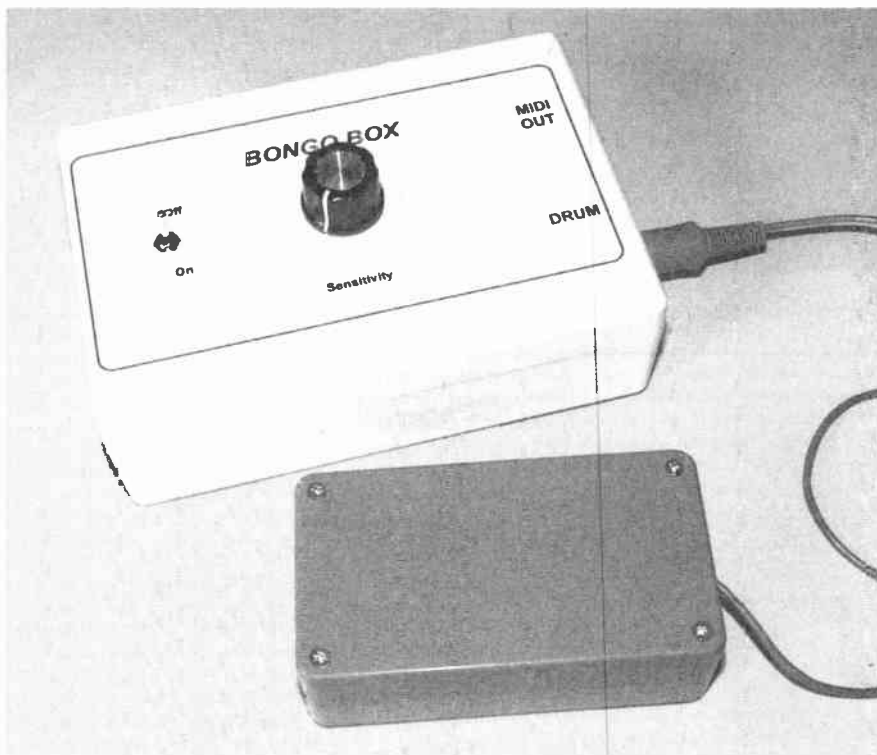


Fig.2. Complete circuit diagram for the Bongo Box. The microphone is linked to the main circuit by a twin-core screened lead.



for the reduced peak output of the active rectifier, the trade-off for overcoming the forward voltage drop at the point where the signal changes from positive to negative and vice versa.

## Volume Sampling

In conjunction with control signals from the PIC (IC3), the next stage of the circuit, consisting of transistors TR1 and TR2, and associated components, acts as a form of combined "gate/peak detector" and "sample-and-hold" function. Under conditions of no input from the microphone, the PIC holds TR1 off and TR2 on via signals at points B and C respectively. The output from IC2d is therefore blocked by TR1, and capacitor C3 is discharged via TR2.

Under these conditions, the signal at point P (AN1) is reset to 0V. When the signal from the microphone is sufficient to trigger a PIC interrupt (via point A) the interrupt service routine (ISR) causes the digital levels at points B and C to be reversed. Transistor TR1 switches on and TR2 switches off. The voltage at the output of IC2d therefore appears across C3 and is seen by the PIC (as at point P).

Diode D4 prevents C3 discharging when the output of IC2d goes less positive, and so the voltage at P is a series of increasing steps corresponding to the (positive) peak values of the positive- and negative-going excursions of the waveform output by the microphone. After approximately 3ms the ISR reverses the control signals at B and C again, effectively blocking the "gate" and resetting the "peak detector".

Meanwhile, during the 3ms period, the ISR samples the voltage at P at several intervals and uses the voltage sampled in the integration process to determine the volume level that is output with the MIDI message by other steps in the ISR.

Capacitor-resistor combinations C2/R11 and C4/R17 act as simple high-pass filters, preventing any op.amp d.c. offsets from upsetting the volume level determination.

The PIC microcontroller (IC3) is run at 4MHz, as set by crystal X1, plus capacitors C6 and C7. It is held in run-mode by resistor R18. The output to the MIDI socket (SK1) is via resistor R20. The socket is also coupled to the positive power line via resistor R19.

## Power Supply

The Bongo Box is powered by a 9V battery. This voltage is effectively split into a dual supply by the circuit around IC4, which is used as a buffer. The voltage applied to IC4's non-inverting input (pin 3) is set at approximately 5.1V by Zener diode D5, in conjunction with resistor R21. IC4's output voltage is then taken as the mid-supply level, i.e. 0V (or ground). The upper supply rail provides the +5V required by the PIC.

Op.amp IC4 is a type TS921 rail-to-rail device, so the positive rail will be within a few millivolts of 5.1V. This device is also a high output type, capable of sinking or sourcing around 80mA.

Op.amps IC1 and IC2 are used with a dual supply since the analogue signals at the "front-end" of the circuit require a bipolar supply to process the bipolar analogue signal from the microphone. For this part of the circuit, therefore, IC4 provides a non-stabilised voltage of around -4V as well as the stabilised +5V.

The main reason for using TS3V904 op.amps (IC1/IC2) is that these are rail-to-rail types, allowing maximum output range for the analogue signals. The magnitude of the analogue signal where it is bipolar is only in the order of a few hundred millivolts, so there is plenty of "head-room". This allows for the reducing output voltage of the battery as it ages. The critical +5V supply will remain stabilised; the non-critical negative rail will decrease in magnitude, but the battery voltage can fall to 6V or 7V before it will affect the circuit performance.

Capacitors C5, C8 and C9 provide the usual smoothing and filtering of noise and spikes on the supply rails.

## Construction

The Bongo Box is constructed on two circuit boards. The main circuit is built on a printed circuit board (p.c.b.), for which component layout and tracking details are shown in Fig.3. This board is available from the *EPE PCB Service*, code 451.

## COMPONENTS

### Resistors

R1, R16,	
R18, R21	1k (4 off)
R2	100k
R3	47k
R4 to R11,	
R13, R14,	
R17	10k (11 off)
R12	1M
R15	20k
R19, R20	220Ω (2 off)
All 0.25W, 5%, carbon film	

### Potentiometer

VR1	10k rotary carbon, lin
-----	------------------------

### Capacitors

C1	4μ7 radial elect. 16V
C2, C4	470μ radial elect. 10V (2 off)
C3	470n ceramic, 5mm pitch
C5	100n polyester, 5mm pitch
C6, C7	22p ceramic, low K, 2.5mm pitch (2 off)
C8, C9	470μ radial elect. 16V (2 off)

### Semiconductors

D1, D2	1N4148 signal diode (2 off)
D3, D4	1N5817 Schottky diode (2 off)
D5	5V1, 0.5W Zener diode
TR1, TR2	VN10LP <i>n</i> -channel MOSFET (2 off)
IC1, IC2	TS3V904IN quad CMOS rail-to-rail op.amp (2 off)
IC3	PIC16F627 microcontroller, pre-programmed (see text)
IC4	TS921IN CMOS rail-to-rail op.amp

### Miscellaneous

S1	min. d.p.d.t. toggle switch
SK1	5-pin DIN socket, 180 deg, panel mounting
X1	4MHz crystal
MIC1	EM-60B sub-min. electret microphone insert

Printed circuit board, available from the *EPE PCB Service*, code 451; strip-board, 14 strips x 9 holes; 8-pin d.i.l. socket; 16-pin d.i.l. socket (2-off); 18-pin d.i.l. socket; PP3 battery and clip; p.c.b. supports, self-adhesive (4 off); case to suit (see text); 1mm terminal pins; connecting wire; MIDI cable; twin-core screened microphone cable; 22s.w.g. tinned copper wire (for links); solder, etc.

Approx. Cost  
Guidance Only

**£22**  
excl. case & batt.

Assemble the board in order of component size, starting with the link wires. Ensure that all polarised components are the correct way round. Sockets should be used for all four i.c.s. Normal precautions against electrostatic damage should of course be observed with these devices (touch a grounded item of equipment before handling them).

Thoroughly check the assembly for component positioning accuracy and for the quality of your soldering before inserting the i.c.s. and applying power.

Stripboard is used for the microphone insert (MIC1) and its associated resistor R1 and capacitor C1. This board is intended to be placed inside the box or housing the user wishes to "play" like a drum. Its component

layout and track cutting details are shown in the inset diagram Fig.4. Note that the microphone insert is polarised – the positive terminal is usually the one not attached to the casing. Also ensure that capacitor C1 is correctly orientated.

Ideally, the microphone board should be suspended inside the box, supported between the four board-mounting pillars by elastic

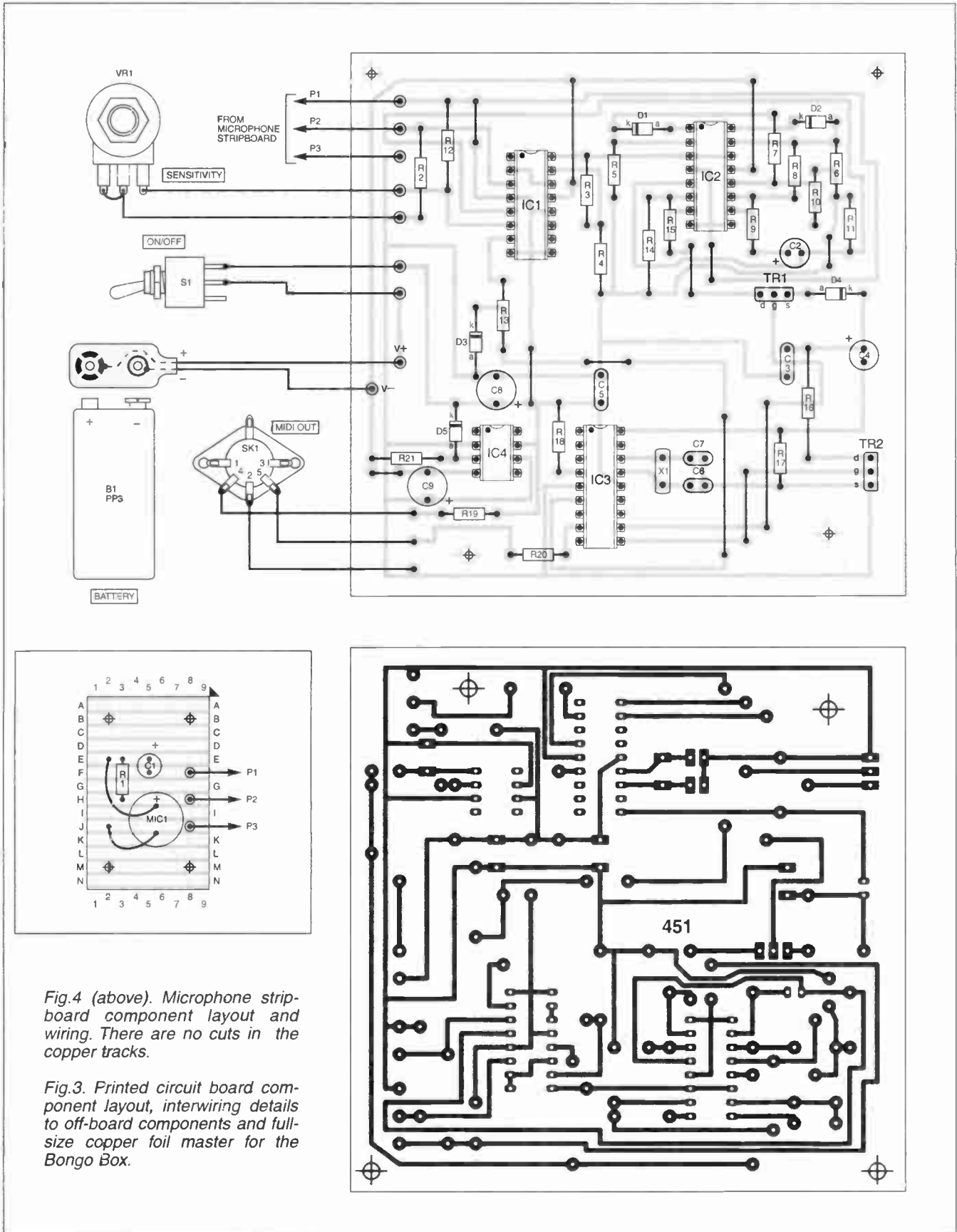
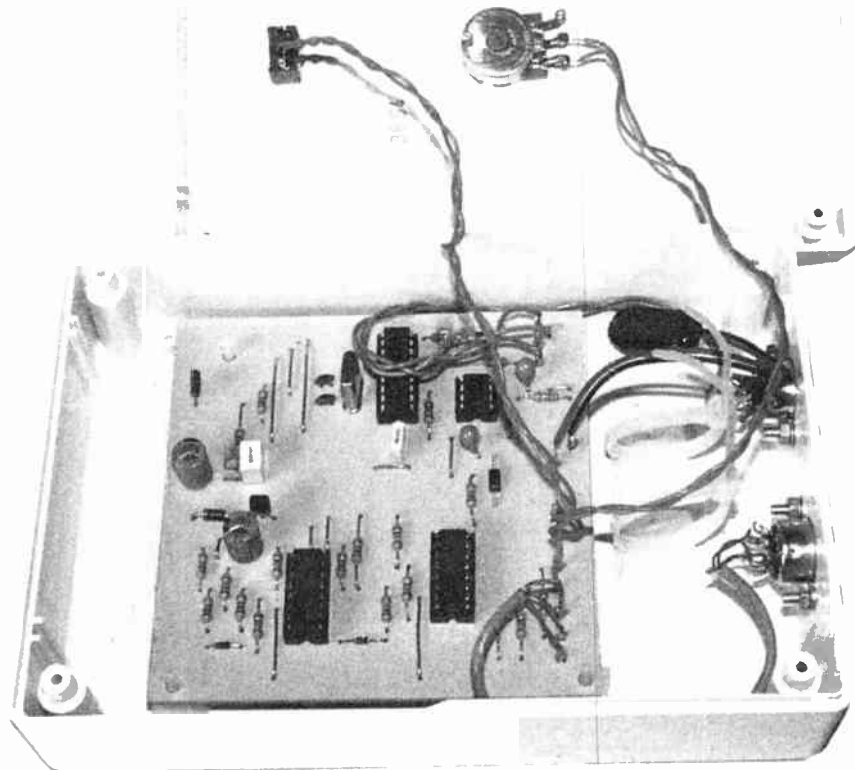


Fig.4 (above). Microphone strip-board component layout and wiring. There are no cuts in the copper tracks.

Fig.3. Printed circuit board component layout, interwiring details to off-board components and full-size copper foil master for the Bongo Box.



Finished Bongo Box, with lid removed, showing the main PIC controller printed circuit board and general positioning of off-board components.

bands (see Fig.5). This helps to ensure that only *sound* is picked up, rather than mechanical vibration. This is the same principle as that employed in the "spider" shock mount used with high quality microphones, as seen in recording studios for example.

The p.c.b. pillars may need to be glued into position in the box – it was found that the self-adhesive bases became unstuck over time under the tension of the elastic bands.

This board is connected by a cable to the main control board, mounted in whatever type of enclosure is preferred.

### Software Operation

The trigger pulse from point A in Fig.2 is connected to PIC pin RB0, which is monitored by the PIC's interrupt controller. On receipt of an interrupt trigger pulse, the software jumps to the interrupt service routine (ISR). Incorporated into this is a "hold-off" timer which sets a time delay to prevent another signal from causing a further trigger pulse prematurely.

In conjunction with setting the Sensitivity control, VRI, this allows the Bongo Box to be played softly or loudly without "after-vibrations" of the original "hit" causing unwanted re-triggers.

The ISR also generates the timing pulses needed in the path that the analogue signal takes. As said, the purpose of this path is to generate volume level information. Because of the percussive nature of the sounds involved, the desired sound volume level is not purely proportional to the maximum voltage level of the signal. The frequency and duration of the sound also affect the perceived volume, which is more realistically indicated by the total energy "contained" in the signal.

A simple peak-level detector is inappropriate for this application. To determine a value for the volume, therefore, the signal level is integrated during the length of time in which the microphone gives an output

after the initial striking of the "drum". The integration function is also performed in the ISR section of the software.

Before the PIC can act on the signal information, however, it has to be converted to a digital format, and this of course means some form of analogue-to-digital converter (ADC) is needed.

Each drum sound has its own "envelope", which fixes the rate at which the sound builds up and then decays. This is pre-determined by the system that generates the sound, whether it is by synthesis or sampling. The more levels there are employed, the better for realistic drum sounds.

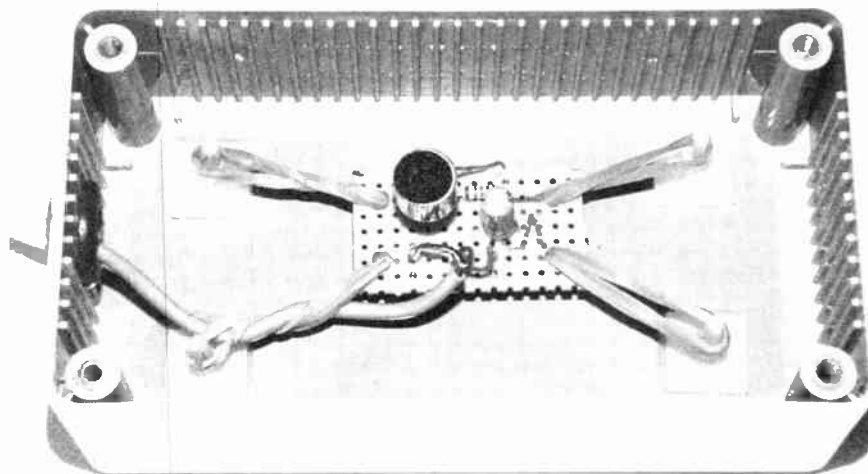
However, the Bongo Box is not involved in creating the drum sounds. It is simply intended to allow a realistic rhythm to be generated, and this could in fact be achieved using only two levels (a normal and an "accented" beat), as some early drum machines did.

### Expressive Note

Later dedicated drum machines had more volume levels, but even using a MIDI sequencer with full control over editing MIDI messages, there are only 128 possible levels, including silence. Initial tests on the prototype of this project were performed with a drum machine having six levels, which gave good results. Consequently, having eight levels seemed plenty to achieve an expressive feel.

To achieve the required results, without resorting to the larger PIC16F87x family, it was decided to use a relatively modest PIC16F627. This device allows its internal comparator to implement an 8-level ADC function in software.

The principle involved is that of applying the sound level input voltage and the voltage reference to the inputs of its



Microphone sensor board suspended inside the "drum" box.

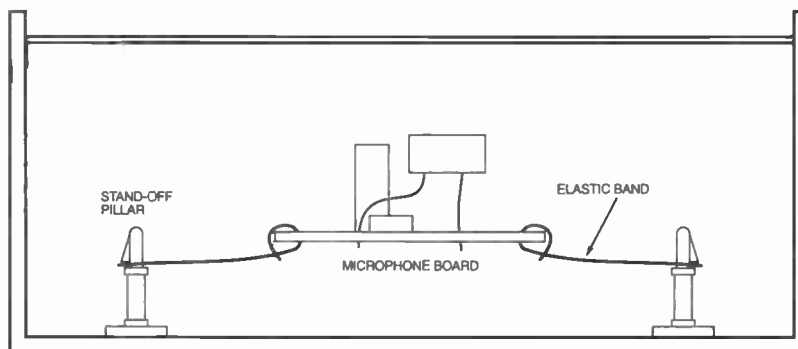


Fig.5. Suspending the "pick-up" board between mounting pillars using elastic bands.



comparator, and then incrementally increasing the value of an internal voltage reference until the change of state of the comparator output indicates that the voltage reference value nominally matches the sound input level voltage. This value is then used in the integration process to determine the final volume output level that is used for the MIDI output.

Having been triggered by the initial pulse, and having determined a sound level by integrating the input voltage values, the PIC then outputs through its USART (universal asynchronous receiver-transmitter) the appropriate MIDI message via pin RB2. This is connected as a standard MIDI output via a 5-pin 180° DIN connector. SK1.

## Drumming

The Bongo Box circuit is sensitive enough to pick up the quiet sounds of fingertips playing softly on the enclosure, and will trigger low volume percussive sounds. If hit hard it will generate MIDI volume messages close to the maximum possible value and trigger loud percussive sounds.

As the device is triggered by sound rather than the "hit" itself, this sensitivity can cause unwanted sounds as a result of the "scraping" sound made by movement of the box, if it is on a hard surface for example. Consequently, it is best

### Listing 1: Setting Channel Number and Instrument

```
Start:
      call con_io      ; Configure
                       ; in/out
                       ; registers
      call con_usart   ; Configure
                       ; the USART
      call con_tmrl    ; Configure
                       ; Timer 1
      movlw %10011001 ; note on
                       ; channel 10
      movwf ms_byte_1
      movlw 61         ; low bongo
                       ; drum
      movwf ms_byte_2
```

played on a soft surface, or a perhaps a foam pad.

To determine the best setting for the Sensitivity control, first turn the sensitivity to maximum. Playing the drum will most likely produce unwanted sounds after the initial "hit". Then decrease the sensitivity until these extra sounds disappear. The drum is now set up, and it will be possible to play the drum rolls etc. that are not possible using a keyboard.

The software has been written with fixed parameters so that the instrument

which sounds when the box is struck is a bongo drum, and the MIDI channel on which it is output is on channel 10, the normal percussion channel. Readers with PIC programming facilities can easily modify these settings if desired since altering only one line for either will allow the drum or channel to be changed (see software Listing 1).

However, although changing the channel number may prove interesting experimentally, musically it will be of little use as only one note of a non-percussive instrument, such as a piano, will sound. Similarly, although any of the percussive instruments available on channel 10 can be chosen, most of these are part of a drum kit; normally only a drum such as a Bongo is played "solo". Of course, several of these devices could be built and each programmed for a different percussion sound – partner, parent or pet willing!

## Resources

The software for the Bongo Box is available from the *EPE PCB Service* on 3.5in disk (for which a nominal handling charge applies). It is also available for free download from the *EPE* website, accessible via the Downloads click-link on our home page at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk) (path PICs/BongoBox). □



### Portable Mini Alarm

It would appear from our searches that the HCF40107B dual 2-input NAND gate, with open-drain outputs, i.c. used in the *Portable Mini Alarm* project will be hard to track down from the usual local sources. The only listing we have come across so far is from **Farnell** (☎ 0870 1200 200 or [www.farnell.com](http://www.farnell.com)), code 386-674. If any readers do find another source or any advertisers have supplies of the 4017, we will be pleased to notify readers through *Shoptalk*.

Resembling a metal-cased "top-hat" transistor, the Murata IRA-E700STO PIR sensor used in the model also came from the above company, code 731-950. A similar device, designated E600STO, is stock by **Maplin** (☎ 0870 264 6000 or [www.maplin.co.uk](http://www.maplin.co.uk)), code UR69A.

For those readers wishing to use the same horn-shaped miniature warning siren as the author's, this was purchased from **Rapid Electronics** (☎ 01206 751166 or [www.rapidelectronics.co.uk](http://www.rapidelectronics.co.uk)), code 35-0272. It is also stocked by our advertiser, **Squires** (☎ 01243 842424 or [www.squiresools.com](http://www.squiresools.com)) code 800-800.

The two printed circuit boards are available from the *EPE PCB Service*, codes 452 (Sensor) and 453 (Counter) respectively.

### Bongo Box

Some of the semiconductor devices called-up for the *Bongo Box* project may be hard to locate, but the rest of the components should be readily available. The CMOS rail-to-rail op.amps types TS3V904IN and TS9211N used in the prototype were obtained from **Farnell** (☎ 0870 1200 200 or [www.farnell.com](http://www.farnell.com)) codes 163-170 (TS3V904IN) and 332-6263 (TS9211N). The diodes and *n*-channel MOSFET should be widely stocked.

The microphone insert is the sub-miniature omni-directional EM-60B electret type and an identical alternative is currently listed in the **Squires** (☎ 01243 842424 or [www.squiresools.com](http://www.squiresools.com)) catalogue, code 800-220 (solder pad) or 800-225 (p.c.b. pins).

For those readers unable to program their own PICs, a ready-programmed PIC16F627 microcontroller can be purchased directly from the author for the sum of £5.00 each inclusive (add £1 for overseas). Orders should be sent to **David Clark**, 58 Murray Road, Sheffield, South Yorks, S11 7GG. Email: [d.d.clark@btopenworld.com](mailto:d.d.clark@btopenworld.com). We understand the author is also proposing to provide kits of parts (excluding p.c.b., stripboard, case and MIDI cable) for the sum of £30. Payments should be made out to **David Clark**, in £ sterling only and drawn on a British bank, UK postal orders are also accepted.

The Bongo Box software is available on a 3.5in. PC-compatible disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 511). It is also available for Free download from the *EPE* website, accessible via the Downloads click-link on our home page at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk) (path PICs/BongoBox).

The printed circuit board is available from the *EPE PCB Service*, code 451 (see page 511).

### Hard Drive Warbler

We do not expect readers to have any problems finding parts for the *Hard Drive Warbler* project and have only a couple of minor points to make regarding components.

The phototransistor must be a type having a clear package so that it will admit visible light. Various phototransistors should work in this simple circuit

– not just the one used in the prototype. However, it must not be an infra-red type. The SFH300-2 phototransistor used in the model came from **Maplin**, code NP64U.

The low-profile d.c. buzzer should be one with an operating voltage of 3V to 24V d.c. and a current rating of 5mA maximum at 12V. Note you require two 10 megohm feedback resistors (R4) as a single 20 megohm one is not available.

The printed circuit board is available from the *EPE PCB Service*, code 450 (see page 511).

### EPE Teach-In '04 Part 9

Readers wishing to develop the Simple PIC-based Alarm (Fig.9.13) or the PIC-controlled Combination Lock Alarm Monitor (Fig.9.19) circuits, from this month's *Teach-In '04* series, should have no difficulty in obtaining suitable components, apart, of course, for the programmed PIC microcontroller. Note that if you use a PICAXE-18 chip, it *must* be one with the suffix X.

A pre-programmed PICAXE-18X can be obtained from: **Max Horsey, Electronics Dept., Radley College, Abingdon, Oxon OX14 2HR**, for the sum of £5 per PIC, including postage. Specify that the PIC is for *Teach-In 2004* Part 9 and quote the figure number/circuit for which the device should be programmed. Enclose a cheque payable to **Radley College**.

The software for the PIC program (except for the PICAXE programming software) is available on a 3.5in. disk (Disk 7) from the *EPE Editorial Office* for the sum of £3 each (UK), see page 511 for overseas charges. It is also available for Free download via the click-link option on the *EPE* home page at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk); enter the PIC microcontroller source codes folder and select *Teach-In 2004*.

PICAXE programming software can be obtained from: **Revolution Education, Dept. EPE, 4 Old Dairy Business Centre, Melcombe Road, Bath BA2 3LR** (☎ 01225 340563 or [www.rev-ed.co.uk](http://www.rev-ed.co.uk)).

A printed circuit board for the *PIC-controlled Combination Lock Alarm Monitor* circuit (only) is available from the *EPE PCB Service*, code 454.

### PIC Magnetometry Logger

We found only a single listing for the 24LC256 256 kilobit serial EEPROM memory chip, used in the *PIC Magnetometry Logger* project, and that was **Farnell** (☎ 0870 1200 200 or [www.farnell.com](http://www.farnell.com)), code 300-1696. The RS-232 interface driver type MAX 232 was purchased from **RS Components**. If a local source proves to be elusive, it can be ordered direct (credit card only) from **RS** on ☎ 01536 444079 or [rswww.com](http://rswww.com), code 655-290. The interface i.c. should be available from our components advertisers.

Two FGM-3 magnetic flux sensors are needed for this project and they came direct from **Speake & Co., Dept EPE, 6 First Road, Llanfapley, Abergavenny, Monmouthshire, NP7 8SL** (☎ 01600 870150 or [www.speakesensors.com](http://www.speakesensors.com)). The inclusive charge for these will be £38.83 for the pair. Overseas readers should contact Bill Speake for details of any additional cost.

For those readers unable to program their own PICs, a preprogrammed PIC16F877-20 (20MHz) microcontroller can be purchased from **Magenta Electronics** (☎ 01283 565435 or [www.magenta2000.co.uk](http://www.magenta2000.co.uk)) for the inclusive price of £10 each (overseas add £1 p&p). Note that it must be the 20MHz version.

The software, including source code files, for the PIC unit and PC interface, is available on its own 3.5in. PC-compatible disk from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 511). It is also available for Free download from the click-link option on the *EPE* home page at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk) (take path PICs/PICmagnetometry).

The printed circuit board is available from the *EPE PCB Service*, code 455 (see page 511). This includes the small sensor p.c.b.s which have to be trimmed from the main board.

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- AVIDICY supports normal and Mega range devices
- Demonstration download available :

[www.fored.co.uk/CDemo.htm](http://www.fored.co.uk/CDemo.htm)



Screen shot (left) shows push button element connected to a PIC, Parameters may be set to control debounce and repeat. C function may be specified to call when the button is pressed

FED ANSI C Compiler for PIC and AVR

- C Compiler designed to ANSI standards
- Supplied with library routines for C standard functions and many interface applications including I2C, LCD, LED's, timers, EEPROM, IRDA, Dallas 1 Wire, Hex Keypad, Maths, asynchronous serial interfacing, clocked data etc.
- With complete development/simulation environment including LCD/Keypad/LED/RS232 terminal
- View your simulation on a logic analyser application showing waveforms, timing or analogue results
- Profiler shows execution count, execution time and average time for functions and code blocks
- Smart linker – efficiently tiles routines throughout memory to minimise long jumps and page setting bits
- Supports the FEDPIC Key and FED In Circuit Debugger for PIC devices 16F87x and 18Fxx devices – See web site for more details.

**WIZ-C and C Compiler Pricing :**

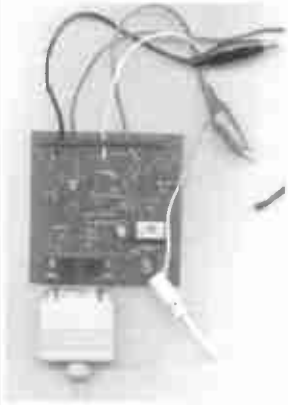
AVR or PIC C Compiler	£60.00
AVR or PIC C Compiler Professional	£90.00
AVIDICY or WIZ-C	£70.00
AVIDICY or WIZ-C Professional	£100.00

WIZ-C products are provided with introductory tutorial, full extensive manuals provided on CD.

All prices may be **reduced by £20.00** if the product is purchased at the same times as WIZ-ASM, serial or USB programmer, or our Development board.

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Supports 16F87x and 18Fxxx



- ICD and FEDPIC Key, allow real hardware to be examined & programs to be debugged and to be run in real time on your application
- The FED ICD requires only one data I/O pin on the PIC which can be chosen from any of ports B, C or D.
- Can program and re-program applications in circuit
- Up to 13 breakpoints (18F version)
- Run, Animate, single step and step over, run to cursor line, set PC to any value in the program
- Trace execution in the original C or Assembler source files
- View and change values of PIC special function registers, W and the ports.
- Standard serial interface to PC

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**USB Programmer** - 40 pin multi-width ZIF socket. Same range of devices as our serial programmer (below).

Price : £90/kit

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The CD-ROM is supplied with FED PIC BASIC and Compiler

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# PIC Magnetometry Logger

## Part One

John Becker

Logging your search for magnetic fields that might reveal hidden artifacts.

**M**AGNETOMETERS are instruments for measuring the direction and/or intensity of magnetic fields. Such fields are created by electrical current flow and also exist naturally in ferromagnetic substances, such as iron and nickel.

It is the latter fields that this magnetometer has been designed to detect, particularly those associated with man's activities, principally in relation to iron-based artifacts, although not solely so.

Anthony Clark in his book *Seeing Beneath the Soil* says that, "Iron constitutes about six per cent of the Earth's crust, but little of it is readily apparent. Most of it is dispersed through the soils, clays and rocks as chemical compounds which are very weakly magnetic.

"Man's activities in the past have redistributed some of these compounds and changed others into more magnetic forms, creating tell-tale patterns of anomalies in the Earth's field, invisible to a compass but detectable with sensitive magnetometers."

### FGM Sensors

Several sophisticated techniques exist for sensing magnetic fields. Perhaps the

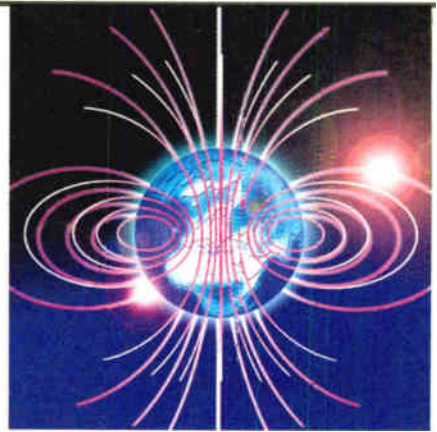
most well-known implementation, and probably the most sensitive, is known as the proton magnetometer. Hall Field Effect devices can also be used, although they are less sensitive and are prone to temperature drift. Fluxgate sensors are in widespread use, too, but they are notoriously difficult for the hobbyist to construct from scratch.

However, Speake & Co manufacture a range of fluxgate devices, the FGM-X series. Speake describe them as "very high sensitivity magnetic field sensors operating in the  $\pm 50$  microtesla range ( $\pm 0.5$  oersted)." This range covers the Earth's magnetic field (they can also be used in electronic compasses).

Browsing the web, it is apparent that one of the series, the FGM-3, is the device "of choice" in many magnetometer designs.

The data sheet states that applications include conventional magnetometry, ferrous metal detectors, internal vehicle re-orientation alarm sensors, external vehicle or ship passage sensors, wreck finders, non-contact current sensing or measurement, conveyor belt sensors or counters, magnetic material measurement and archaeological artifact assessment.

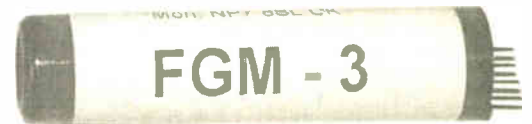
The sensors run from a single 5V supply, typically at about 12mA. Their operating temperature range is 0°C to 50°C. The output is a robust 5V rectangular pulse whose period is directly proportional to the magnetic field strength (giving a frequency which varies inversely with the field). The typical period swing for the full range of an FGM-3 is from



8.8 $\mu$ s to 25 $\mu$ s (approximately 120kHz to 50kHz).

A more sensitive sensor is also available from Speake, the FGM-3h. It produces a 1Hz change in frequency for a 1nT change in magnetic field. The author has not tried it, though.

Speake say that "unlike Hall Effect field sensors . . . the FGM series has a very low temperature coefficient". They do not quantify this statement, however.



### Design Concept

Two FGM-3 sensors are used in this design, aligned in same direction at about 0.5 metres apart within a plastic tube (standard 18mm plumbing pipe). They both "see" the same absolute magnetic field, irrespective of orientation, as long as they remain aligned with each other. If there is a local magnetic source closer to one sensor than the other, the output frequencies from the sensors will vary accordingly.

This arrangement is widely known as a *gradiometer* because it detects *gradients* in magnetic fields. However, the general term of *magnetometer* will be used in this article. The sensor assembly can be used vertically or horizontally (discussed in Part 2).

Speake also make a device (SCL007) that can be used with two sensors in gradiometer mode, producing an 8-bit digital output relative to the difference between the frequencies of the sensors. It was decided, though, that the use of a PIC16F877-20 microcontroller would be preferable. This is used to monitor the sensor output frequencies separately and store the results to a non-volatile serial memory, from where they can subsequently be downloaded to a PC-compatible computer for detailed analysis and graphical display.

The design has also been provided with an alphanumeric liquid crystal display (l.c.d.). This is for basic monitoring use "in the field", but its associated switch controls do not affect the sensor values recorded to the serial memory.



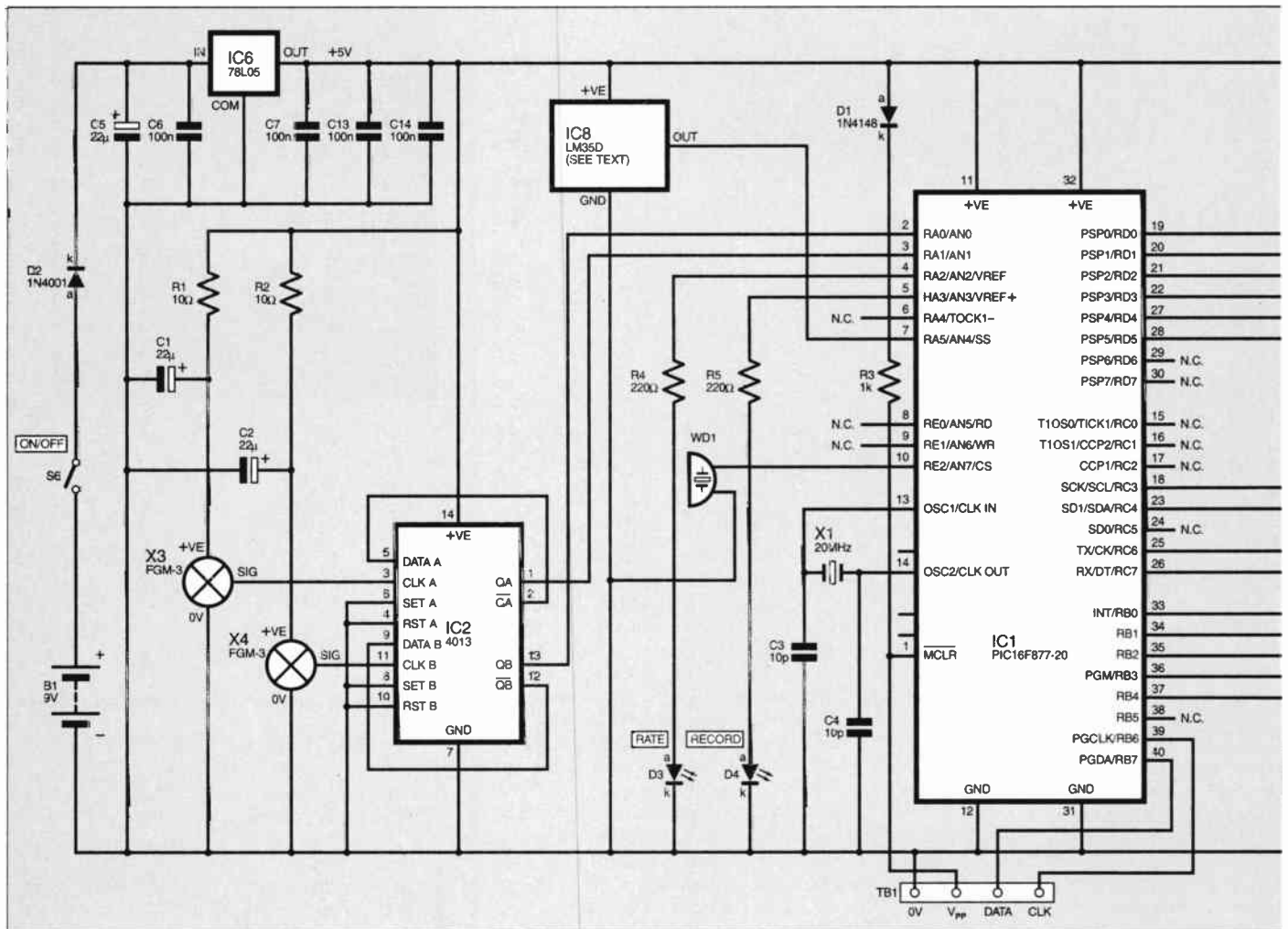


Fig. 1. The complete circuit diagram for the Magnetometry Logger.

Facilities to connect a GPS (Global Positioning System) handset to the unit have also been provided. Its use is optional – see later.

## Software

It is worth noting at this point that the PC software for this Magnetometry Logger can also be used with the author's *Earth Resistivity Logger (ER)* of April/May '03. More on this in Part 2.

Software, including source code files, for the PIC unit and PC interface is available on 3.5-inch disk from the Editorial office (a small handling charge applies – see the *EPE PCB Service* page) or it can be downloaded *free* from the *EPE* Downloads site, accessible via the home page at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk). It is held in the PICs folder, under Magnetometer. Download all the files within that folder.

This month's *Shoptalk* provides information about obtaining pre-programmed PICs.

The PIC program source code (ASM) was written using *EPE Toolkit TK3* software (also available via the Downloads site) and a variant of the TASM dialect. The run-time assembly is supplied as an MPASM HEX file, which has configurations embedded in it (crystal HS, WDT off, POR on, all other values off).

The PC interface software was written under Visual Basic 6 (VB6), but you do not need VB6 on your PC in order to run the software.

Whether or not VB6 is installed, copy *all* of the Magnetometer files (except the PIC

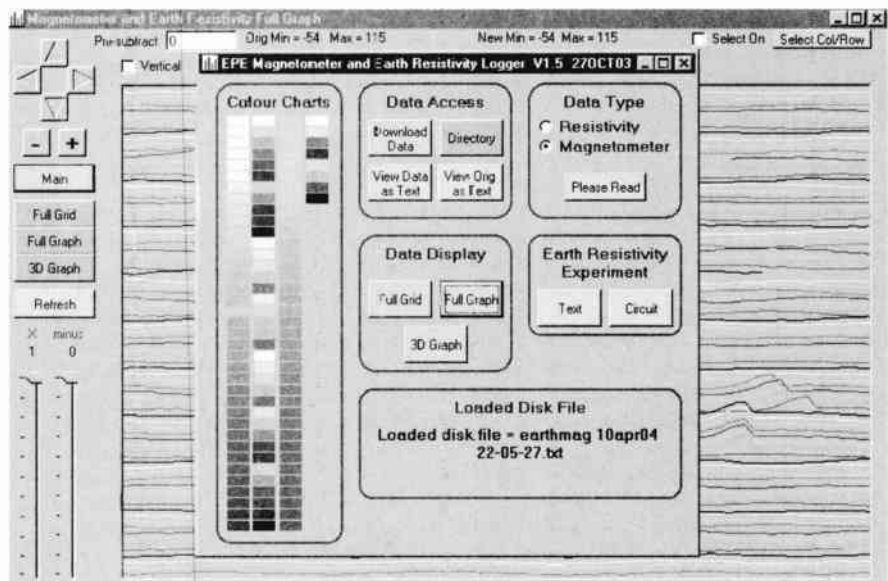
files if you prefer) into a new folder called **C:\Magnetometer**, or any name of your choosing, on Drive C (the usual hard drive letter).

If you do not have VB6, you also need three other files, **comdlg32.ocx**, **Mscmmct1.ocx** and **Msvbm60.dll**, held on our 3.5-inch disk named *Interface Disk 1*, and in the *Interface* folder on our Downloads site (they are also included with the *TK3* software, in *Disk 2*). These files

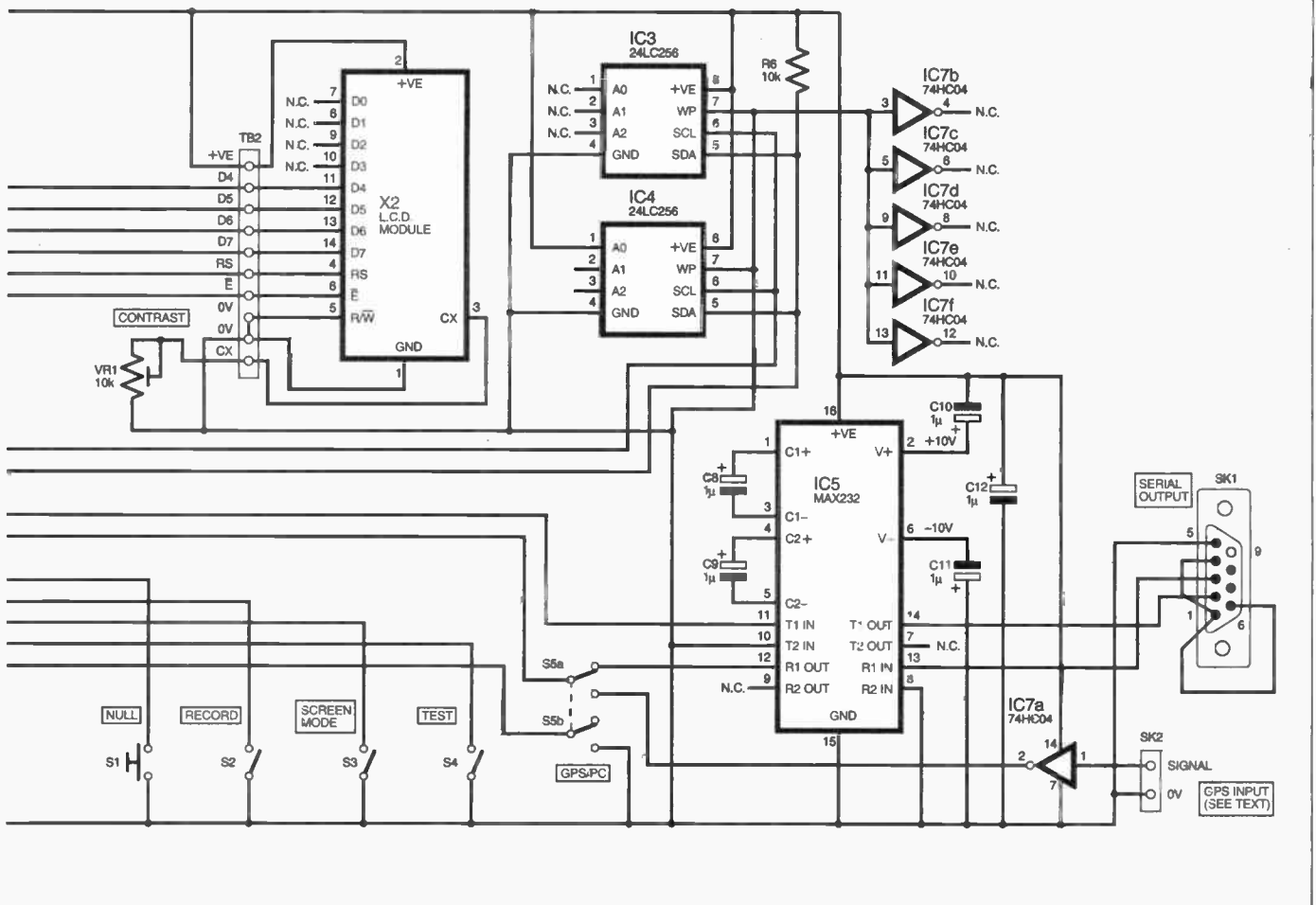
must be copied into the same folder as the other Magnetometer files.

These three files are not supplied with the Magnetometer software as they are common to several *EPE* VB6 projects and amount to about 1MB of data.

Additionally, the VB6 source code makes use of Joe Farr's excellent *Serial Interface for PICs and VB6* (Oct '03) software. In order to access (and perhaps modify for your own purposes) the Magnetometer VB6



Main control screen superimposed on the Full Graph screen in the background.



source code files, you need to have Joe's software installed on your PC as well (see his published text). This is also available via our Downloads site.

Without Joe's software installed, if you try to access the Magnetometer source code, it will crash.

Note that you should not attempt to "install" the Magnetometer VB6 files via Explorer or other similar PC facility. Use Windows' own normal Copy facility.

### Circuit Description

The complete circuit diagram for the Magnetometry Logger is given in Fig.1.

The PIC16F877-20 microcontroller is shown as IC1. It is operated at 20MHz, as set by crystal X1 in association with capacitors C3 and C4.

At about one-second intervals the PIC behaves as a dual-frequency counter, counting the pulses derived from the two FGM-3 sensors, X3 and X4, via flip-flop IC2 and input pins RA0 and RA1. The use of IC2 was found to be necessary in order to "square" the non-uniform sensor output pulses prior to the PIC polling its RA0/RA1 inputs during the counting cycle.

As the sensors are mounted off-board via a cable that can be several metres long, the positive power lines feeding them are decoupled at the sensor end. This simply involves the inclusion of resistors R1 and R2, and capacitors C1 and C2. Without this decoupling, the sensors could react to each other's output frequency and "lock-on" to each other.

Each pair of frequency count values is stored to non-volatile memory *exactly as received*. It was decided to let the PC computer software perform the analysis of the values following their download, without any intervention from the PIC software.

There is, though, a certain amount of data processing performed by the PIC. This is purely for immediate monitoring purposes and does not affect the stored data. It will be described later, when the mode control switches S1 to S5 are discussed.

Two serial memory chips are provided, IC3 and IC4, although IC4 may be omitted if preferred (the PIC software recognises how many memory chips are used and behaves accordingly). The devices retain their data even after power has been switched off.

In common with the author's similar logging designs, the memory chips are Microchip type 24LC256, each having 256 kilobits (32K bytes) of data storage accessed in I<sup>2</sup>C mode via the PIC's RC3 and RC4 pins. Pull-up resistor R6 is common to the outputs of both chips.

Selection of whether IC3 or IC4 is accessed is determined by the software and the binary address code set via the chips' A0 to A2 pins, which are internally biased low when unconnected.

The l.c.d., X2, is a standard 2-lines by 16 characters per line module, controlled in the author's usual 4-bit mode, via Port D on this occasion. Preset VR1 sets the l.c.d. screen contrast.

### External Interfacing

Serial connection to the PC is via IC5, an RS232 interface device, Maxim type MAX232 (again as has become standard in many EPE designs). It is operated in both input and output modes at 9600 Baud with handshaking. Connection to the PC is via a 9-pin D-type female connector, SK1.

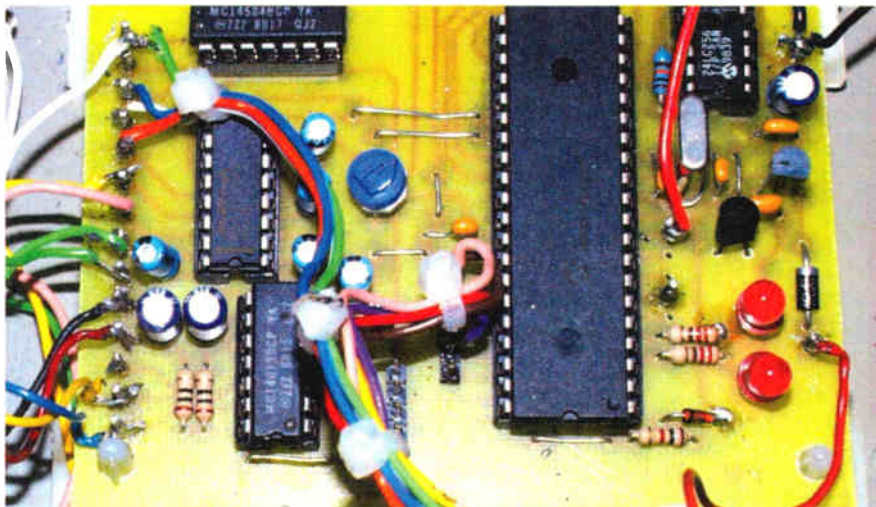
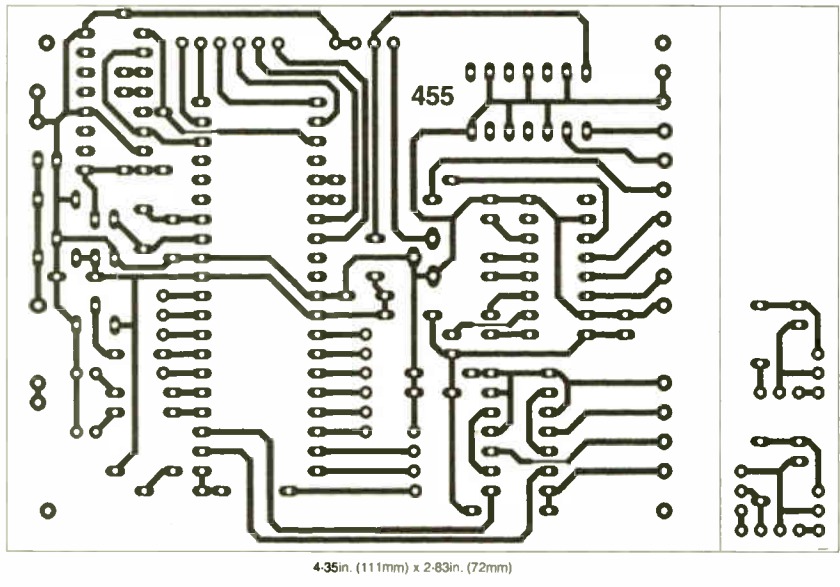
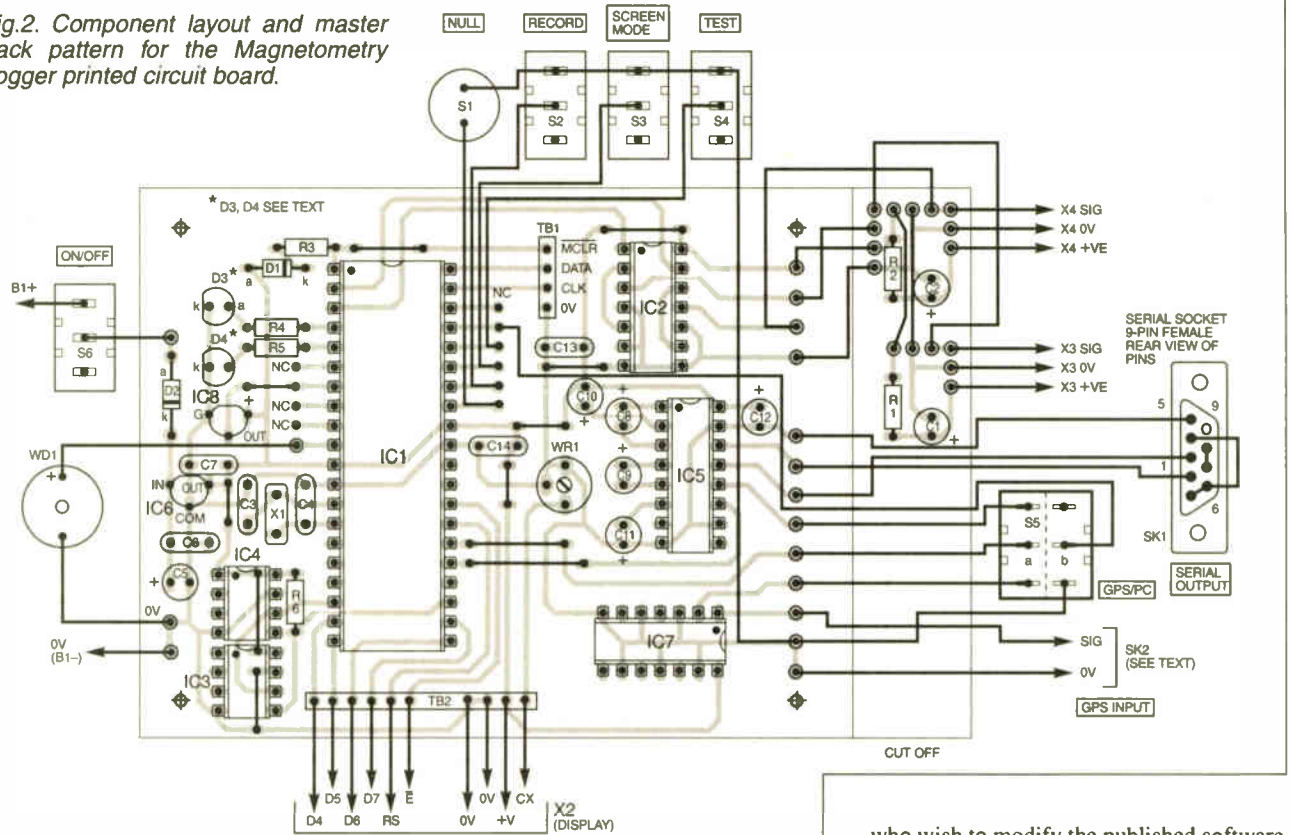
GPS handset interfacing was discussed in EPE Jan '04, in which the common NMEA 0183 protocol was described and example decoding software provided. The GPS handset is connected by two leads, signal and 0V input via socket SK2. A 3.5mm jack socket and plug were used in the prototype, but other connectors may be used. The signal is inverted by IC7a prior to connection to the PIC through switch S5. The GPS should be used at 4800 baud, the basic NMEA 0183 standard rate.

Switch S5a selects whether the signals from IC5 or IC7a are routed to the PIC's serial-receiving pin, RC7. Switch S5b informs the PIC about which data path has been selected. Note that the switches are monitored by Port B, used with its internal pull-ups held high.

Light emitting diodes D3 and D4 are buffered by resistors R4 and R5. D3 flashes at the sensor sampling rate (about 1Hz), and D4 is illuminated when the software is in Record mode. Buzzer WD1 "beeps" as each sample is taken.

Connector TB1 is the author's standard PIC-programming access point for readers

Fig.2. Component layout and master track pattern for the Magnetometry Logger printed circuit board.



who wish to modify the published software for their own needs and then send to the PIC *in situ*. Diode D1 and resistor R3 prevent programming voltages adversely affecting the unit's 5V supply line.

A temperature sensor, IC8, was included with the prototype. Its use is optional, as will be discussed further on.

The circuit is intended to be powered by a 9V PP9 battery. This is switched into circuit by S6, through polarity-protection diode D2, and to the voltage regulator IC6. This outputs a well-stabilised +5V, as required by the rest of the circuit. Current consumption is somewhat higher than had been expected, typically at about 45mA.

## Construction

Details of the component and track layouts for the printed circuit board (p.c.b.) are shown in Fig.2. This board is available from the *EPE PCB Service*, code 455.

Before assembling the board, cut off the two sub-sections on which components R1, R2, C1 and C2 are to be mounted. These sub-assemblies are ultimately mounted close to the sensors within their housing.

Assemble the main and sub-section p.c.b.s in any preferred order, ensuring that all on-board link wires are included (noting that two are under i.c. socket positions), and that all polarity-sensitive components are the correct way round. The use of sockets for all dual-in-line (d.i.l.) i.c.s is recommended; it is *essential* to use one for the PIC, IC1.

Treat all i.c.s as static sensitive and discharge static electricity from yourself before handling them, by touching the bare grounded metal of an earthed item of equipment, for example.

Double-check the perfection of your soldering and component positioning before applying power. Do not insert any of the d.i.l. i.c.s, or the l.c.d., until the correctness

### Resistors

R1, R2 10Ω (2 off)  
R3 1k  
R4, R5 220Ω (2 off)  
R6 10k

All 0.25W 5% or better

### Potentiometer

VR1 10k min. round preset

### Capacitors

C1, C2, C5 22μ radial elect. 16V (3 off)  
C3, C4 10p ceramic disc, 5mm pitch (2 off)  
C6, C7, C13, C14 100n ceramic disc, 5mm pitch (4 off)  
C8 to C12 1μ radial elect. 16V (5 off)

### Semiconductors

D1 1N4148 signal diode  
D2 1N4001 rectifier diode  
D3, D4 red l.e.d., high brightness (2 off)  
IC1 PIC16F877-20 microcontroller, pre-programmed (see text)  
IC2 4013 dual type-D flip-flop  
IC3, IC4 24LC256 serial EEPROM (2 off) (see text)  
IC5 MAX232 RS232 interface driver  
IC6 78L05 +5V 100mA voltage regulator

See  
**SHOP  
TALK**  
page

IC7 74HC04 hex inverter  
IC8 LM35DZ temperature sensor (see text)

### Miscellaneous

S1 min. s.p. push-to-make switch  
S2 to S4, S6 min. s.p.s.t. (or s.p.d.t.) toggle switch (4 off)  
S5 min s.p.d.t. toggle switch  
SK1 9-pin D-type female connector  
SK2 see text  
X1 20MHz crystal  
X2 2-line 16-character (per line) alphanumeric l.c.d. module  
X3, X4 FGM-3 magnetic flux sensor (2 off)  
WD1 active buzzer (optional)

Printed circuit board, available from the *EPE PCB Service*, code 455; plastic case, 190mm x 110mm x 60mm (see text), grey body, clear lid; 40-pin d.i.l. socket; 16-pin d.i.l. socket; 14-pin d.i.l. socket; 8-pin d.i.l. socket (2 off); self adhesive p.c.b. supports (4 off); PP9 9V battery or equivalent, plus clip; 1mm terminal pins; mono screened lead (approx 0.7m); 4-way intruder alarm cable (length as needed, see text); connecting wire; solder, etc.

### PROBE ASSEMBLY MATERIALS

For Fig.5 (see text).  
Plastic plumbing tube, 22mm o.d., 17mm i.d., approx 0.7m; T-junction; in-line connectors (2 off); end-caps (3 off).

He also comments that, whereas a sensor separation of one metre used to be common, 0.5 metres (1.6 feet) is now in general use. This makes the necessary rigidity of the assembly easier to achieve.

It is stressed that the materials used in the sensor housing should be totally non-magnetic and incapable of disrupting the sensors' fluxgate response. Some commercial assemblies use square-section aluminium tube. Browsing the web, it was found that right-angled aluminium section can also be used, providing excellent rigidity.

Additionally, Carl Moreland ([www.tthn.com/geotech](http://www.tthn.com/geotech)) describes a fluxgate magnetometer based on the FGM-3 and SCL007 devices, followed by an audio output stage, with which he mounts the sensors in a 2-inch (50mm) diameter PVC tube. Carl illustrates two techniques for mounting the sensors in the tube, as shown in Fig.4.

The author, though, used a 0.5m long right-angled aluminium section, to which the sensors were initially secured using Blu-Tack. This was subsequently reinforced by hot melt glue once the alignment had been achieved. The assembly was then placed within a plastic plumbing pipe of the same length and having an internal diameter of 17mm (externally 22mm).

Whichever technique is used, and referring to Fig.5, first connect the sensors to their p.c.b. pins. As the sensors have rigid pins spaced at 0.1-inch pitch, a pin header (or cut-down i.c. socket) can be used as a connector. DO NOT solder leads directly to the sensor pins which might damage the assembly. Keep the distance between the p.c.b. sections and the sensors reasonably short (say 1cm to 2cm).

A schematic of the author's full "probe" assembly, including the other connection cables, is shown in Fig.6. The "handle" is also useful in showing the orientation of the assembly during a survey.

It may be necessary to file off the entire edge of the external "V" of the aluminium section so that it slides easily into the plastic tube.

Full alignment of the sensors can be a bit tricky, and can only be done once the electronics are fully functional. To a small extent, though, absolute alignment is probably not essential for many of the applications in

of the +5V output regulator IC6 has been proved.

The main electronics are enclosed in a plastic case whose base measures 190mm x 110mm x 60mm. In the prototype, this was one half of a case whose transparent lid had been used in another application. In this Logger it was replaced by a sheet of acrylic (Perspex) cut to the same rectangular size, suitably drilled for the switches and securing holes. The l.c.d. was bolted behind the acrylic.

It is best to mount the l.e.d.s in the lid as well rather than on the p.c.b. (as they were with the prototype). Holes for the serial connector, GPS socket and the sensors cable were drilled at the rear of the case.

## Probe Assembly

Schematic details of the FGM-3 sensor are outlined in Fig.3. It will be seen that it has four pins, one of them marked F/B

(feedback). This pin is not used in this design and should be left unconnected.

To achieve maximum benefit from the two sensors they must be aligned with each other as accurately as possible within their tube. The external construction is shown in the photograph. Anthony Clark says on this point:

"The practical effect of any misalignment of the detectors is to make the instrument direction sensitive . . . if it is rotated."

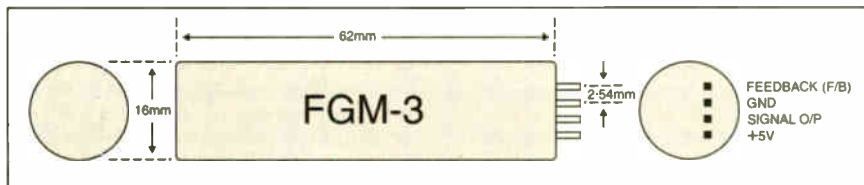


Fig.3. Details of the FGM-3 sensor module.

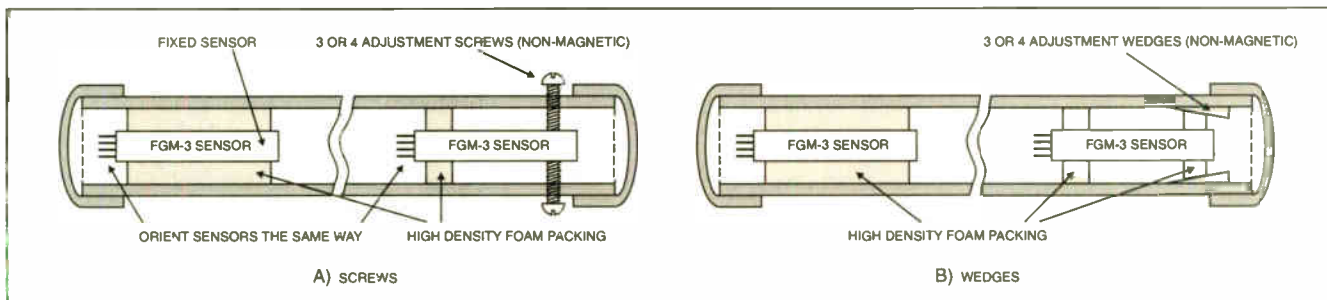


Fig.4. Alternative techniques for mounting the FGM-3 sensors, as used by Carl Moreland ([www.tthn.com/geotech](http://www.tthn.com/geotech)).

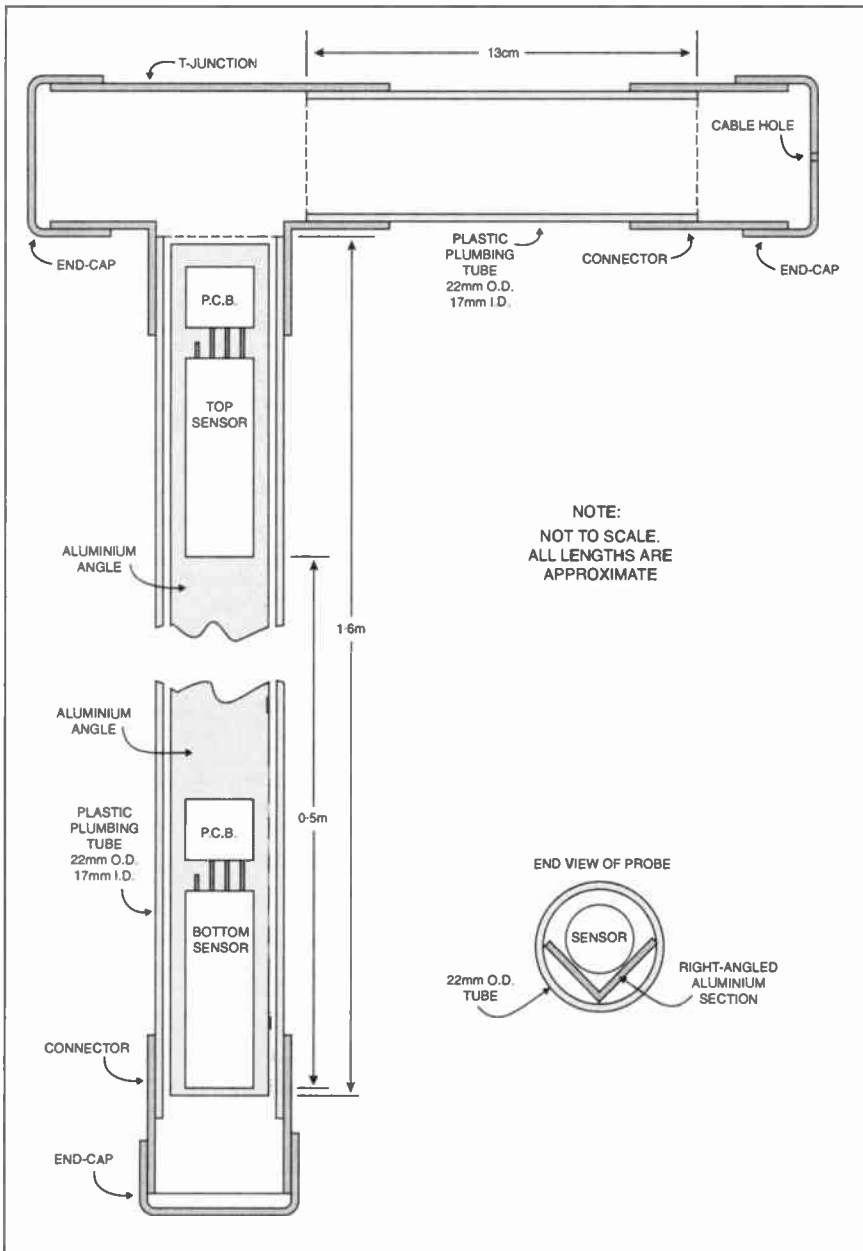


Fig. 5. Probe assembly details.

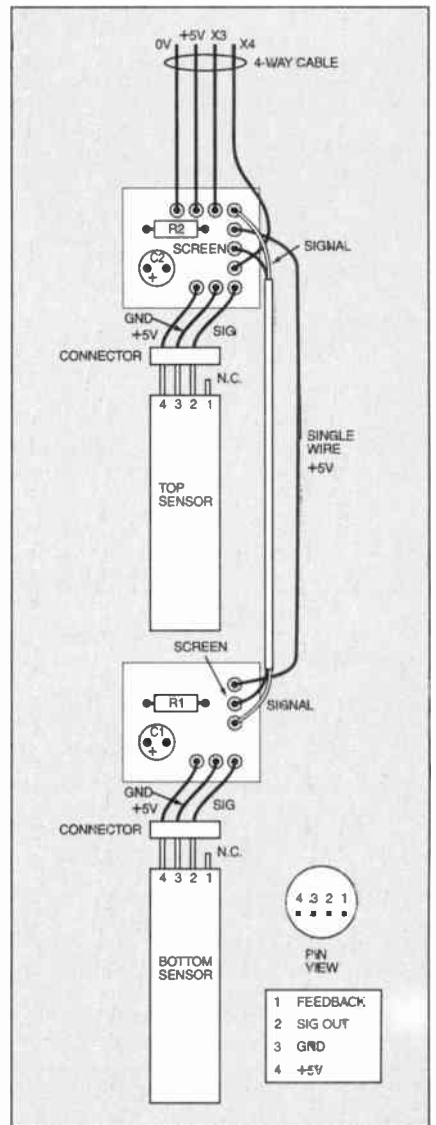


Fig. 6. Sensor wiring details.

which the magnetometer is likely to be used.

Provided that the sensors are maintained at a constant angle with respect to the Earth's magnetic field, any local magnetic anomalies should become apparent when the recorded survey data is displayed via the PC screen. Sensor alignment is detailed in Part 2.

It is important that screened cable should be used as shown in Fig. 6, to avoid the signal from the bottom sensor interfering with the response of the top sensor. It was found that 4-way intruder alarm cable was satisfactory for connection between the probe assembly and the unit.

The sensor cable was soldered to the main p.c.b. in order to avoid the danger of a plugged connection separating during a survey.

## First Tests

For the first test of the Magnetometer, set preset VR1 midway and the switches as follows:

Record off (S2 up), Screen Mode 2 (S3 down), Run on (S5 down), Test on (S4 down), Power off (S6 up). Although

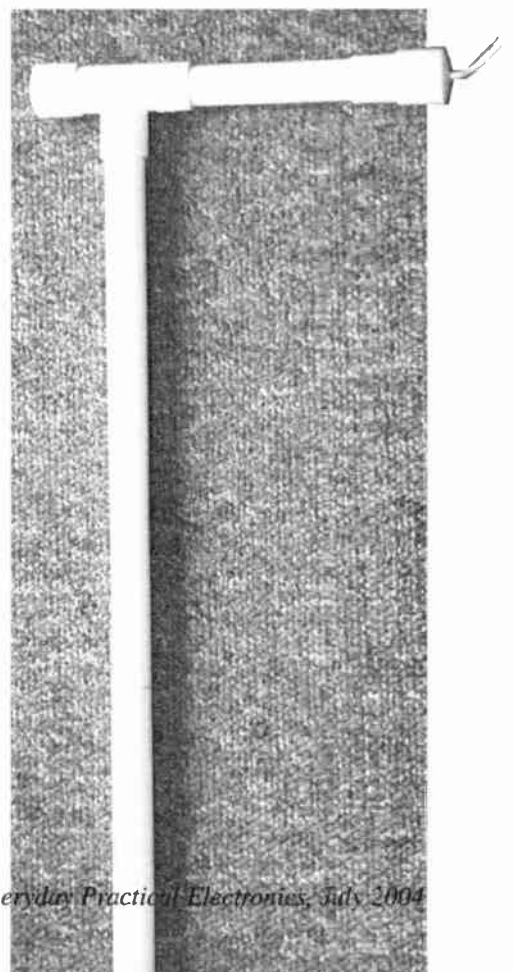
Null switch S1 is seen as a toggle switch in the photograph, a push switch should be used here – ignore the switch for the moment.

With the sensors connected to the main p.c.b. (don't worry about their alignment at this stage) switch on the power (S6). A "title" message will appear briefly on the l.c.d. screen top line (adjust preset VR1 for the best screen contrast). Line 2 shows the number of serial memory chips that the software has detected, two if both are installed.

Also note that l.e.d. D3 now flashes at about once per second. This is the rate at which each pair of sensor samples is being taken. The other l.e.d., D4, should be off.

After a couple seconds or so, the screen will change to show Test Mode details.

On the top line, the value shown following letter A indicates the total number of





```
A 6956 197 16+
B 52301 T 52544
```

recordings made to the serial memory chip(s). This is followed by another value, showing the number of samples recorded when Record mode was last used. Both numbers could have any value at this stage until the serial memories have been reset (see later).

At the right of the top line you may see either a value or a series of asterisks, and which may be followed by a negative sign. This part of the line normally shows the difference in the values of the two sensors in relation to a "null" reference value (more later).

The asterisks are shown when the value is greater than 999.

On line 2 are two values preceded by the letters *B* and *T*. These values show the actual frequency count being detected from the sensors by the PIC. The value for the bottom sensor in the probe assembly is preceded by *B*, and the top sensor value by *T*. The actual values seen will depend on the magnetic field strengths present in the room where you are testing the unit. In the author's workshop they are typically in the region of about 60000.

## Magnet Test

Bring something magnetic (something with iron or nickel in it – even a small magnet) into proximity with each of the sensors in turn and observe how the values change.

You will find that the closeness of the object and its angle in relation to the circumference of the sensor determines the count value, as will the orientation of the probe assembly in relation to the magnetic fields in your room. You will also observe when the probe is well away from household artifacts that the sensors are sensitive to the compass direction in which they face.

In the sensor alignment process, the sensors positions are adjusted while referring to these values in relation to the Earth's magnetic field.

Now briefly press the Null switch, S1. This causes the software to store the current sensor values as references. The word NULLED appears at the top left of line 1 until the switch is released.

When the switch is released, the value at the right of line 1 should now show as 0 (although it may shift up or down due to the fluctuating magnetic fields in your room).

The software takes the two sensor readings, subtracts their above reference values, and calculates the difference between these two results. This value is displayed on the top line, followed by a plus or minus sign as appropriate. **This value is purely for "in the field" information and does not affect the sensor values actually recorded when in Recording mode.**

Switch off Test switch S4. The top screen line continues to show the same details, but the bottom line now displays a

```
NULLED 0 0+
B 52301 T 52544
```

bargraph representing the absolute (ignoring minus signs) difference value divided by four. Each value unit controls one vertical line of pixels across the display. There are five of these lines per character cell, so the display has a resolution of 80 values. Observe how the bargraph changes in relation to the magnetic fields detected by the sensors.

```
A 7922 12 98+R
+■■■■■■■■■■
```

Switch on Record switch S2. The letter *R* will appear at the top right of line 1 and l.e.d. D4 will turn on, indicating that the unit is now in Record mode. The value at the centre of line 1 is simultaneously set to zero.

At each flash of l.e.d. D3, the sample values read from the two sensors are stored *without modification* to the serial memory. Data recording is done in strict ascending address order, following on from the address at which the previous recording session ended.

The current total recording count is shown to the left of line 1, incrementing by four for each sample. This represents the number of memory locations actually used. Each sample requires four locations, two for each of the sensor values, allowing for a maximum value of 65535 (two 8-bit bytes).

The number of samples taken during this Recording session is shown at the centre of line 1, incrementing by one for each complete sample recorded. **There is no limit to the number of samples recorded in any one session, other than that imposed by the memory capacity.**

To end the recording session, switch off S2, at which the message RECORDING ENDED will be displayed briefly.

At both switch-on and switch-off, additional data is also recorded to the serial memory: the geographical location if a GPS handset is connected, and the current value read from the temperature sensor.

If a GPS handset is not connected, the letter "a" is written to the same number of memory locations as would be the GPS data.

Discussion of downloading recorded data to a PC will be covered in Part 2. Switch S5 controls this mode, causing the l.c.d. screen to display the message WAITING PC TRIG when switched on. The mode is exited when S2 is switched back to Run. You may try this now without disrupting anything even though the PC is not presently connected.

## GPS Interfacing

A GPS handset may be interfaced with the Logger to record the geographic location at the start and end of each recording session. This will be of particular benefit when doing a large-scale survey across a broad area. **GPS use is optional.**

As discussed in the article *GPS to PIC Interfacing* in the Jan '04 issue, GPS handsets can output their navigational data to a PC or other digital destination via a serial link, for which a connector is provided on the handset.

Data can usually be output under a variety of format protocols, depending on the

type of handset. All handsets should offer the "standard" protocol that conforms to what is known as NMEA 0183. NMEA stands for National Marine Electronics Association. This standard specifies the serial Baud rate at which data is output, and in what format.

To set the handset to output under this protocol, refer to your handset's manual, which will also give the pinouts for the set's connector. Using a connector suited to the handset, make connections from the handset for the signal output and the 0V (ground) lines, using a screened lead of any length you prefer. Connect the leads to the Logger. Ignore any other pins that the handset connector may have.

With the GPS and the Logger switched on, switch on S3 to select Screen Mode 2. Once the GPS has acquired satellite data, that giving the handset's current latitude and longitude coordinates will be displayed, using both l.c.d. screen lines.

```
50° 48.349N A
001° 54.706W
```

For as long as S3 is on, this data will continue to be updated. If data is not being adequately received, a screen message will tell you so.

Following S3 being switched off, the GPS data is only read immediately prior to and following the start and end of a recording session, at which point it is also stored to the serial memory, as said earlier.

It was decided not to record GPS data for each recorded sample for several reasons. First, it would consume a great deal of serial memory. Secondly, it takes about a second to select and decode the data coming in from the GPS (which outputs all sorts of navigational data in batches). This, coupled with the required one-second period for sampling the sensors, would have made sampling too slow to be convenient.

With the Logger only dependent on a one-second sensor sampling rate, it is easy to survey a site at a normal walking pace, in time with the flashing l.e.d. D3.

Thirdly, GPS handsets can be prone to "losing" the satellite signals. The author's Garmin GPS12 handset does not like trees or other cover above it, for example. If the handset lost the signal while recording a stream of samples, the sampling rate could become inconsistent.

By sampling the GPS only at the start and end of a recording session, there is the opportunity to read the l.c.d. screen to establish whether a valid GPS location is being received at that time.

The software has been written so that Recording mode can be entered while switch S5 is set to GPS reception and display. For the above reasons, the screen then reverts to show sensor data. At the end of recording, it changes back to GPS display.

## Temperature Monitoring

In GPS mode, the l.c.d. screen also displays, at the bottom of line 2, the value read from the temperature sensor IC8.

This value is not quantified in relation to Celsius or Fahrenheit, it is just the analogue value from the sensor as assessed by the PIC's internal analogue-to-digital conversion (ADC) routine. This value is also

recorded to the serial memory at the start and end of a recording session.

The facility was included by the author to see if any significant temperature drift occurred while recording any batch of sensor data. Drift was found to be insignificant and so the software has not been provided with any temperature correction routines.

The sensor may be omitted if preferred, but if you do so, link IC1 pin 7 (RA5) to the 0V line to prevent it from "floating". Note that the PIC will continue to read this pin for an ADC value and record it to the serial memory even if the pin is grounded.

## Memory Clearance

A "safety" feature prevents the serial memory data from being reset unwittingly. To reset the memories, first switch off the power and wait a few seconds to allow the power line capacitors to discharge.

Press down Null switch S2 and hold it pressed. Switch on the power and wait until you see the screen message stating CLEARING EEPROM, then release S2.

The resetting process is somewhat slow as the memories require minimum pause durations during the process. It takes about three and half minutes per memory chip. The l.c.d. shows the progress of the reset count.



## Sensor Alignment

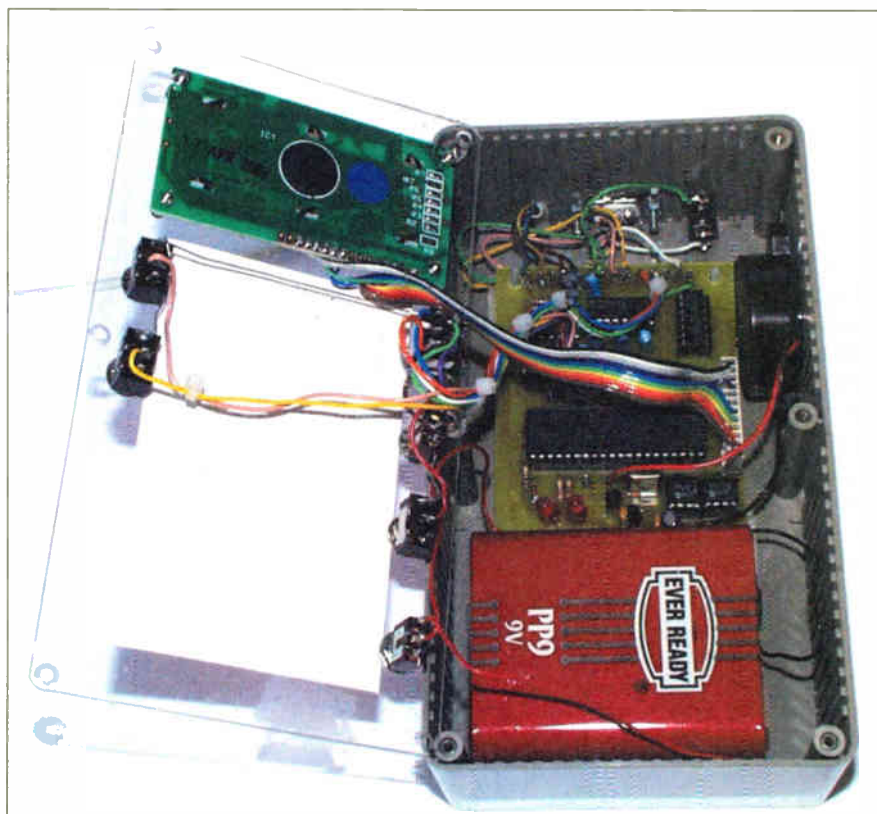
For optimal performance, the Logger's sensors need to be aligned. It is worth commenting though, that in the early stages of software development, a probe with unaligned sensors was used to gather data around the garden. Some very respectable results were achieved from small artifacts scattered around at random.

Precise alignment is best done outdoors, well away from the influence of domestic magnetic fields. The probe assembly should be positioned in an east-west orientation, held in such a way that it cannot shift from that position, but can be rotated about the main axis of the probes themselves. Two 22mm pipe clips could be used for this, bolted to a stable surface and the main probe tube clipped into them.

It is important that the probes are in a true east-west position since the alignment must be made with respect to the Earth's magnetic field. Use a compass to check this (but move the compass well out of sensor range before carrying out final alignment of the sensors).

To set the sensor alignment, you now need patience! If you are using Carl's assembly mentioned earlier, adjust the screws (which must be non-magnetic) or the wedges to change the orientation of the sensors. If using the author's probe assembly, take advantage of the flexibility of the Blu-Tack to move the sensors.

With the unit switched on and in Test mode, observe the count values displayed for the sensors. First adjust the sensors so that their connectors appear to be in the same relative positions horizontally. Look along the length of the assembly and check that the sensors are horizontally in line with each other along their axes.



Observe the l.c.d. values. Very carefully adjust the precise orientation of the sensors until the two readings are as close to each other as you can achieve. There is always likely to be a difference, however, due to the individual characteristics of each sensor.

Now rotate the entire tube assembly about its axis within the pipe clips, while still observing the l.c.d. values. If the values change disproportionately to each other as rotation continues, minutely adjust the sensor positions until this is minimised.

When you are satisfied with the alignment, the sensors can be secured in position with hot melt glue.

## Wellyquipped!

It is important that you should not wear any potentially magnetic materials during alignment and general survey. In early static tests with the prototype (while looking for temperature drift) the author was puzzled by unexpected changes in the recorded

results when viewed on the PC. Further investigation showed that he was partly responsible for them, moving to and from the stationary unit over the several hours during which the test was conducted.

The effects turned out to be due to: a metal buckle on his belt; a 90mm x 100mm x 10mm tin in one pocket; many plastic cards with magnetic strips in his wallet in the other; the ancient wrist watch being worn; his glasses to a very small extent; a passing cat (twice) which had a magnet on its collar to allow controlled access to a cat-flap!

So be warned – when setting-up or using the magnetometer, be very wary of what you wear. Probably the only way to be sure is to employ survey apparel that only consists of green wellies! (and even they should be given the boot if they have buckles...)

## Next Month

In the concluding part next month, the PC software will be described.

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## ★ LETTER OF THE MONTH ★

### HALF KEYBOARD

Dear EPE,

Having read Andrew Jarvis's new column *PIC n' Mix* in the April issue and his comments on the many uses of PICs, I wish to tell you about one PIC16F84 I have used for a special PC keyboard I bought over the Internet from [www.halfkeyboard.com](http://www.halfkeyboard.com) about a year ago. It was to replace a normal keyboard as I lost my right arm in an accident 45 years ago. It has 22 keys, each key having up to six functions, the space bar and the shift key are used to change the key map from one side of the keyboard to the other and one extra key.

It is this key that I had the most difficulty with as it has to be pressed up to four times to change to a different key map, two for the number keys, three for the cursor keys, and four for the function keys plus a single press to return. To overcome this I've used a PIC16F84 with a transistor connected across this key plus three l.e.d.s and two home-made footswitches. If the first footswitch is pressed the PIC sends two pulses to the transistor and to a red l.e.d. and

turns on one of the green l.e.d.s. Releasing the switch sends a single pulse to return. The same is for the second footswitch. However, if the key on the keyboard is pressed at the end of the three pulses it takes me to the function keys.

This means that I can now use a keyboard with very little arm movement and is quicker than I could ever be. This now stands alongside my solder dispenser as one of the most useful aids I've made over the years. I hope you find this of interest.

**Brian Milner, via email**

*That is indeed interesting Brian, congratulations on your achievement.*

*I have occasionally asked via our Chat Zone what suggestions readers have for electronic designs to help disabled people. There have been no responses that I felt I could follow up. Brian's is an excellent example of a simple and helpful circuit. Do any readers have any further implementations to highlight, or ideas to suggest?*

### NO POOH IN MY GARDEN!

Oh that *Skeggy Does It* headline in *EPE* May '04! It took me back to the early 1950s and the one week spent at Butlins Holiday Camp at Skegness in the middle of my RAF National Service days working as a Air Radio Fitter. Things happened there that week that I daren't mention to my Mum in my weekly letter to her at home in Littlehampton in Sussex!

These were the days when the "bible" of us dead keen radio builders was the never to be missed monthly *Practical Wireless* (can't remember the price now) but the circuits offered in each issue meant that we had to go to the ex WD shops in Brighton and buy (at ridiculously cheap prices) the necessary components to have a go at producing our own sound.

What about that F. G. Rayer writer/designer who had several easily recognised sayings and went with other pen names like F. R. Gee and other suchlike handles? His "All Dry Summer Portable" was one of the many circuits that I and others never could get to work but it really didn't matter and we spent so many hours in the shed. In my case it was that "apprenticeship of practical learning" that eventually got me into the BBC as an engineer for a long and very enjoyable 41 years.

Thank goodness now for my *EPE* which has, for some years, provided me with lots of excellent articles to read and things to enjoy building as well. You are "simply the best" and it sometimes seems a long time between each edition. I can only give just the one criticism and that is, on the photographs in the opening headings on page three, would you please put a number which relates to the particular circuit you are referring to.

Now, why the heading then of "No Pooh In My Garden"? Well apart from a long time ago, making my wife and grandsons happy with their radio controlled boats after building your electronic speed controllers for three of them, I

bought the Magenta *Micro Pest Scarer* double kit from them and it has been working with its slave in my garden for four years without stopping once. Consequently no dogs or cats come near to us and we can walk about freely without any lungful of that stinking stuff that other people have to put up with and who haven't had the help of *EPE* and its advertisers.

Thanks a bunch from a grateful someone whose hair has turned white but the brain still ticks over pretty damn quick. May your soldering iron never go cold.

**David J. Bishop, Kent, via email**

*Yes indeed Dave, Rayer and Gee were names around significantly when I got into electronics in the '60s. I used to buy comps from Gee's Radio shop in Lisle St, London. Indeed the whole of Lisle St was an electronics delight!*

*Nice to know about your Pest success (even though I am a cat owner!). I was skeptical about it when it was published but I have been proved wrong.*

### PIC LCF METER

Dear EPE,

Regarding the correspondence about the *PIC LCF Meter* in the April issue – CMOS has been around for over 30 years and I remember reading about the problems with using buffered gates in oscillators some 20-odd years ago. The advice was to use unbuffered versions as the higher gain of the buffered versions could lead to spurious effects.

About 14 years ago I used this information to solve a problem that some others had experienced for several months, in a few minutes by replacing a buffered chip with its unbuffered version, receiving a handsome reward in consequence.

**Dave McQue, via email**

*Thanks for that Dave.*

### PIC16F87x MICROCHIP ERROR!

Dear EPE,

I thought you'd like this one – I lost five days and a client's confidence on this – then I sent an email to Microchip, part of which is repeated below. To their credit they responded in two working days, but why couldn't I find this myself when I searched their website (several times) for "Timer1 errors"?

Dear Microchip,

There is a curious problem on the PIC16F876 – in-circuit emulation works, chips don't. My application uses Timer 1 to count clean 14Hz or slower pulses on port C0. In the main loop I am reading TMR1H and checking bit 4 so that I can update an EEPROM every 8k counts. Another part of the program reads TMR1H and TMR1L and transmits the result from the serial port at 250ms intervals.

The problem is that every now and then, TMR1L reads less than the last time it was read – by a number which varies – usually between 1 and 100. It hasn't overflowed, and I am reading the high/low byte correctly to eliminate rollover errors. On the ICE 2000 it works perfectly 100% – always. In a chip it randomly miscounts – always!

The real worry is that the code works so well on the ICE, and I wonder what other delights await me in code that I thought was OK!

I can't find any references to this problem, and the literature all says "TMR1 read is always correct – taken care of in hardware". Can you possibly add anything?

**Mark Stuart, via email**

*John Bradshaw, Microchip Engineering Support, responded, "Could be the errata for this device that is causing problems for you", and attached the PIC16F87x Rev. B5 Silicon Errata Sheet DS80051C, which highlights four problems with the chips not meeting datasheet specifications. In its third section (3. Module: TMR1) it states:*

When operating in external clock mode (TMR1CS is set), reading either of the timer 1 registers (TMR1H or TMR1L) may cause the timer not to increment as expected. This occurs for both synchronous and asynchronous inputs. The scenarios which display this are:

a) When a read operation of the TMR1H register occurs, TMR1L register may not increment.

b) When a read operation of the TMR1L register occurs, TMR1H register may not increment. This improper operation is only an issue when the TMR1L register increments from FFh to 00h during the read of the TMR1L register.

Work around – do not read either the TMR1H or the TMR1L register when operating in external clock mode (TMR1CS is set). If the application needs to read the 16-bit counter, evaluate if this function can be moved to the TMR0 or one of the other timer resources on this device.

*Thank you Mark, and John, that's very useful information. Readers, the errata sheet is on Microchip's website, [www.microchip.com](http://www.microchip.com).*

## THIRTY-YEAR EGG!

Dear EPE,

I just thought you may be interested to know that one of your projects from 30 years ago still works and is in frequent use. The *Egg Timer*, from *Everyday Electronics* May 1974, was the first project I built, starting when I was 14 and finishing some months later when I was 15.

The unit was designed by Robert Penfold, and uses a unijunction transistor as the timer. This trips a two-transistor bistable at the end of the timing period. A further two transistors, connected in a simple oscillator circuit, are then brought into operation resulting in a buzz from a loudspeaker.

The original article specified a plastic box, but I made a plywood console (rather over the top), and covered it with "contact" wood-effect adhesive plastic. I built the circuit board, sticking rigidly to the article details, but it didn't immediately work so I abandoned it for several months until I'd gained enough knowledge (helped by buying *EE* each month) to understand the operation and could systematically fault-find. Apart from a few component failures over the years, the unit works exactly as it has since Day 1.

Magazines like yours were a great inspiration to me, and I used to love the balance you had between theory and actual "hands-on" practice. I'm now the Technical Director of a medium-sized electronics company, and more's the pity I can't spend as much time as I used to with designing and engineering. It's good to see the magazine still in existence – with Mike Kenward still on the editorial staff – and I still buy it occasionally. Thanks with gratitude.

Peter F. Vaughan,  
Lynton, Devon, via email

*That's an interesting tale you tell Peter. I wonder how many readers have such ancient EE or PE designs still in use?*

*Mike is more than just "on the editorial staff", he is the owner of EPE and other publications through Wimborne Publishing Ltd. And I've known him for 32 years! He first worked on PE in 1968.*

## PEAK LCR ANALYSER

Dear EPE,

I have discovered that the "standard connector" on the Peak LCR Analyser (your *Readout Letter of the Month* prize) accepts an ordinary 0.1 inch header (square) pin. The Peak Semiconductor Analyser has no such connector, but by cutting off its existing microhooks and soldering on "standard connectors" (sold by Peak as spare leads for the LCR Analyser) it makes both testers compatible with the same tools/accessories.

I have suggested to Peak that they make this a production feature but I don't know if they'll adopt the idea.

Godfrey Manning G4GLM,  
Edgware, Middx, via email

*Thanks Godfrey. As I've said before, I find Peak's products excellent but even good products can sometimes benefit from later mods.*

## LOFT LIGHTS

Dear EPE,

Regarding the *Loft Light Alarm* in April '04, there is a problem. If the battery goes flat you get no indication the loft lights are left on next time round. Lateral thinking gives a foolproof answer – just cut a hole in the loft flap and glue in an empty picture frame so you can see the light glowing. No batteries and the only maintenance needed is an occasional flick over the glass every five years with the feather duster!

G. S. Chatley, via email

*Yes indeed, GS, I agree – but we are an electronics magazine after all, not Everyday Practical Woodworker (although one of our team actually worked on a similar title many decades back)!*

## PIC PROGRAMMING DISRUPTION

Dear EPE,

I use a scanner detector program on my computer. Having fired up the scanner the detector then carries on running in the background. I wonder if this explains why I've had problems programming PICs. Sometimes they program ok and sometimes not. I don't remember seeing any comment about it in *EPE*.

Alan S. Raistrick,  
via email

*Whilst I know about PICs, Alan, I'm not an expert on PCs and don't know the answer to your question. However, I have found that some pros should not be "minimised" in the background when programming PICs. The reason seems to be that the timing protocol required by the PIC in programming mode gets disrupted for some reason and so it does not fully accept some bytes. For example, my ancient Easy-PC CAD program, which is in DOS, thoroughly disrupts the process and has to be closed first. So the moral is to close down all you can if programming PICs. Using ALT-CTRL-DEL will open the window which tells you what's currently running.*

*I wonder if any readers can throw more light on this?*

## DISCO L.E.D.S?

Dear EPE,

Some time ago I was experimenting with l.e.d.s. and was impressed with the output of the super-bright types. In the dark they are able to light large areas with little in the way of current consumption. It occurred to me that enough of these super-brights could form the basis for a reasonable set of disco lights. They would most probably not be suitable for big venues but I think that they would suffice for most small dance areas and maybe prove to be better and more economical than conventional lights in some cases.

I expect that they could be driven by a PIC and who knows how many features could be built in. I have done nothing more than this casual glance at the output of super-brights, nor do I wish to get involved further, except perhaps to build myself a set should you produce a design.

I was a subscriber to the paper version of *Practical Electronics* many years ago. It was that magazine which helped me to pass my trade test in 1972. I stopped subscribing when the cost of the paper version became too high for me due to the low value of the Rand. Last year I subscribed to the electronic version of *EPE* and I am able to enjoy your magazine once again. Thank you for the high quality of your publication and the obvious enthusiasm that is put into the articles.

Victor Moisey,  
Cape Town, South Africa,  
via email

*That seems like an interesting and perhaps possible design, Victor. Would anyone else be interested in such?*

*Glad to know you've rejoined us!*

## MOON CLOCK

Dear EPE,

It was good to see the *PIC Moon Clock* article and its purpose in April '04. I am not actually a werewolf, and the days of moonlight serenading are, perhaps, long gone. But my moods – or perhaps my personal biorhythms are definitely dominated by the phases of the moon to such an extent that I can predict what my general mood and energy levels will be well in advance by a simple glance at any calendar showing moon phases. It is really a fascinating science, but no one I know of can explain it.

It was with this in mind that last year's summer semester project for my students at the University of Applied Sciences, Hamburg, where I teach technical English as an auxiliary subject, was to build a moon phase indicator! These students were mainly early semester students whose

knowledge had not really advanced to the levels of processing skills used for PICs, and indeed, neither was mine. However, they did make a valiant attempt getting the basic idea and calculations correct, but time and main examinations pending were our enemy so the project was suspended pending further development.

My projects are intended to get "keyboard kids" into the outside world, so we all enjoyed the experience – pity I did not know there was someone out there willing to fund such things. I'm sure motivation would have been much increased!

The PIC is certainly a wonderful invention, and like many of your readers, I have taken whole-heartedly to it. Being in Germany, one is a little "out of things" from our English language point of view, but I soldier on and now subscribe to *EPE*.

Lawrence Harris,  
Hamburg, Germany, via email

*When the world was young Lawrence (and me with it – say in the 1960s), there used to be a social craze amongst students to create biorhythm charts for themselves so that they could "predict" their future behaviour across days or weeks. Apparently there are many biorhythmic cycles associated with moods, and whose repetition rate differs from moon cycles (supposedly provable on a clinical basis, and in no way associated with astrology).*

*I have no idea whether such "philosophies" are followed now, but if so, perhaps a PIC-based biorhythm display generator might make an interesting project for someone to design.*

## LEAD FREE OK

Dear EPE,

After reading the *Coping with Lead-Free* article in the May '04 issue, I picked up my trusty Weller 25W soldering iron and a roll of lead-free solder as used by plumbers. Coupled with a suitable flux, in my case LaCo, I cleaned the tip thoroughly so that there was no lead solder residue and then proceeded to solder a few resistors to a piece of stripboard. All joints were completed satisfactorily and I then soldered an 8-pin d.i.l. socket, again with satisfactory results.

The only problem is the fact that the solder is rather thick, 10s.w.g. It may be possible to lightly hammer it so that it thins out.

I hope the foregoing is of some help to those looking for an alternative.

Les Pitt,  
Harborne, Birmingham,  
via email

*Thanks for your input Les. It'll hopefully reassure readers about lead-free. I've not tried alternatives yet, but the time will have to come.*

## GO-KARTS

Dear EPE,

I have several second hand go-karts with electronic remote control ignition immobilisers that need renewing. Unfortunately I do not know any information about their make or manufacturer and am hoping you may be able to help. The only evidence I can find from examining an opened circuit is the writing, F101-012050A, 951128 and 6621 clearly written on the circuit board.

These are essential to us and very sought after as they enable us to stop the engines by remote control.

Anthony Ward,  
via email

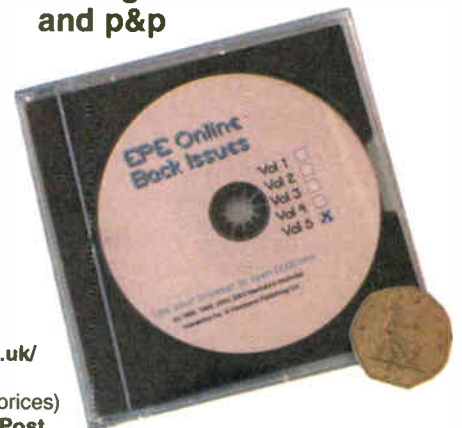
*Apart from driving go-karts in the 1960s I have no knowledge of them Anthony. Nor do I recognise the part numbers you quote – perhaps they are specific to only one manufacturer. If any reader can help, please email me at HQ. It would also be worth asking readers via our ChatZone (access through [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk)) to see if anyone there can help.*

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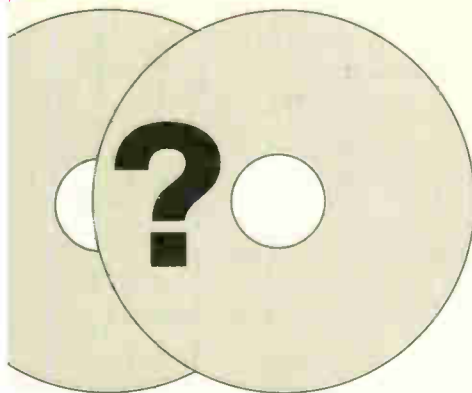
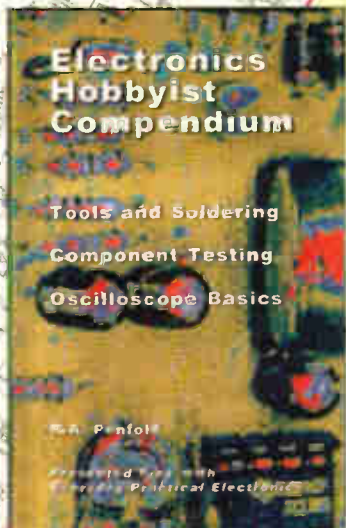
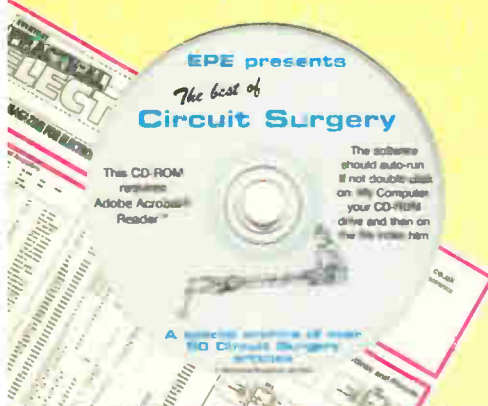
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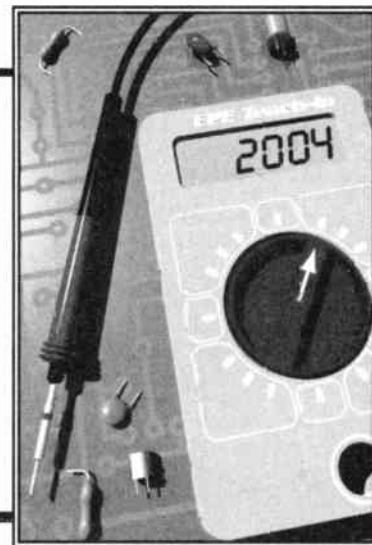
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# TEACH-IN 2004

## Part Nine – Lock and Alarm Systems

MAX HORSEY



**How to apply electronics meaningfully – the aim of this 10-part series is to show, experimentally, how electronic components function as part of circuits and systems, demonstrating how each part of a circuit can be understood and tested, and offering advice about choosing components**

**T**HIS month we examine the use of latching and timing circuits as required in alarm systems, and then see how a keypad can be employed instead of a keyswitch, in order to activate and deactivate the alarm.

One of the simplest ways of creating a latching circuit is by means of a relay, and Fig.9.1 shows a simple relay with a single pair of contacts. Photo 9.1 shows two relays, both of which serve the same purpose, but appear different.

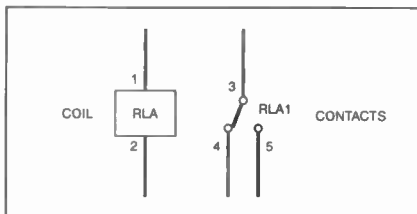


Fig.9.1. Symbol for a simple relay with a single pair of contacts.

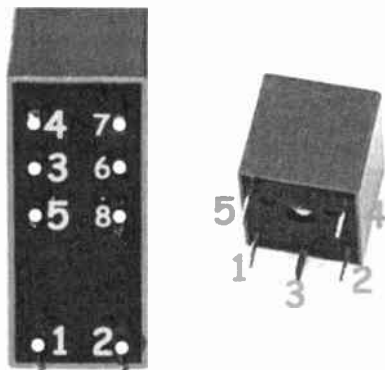


Photo 9.1. Two examples of p.c.b. mounting relays. The numbers relate to Fig.9.1.

Note when buying a relay to ensure that the coil voltage matches the voltage of your power supply, 12V in our case. The contact rating should be the same, or greater than the voltage and current you wish to switch. Many relays have a contact rating of 125V. These are fine in low-voltage work (such as

the applications in Part 9) but if you intend switching a.c. mains voltages, ensure that the relay contacts are rated at 250V or more (**you must be suitably qualified or supervised if you intend to connect to a.c. mains voltages, since they can be lethal**).

There is, unfortunately no general agreement on how a relay is labelled or the pins are numbered. Even worse, the p.c.b. mounting relays have so-called “standard layouts” which are anything but standard! In fact, there are at least three different designs, all with different pin spacings. Hence, if you design a printed circuit board, ensure that you check the pin spacings of the particular relay you intend using!

The pin numbers shown in Fig.9.1 are purely for identification and comparison with Photo 9.1. Pins 1 and 2 are connected to the coil. It does not matter which way round you connect these pins in the circuit unless the relay coil has a built-in protective diode. Very few do, but if your relay includes a diode, there should be a diode symbol on the casing showing how it is connected.

Relay pins 3, 4 and 5 are connected to the switch contacts of the relay, pin 3 being the centre (moving) pole, and pins 4 and 5 the “ways” (selectable switching routes). The contacts can be likened to a single-pole changeover (s.p.c.o.) switch. When the relay coil is not energised, pin 3 is connected to pin 5. When the coil is connected to a 12V supply, pin 3 connects to pin 4.

### TESTING A RELAY

When you buy a relay it is often difficult to tell which pin is which. Photo 9.2 shows how the pins can be tested with a multimeter set to resistance measuring range. A particularly complicated relay has been chosen in this illustration, and you should begin by identifying the coil connections.

The pins connected to the coil should indicate a resistance of over 10Ω, probably a few hundred ohms. The pins connected to the relay contacts will either produce a reading of infinity (open circuit), or virtually zero (i.e. making contact). Note that

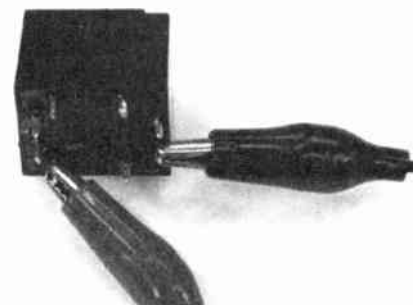


Photo 9.2. Checking the functions of relay pins.

relay contacts are often labelled NO (or n.o.), meaning *normally-open* and NC (or n.c.) meaning *normally-closed*. The pins being tested in Photo 9.2 are NO and show a reading of zero ohms when measured on the multimeter.

### LATCHING RELAY

A relay can be made to switch on a buzzer as shown in Fig.9.2. The push-to-make switch, S1, is used to energise the relay coil, this in turn causes pin 4 to be connected to positive via pin 3. Hence the buzzer sounds. Now, if pin 4 is connected to pin 1, pin 1 will remain positive, even if the pushswitch is released. This connection from pin 4 to pin 1 is known as a *feedback loop*. Notice that the relay contacts are

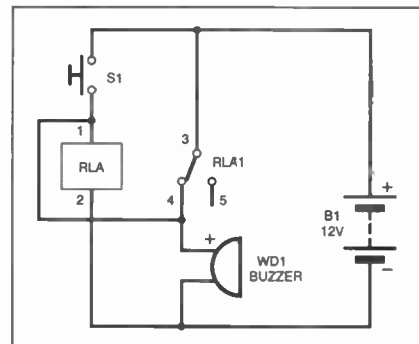


Fig.9.2. Example of how a relay might be used to control a buzzer.



effectively bypassing switch S1. The buzzer will remain on until the power supply is disconnected.

### Alarmed

The latching relay can form the heart of an alarm system if S1 is a microswitch fitted to a door, so that as the door is opened, the switch closes (turns on). This will cause the relay to latch, so keeping the buzzer active, even if the door is closed again.

### Resetting

To reset the alarm, a key operated switch (keyswitch) could be wired in series with the power supply, or inserted into the feedback loop.

### Annoyance

This type of system is unsuitable as a full-scale house alarm or car alarm, since such systems are required to turn off after about 15 minutes to avoid causing undue annoyance to neighbours. You *could* employ a small 12V battery, and ensure that the buzzer or siren uses sufficient current to drain the battery after a short time, but later we will use logic gates to provide timed alarms.

## THYRISTOR

Relays are a little cumbersome and current-hungry, and so a better means of latching an output is offered by a thyristor, sometimes called a *silicon controlled rectifier* (SCR). Thyristors are similar to transistors, except that they "latch-on". In other words, a small current made to flow into the gate (g) causes a large current to flow from the anode (a) to the cathode (k). Once current starts to flow from a to k it continues to flow even if current stops flowing into the gate.

A basic thyristor circuit is shown in Fig.9.3. Virtually any type of thyristor can be employed, providing it can handle the current required by the buzzer. A type C106D is suggested (a TIC106D will also be satisfactory) since this can switch more than sufficient current for typical buzzers and sirens.

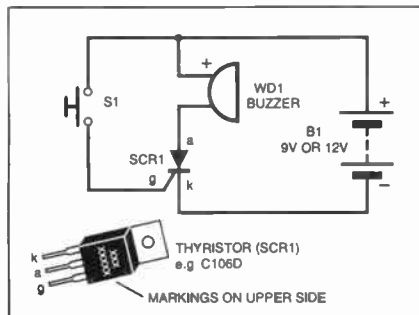


Fig.9.3. Example of how a thyristor might control a buzzer.

In theory, the buzzer (WD1) should remain off until you press switch S1. The buzzer should then sound, and remain sounding even if S1 is released. However, the circuit will probably fail! Firstly, the buzzer is likely to conduct a rather erratic current. As the flow rises and falls, it may fall sufficiently to allow the thyristor to reset. So the circuit fails to latch.

You could replace the buzzer with a small bulb or l.e.d. (light emitting diode) and a series resistor, but a simple solution is

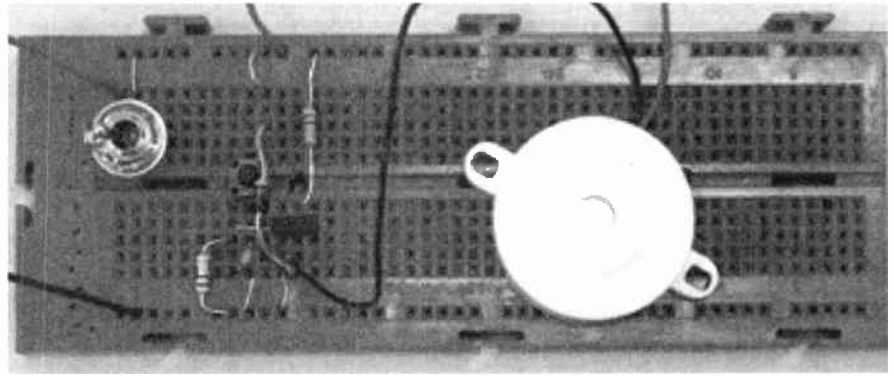


Photo 9.3. Breadboard assembly of the circuit in Fig.9.4.

shown in Fig.9.4 in the form of resistor R2. This provides a steady supply of current regardless of that used by the buzzer, and so helps the thyristor to remain latched. The circuit assumes that a solid-state type of buzzer is employed, otherwise a protective diode should be fitted, shown as D1.

The circuit should now latch properly, but may be prone to false triggering – something particularly irritating in alarm systems! So resistor R1 is employed to hold the gate at 0V unless the switch is pressed. Another wise addition is capacitor C1 which bypasses any stray interference caused by mains appliances being switched on or off. The circuit shown in Fig.9.4 (and Photo 9.3) offers a simple but effective alarm system, and keyswitch S2 can be used to turn off or reset the system as required.

### TRIGGERING THE ALARM

So far we have employed a simple switch to trigger the alarm. While this is fine for simple systems, there are many alarm trigger switches available which offer other advantages. To understand these switches, we need to clarify the fundamental difference between a normally-open switch, and a normally-closed switch.

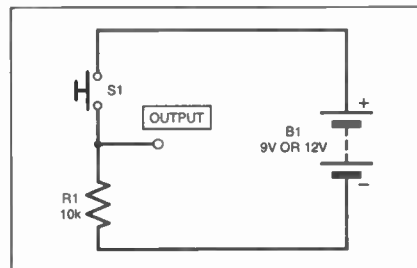


Fig.9.5. Using a normally-open switch to change an output voltage.

The circuit in Fig.9.5 shows a normally-open switch, S1, in series with a resistor, R1. The value of the resistor is not critical, though it needs to conduct enough current to allow reliable operation of whatever is connected to the output. If the output is connected to a logic gate or the input of a PIC microcontroller, then R1 can be increased to say 100kΩ, so reducing the current drain from the battery.

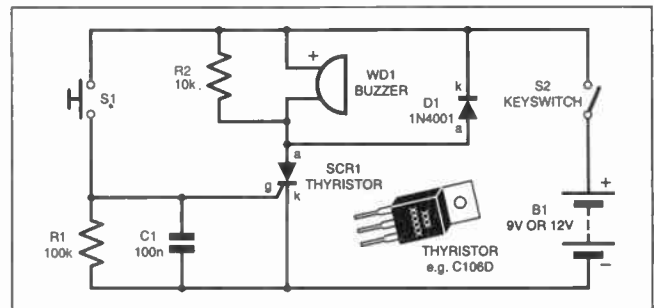


Fig.9.4. Modified circuit of Fig.9.3 which provides greater reliability.

When switch S1 is open (i.e. not pressed) resistor R1 ensures that the output is at 0V. When S1 is pressed, the output switches to positive.

An alternative circuit is shown in Fig.9.6. The switch is a normally-closed type. Hence the output will be at 0V. However, if the switch is pressed, the output will switch to positive, via resistor R1 (whose value can be changed as stated for Fig.9.5).

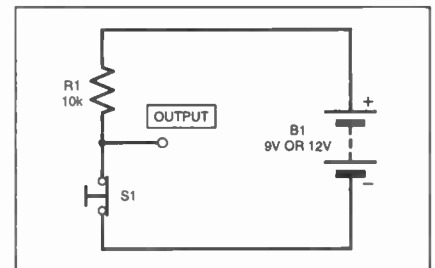


Fig.9.6. Using a normally-closed switch to control an output voltage.

Normally-closed switches are popular in alarm systems since they offer "fail-safe" operation. In other words, if the switch becomes disconnected, or if the intruder cuts the wires, the circuit is triggered.

### TYPES OF SWITCHES

A range of alarm switches is shown in Photo 9.4. The microswitch (an odd name, since it is generally larger than the other types!) has three pins, like the relay discussed earlier. Hence it can be used as a normally-open or normally-closed switch.

The reed switch and magnet is a popular method of monitoring doors and windows. When the door or window is closed, the magnet is alongside the switch and the contacts close. It therefore behaves as a normally-closed switch. Always employ reed switches and magnets which are housed in a plastic case, since they are much more reliable. The sunken type shown is almost

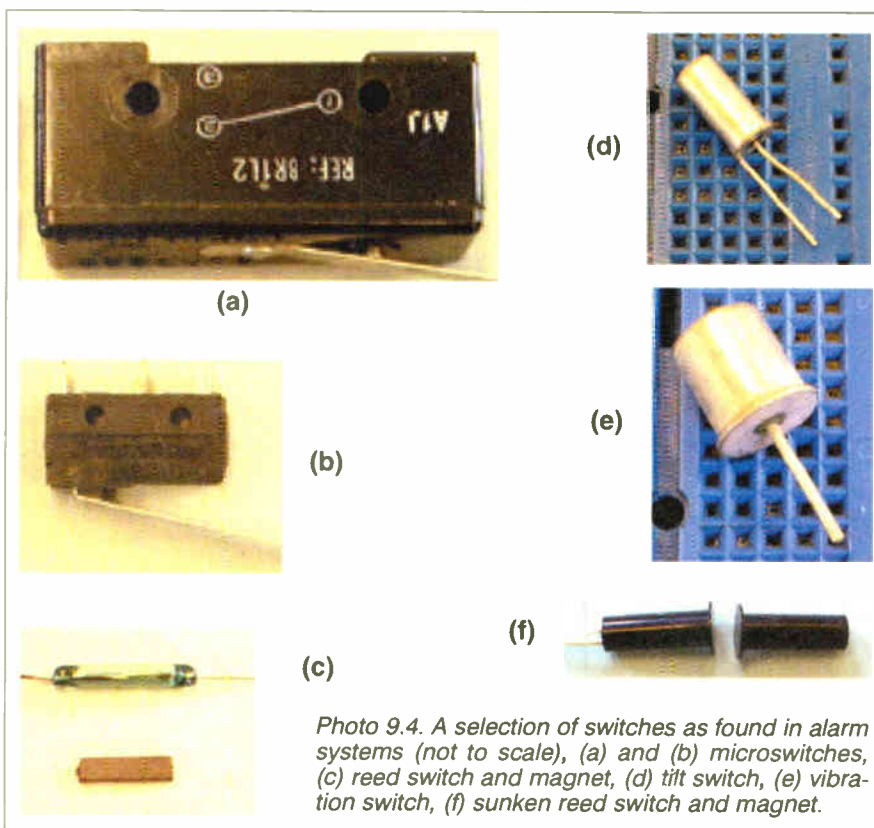


Photo 9.4. A selection of switches as found in alarm systems (not to scale), (a) and (b) microswitches, (c) reed switch and magnet, (d) tilt switch, (e) vibration switch, (f) sunken reed switch and magnet.

circuit to silence the alarm after about 15 minutes. We looked at timing circuits, otherwise called "monostables", based on logic gates in Part 4, and on the 555 timer in Part 8. We can turn any of these monostables into an alarm circuit by connecting the trigger switches to the appropriate input, as shown in Fig.9.7.

Note that these diagrams are to illustrate how the sensor switch is connected to provide a positive signal or negative signal; they are not intended to be complete circuits.

The monostable based on NOR gates requires a positive signal to trigger the timer. The monostable based on the 555 timer requires a negative-going (0V) trigger signal. Note how the switch and resistor can be interchanged to provide the correct polarity of signal. In both cases, we have assumed that the switch is a normally-open type (like an under-carpet pressure mat). If you use a normally-closed switch (e.g. a reed switch and magnet) then swap the resistor and switch in each circuit.

### FULL ALARM CIRCUIT

We will now develop the NOR gate version a little more, as shown in Fig.9.8 and Photo 9.5. It should be stressed that the circuit will not include delayed entry or delayed exit option; if you require these

invisible when fitted into holes drilled in the door and door frame.

The tilt switch is useful when monitoring portable equipment such as a video recorder. It can be used as a normally-open or normally-closed switch, depending upon the angle at which it is housed.

The vibration switch can be employed in equipment which may be left in any position, such as a bicycle. It is normally-open, and the contacts close briefly when it is moved.

Note that you must only use tilt and vibration switches which are said to be "mercury-free", as mercury is a toxic substance.

A number of other switches are available, including "glass break detectors" and under-carpet pressure mats. There are also more elaborate systems such as ultrasonic sensors – often employed in car alarms.

### PASSIVE INFRA-RED (PIR)

The most popular type of house alarm sensor is the PIR (passive infra-red) unit,

which can monitor a large room and detect any movement of a warm (e.g. human) object. Most PIRs include a reed-switch relay which is normally-closed, opening when triggered.

False triggering can be a problem, and the better PIRs require several "triggers" in quick succession before activating the alarm system. Even so, they can be set off by a moving cold object such as a sheet of paper, or a large spider if very close to the sensor window.

### TIMING CIRCUITS

An alarm system can be very annoying, particularly if the siren sounds for many hours (actually an illegal situation in the UK)! Hence it is usual to use a timing

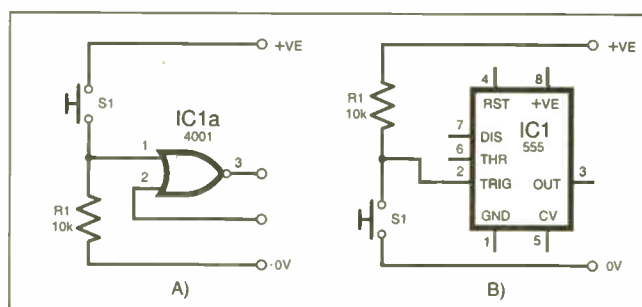


Fig.9.7. Connecting trigger switches to monostable inputs based on (a) NOR gates, (b) 555 timer.

additions, a PIC-based alternative is described later.

Two NOR gates (IC1a and IC1b) are employed to make a monostable circuit, with timing components C2 and R2. This type of circuit was described fully in Part 4 and so will not be described here. The timing period offered by the values of C2 and R2 indicated in Fig.9.8 is given by:

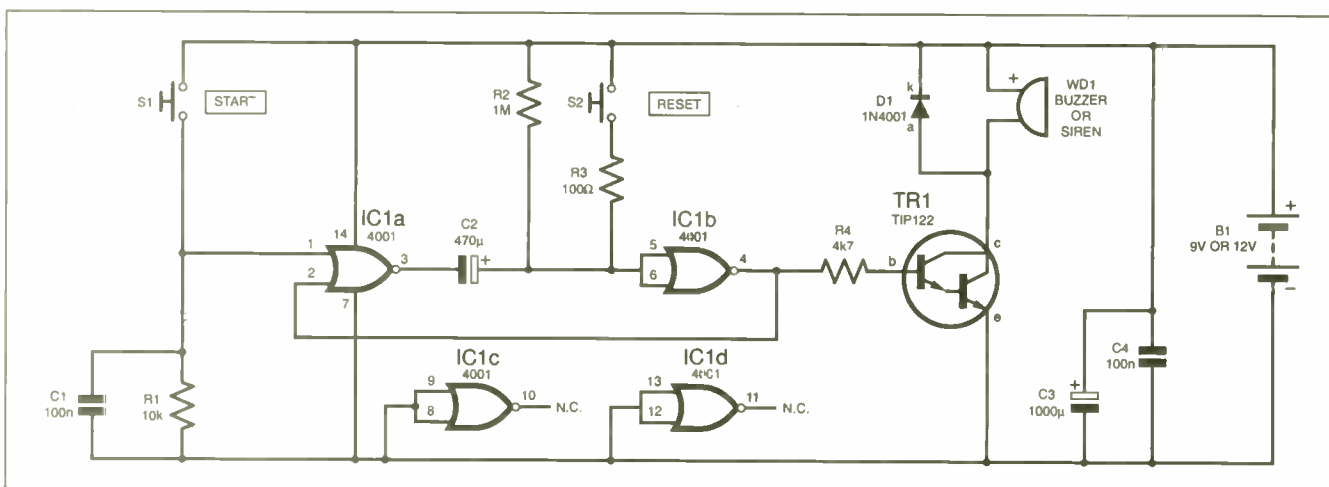


Fig.9.8. An alarm circuit based on a NOR gate trigger function.

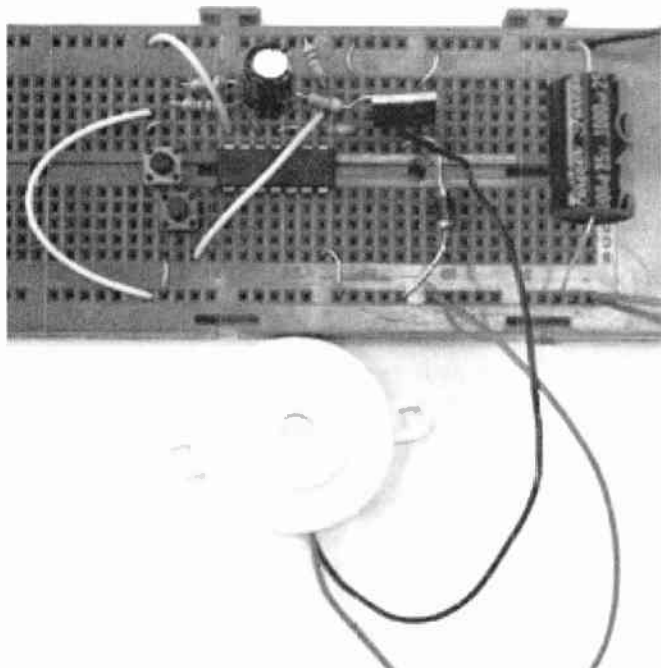


Photo 9.5. Breadboard assembly of the circuit in Fig.9.8.

$$\begin{aligned}
 \text{Time} &= 0.7 \times C2 \times R2 \\
 &= 0.7 \times 470\mu\text{F} \times 1\text{M}\Omega \\
 &= 0.7 \times 470 \times 1 \text{ (since } \mu\text{F cancels} \\
 &\text{with M}\Omega\text{)} \\
 &= 329 \text{ seconds} \\
 &= 5.5 \text{ minutes approximately}
 \end{aligned}$$

Remember that electrolytic capacitors are not made with accurate values, and the actual time achieved may differ by up to 50%. The time can be doubled by employing a value of 1000 $\mu$ F for C2, but remember that current leakage through the capacitor can affect the timing, especially if very large values of electrolytic capacitors are employed, making the timing period even more unpredictable. Also, very long timing periods can make testing tedious!

If Reset switch S2 is pressed, the capacitor will charge very quickly via resistor R3, and so the alarm will stop sounding. In practice S2 could be a keyswitch. The purpose of R3 is to limit the rush of current which would otherwise flow as the capacitor charges.

For reasons described in detail in Part 4, the voltage at pins 5 and 6 of IC1 may rise above the supply voltage, and so – in real life – the gates are internally fitted with protective diodes to shunt the current safely away.

Alarm systems often employ long wires between the switches or sensors and the circuit. This poses a problem since a fairly high voltage caused by mains equipment being switched on or off can be induced into the wire. Since these induced voltages are very short (i.e. spikes) they can be removed by adding a capacitor, C1 in this case.

## OUTPUT

Whenever the output of a gate is used to feed the input of another active circuit component, it is important to not draw too much current from the output, otherwise the output voltage will fall to a lower value than required. Hence resistor R4 is set at 4.7k $\Omega$  to limit the current flowing from IC1b pin 4 into the base (b) of transistor TR1 to 2.5mA (on a 12V supply).

In order to amplify this current sufficiently to drive a siren (WD1), a Darlington pair transistor is employed as TR1. Assuming a gain of 1000 (most Darlington offer even higher gains), 2.5 amps would (in theory) be available for the siren. In practice your buzzer or siren will require much less than this, but it is always wise to design a circuit with plenty of "headroom".

The protective diode D1 removes spikes caused by back e.m.f. from the siren, and capacitors C3 and C4 decouple the circuit, hence helping to provide a steady supply voltage.

Since there are four NOR gates in the CMOS 4001B, the unused inputs must be connected to 0V (or the positive power rail) to prevent them oscillating. The unused outputs must remain unconnected.

## EXTRA SWITCHES

Any number of normally-open switches can be added in parallel with the first switch, S1, as shown in Fig.9.9.

If you are using normally-closed switches, then these must be connected in series, and the connection method is shown in Fig.9.10.

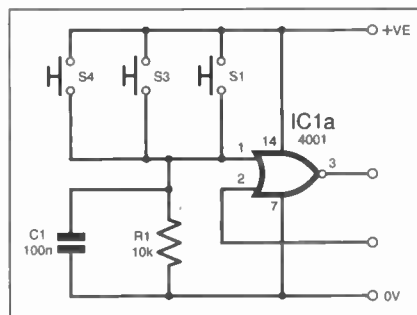


Fig.9.9. Use of multiple normally-open trigger switches.

Note that in this simple circuit, you cannot combine normally-open and normally-closed switches.

## LATCHING INDICATOR

An alarm system with too many trigger switches can become a nightmare if false alarms occur, since you have no way of knowing which switch triggered the system, and the timed siren output means that you have no way of knowing if an alarm occurred during a long period of absence.

In a professional alarm system, each

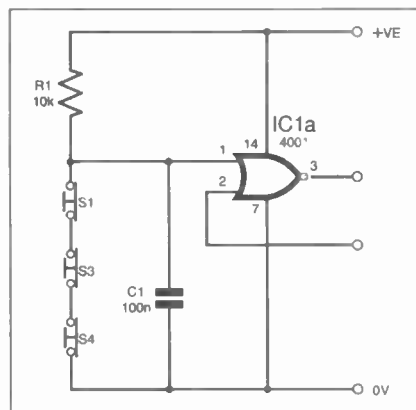


Fig.9.10. Use of multiple normally-closed trigger switches.

switch or sensor is connected to a latching input stage with an indicator light, so that the offending switch can be noted and checked, even after resetting the alarm. We can employ the two spare gates (IC1c and IC1d) to make a latch, and the whole system is shown in Fig.9.11 and Photo 9.6.

There are several ways of making two gates latch (as discussed in Part 4). The method chosen here uses gate IC1d as an inverter, hence making NOR gates IC1c and IC1d together behave like a single OR gate. When S1 is closed, the output from IC1d switches to logic 1 (high), so triggering the timer as before. This logic 1 also feeds back to pin 8 of IC1c, so holding both IC1c and IC1d in this latched state even if S1 is released.

The monostable will time correctly even if pin 1 of IC1a remains high. Part of the current from IC1d pin 11 is used to switch on transistor TR2, via resistor R6, and hence l.e.d. D2, so indicating that the system has been triggered.

Switch S2 now becomes an s.p.c.o. keyswitch. As shown, in its upper position the alarm system is active, but in its lower position the siren is silenced (if it was triggered) and the latching circuit is inactive – allowing normal use of the door or other item which controls S1.

Note, however, that if IC1d pin 11 is high, it will still remain so, allowing you to see that the alarm had been triggered, even if the siren had timed-out. The latch can be reset by pressing S3, which can either be a concealed switch, or another keyswitch. Resistor R5 prevents a short-circuit from IC1d output pin 11 when S3 is pressed.

## ADDITIONAL INDICATORS

Since IC1c and IC1d behave as an OR gate, we could alternatively employ a dedicated OR gate device, such as a type 4071B. This would also allow you to mix

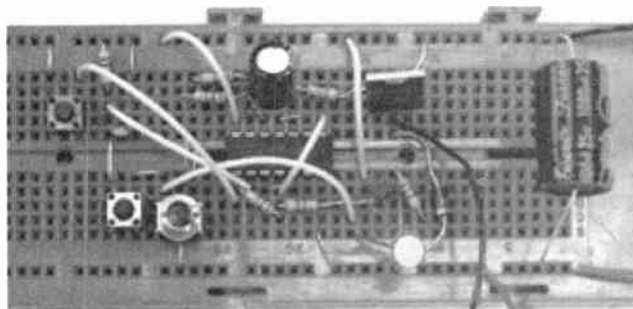


Photo 9.6. Breadboard layout of the circuit in Fig.9.11.

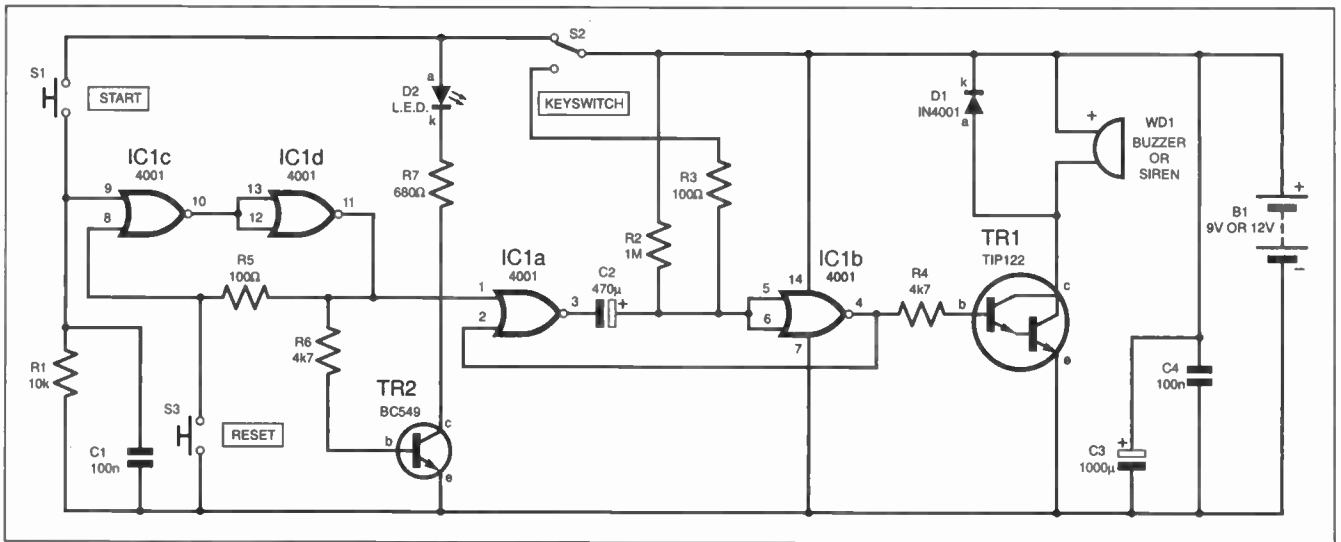


Fig.9.11. Adding a latch circuit to Fig.9.8.

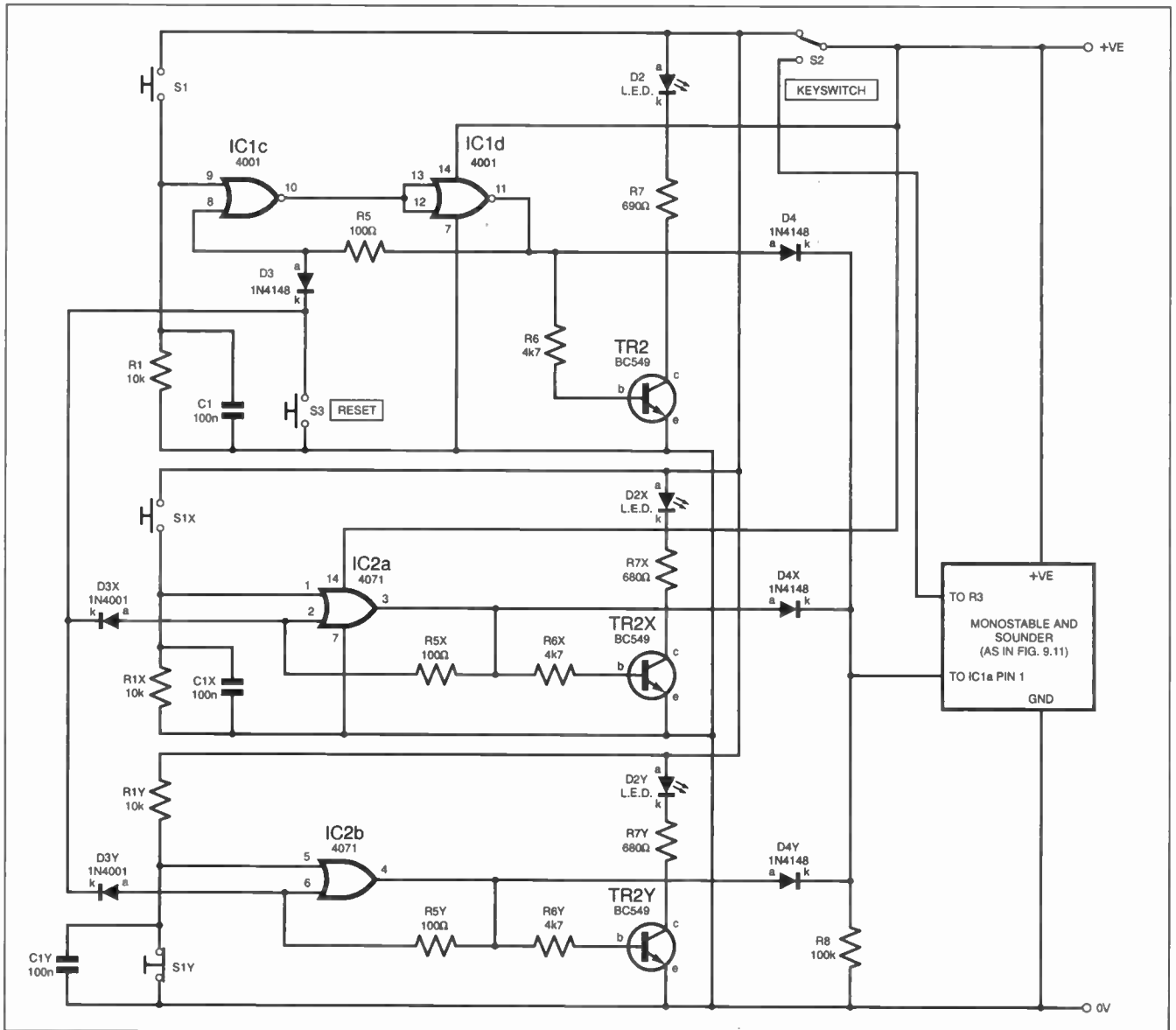


Fig.9.12. Improving the circuit of Fig.9.11 to allow use of both normally-open and normally-closed trigger switches.

normally-open and normally-closed switches in the same alarm system, as illustrated in Fig.9.12.

The original latching input stage of the circuit is shown in the upper part of Fig.9.12. Below it are the circuits for two additional inputs, one for a normally-open switch (S1x), the other for a normally-

closed switch (S1y). Since there are four gates in the 4071 quad OR gate package we could even add two more input stages, each with an indicator l.e.d.

The output of each stage, including that around IC1c and IC1d, is connected to the monostable (i.e. to pin 1 of IC1 in Fig.9.11) via a diode, shown as D4, D4x, D4y. Note

that "pull-down" resistor R8 is necessary to prevent the input of the monostable "floating" when none of the input stage outputs are high.

Each stage could have an independent "unlatching" switch, but Fig.9.12 shows how the single switch S3 can be used to reset all the input stages, providing that

diodes D3, D3x, D3y are used (as shown) to prevent one stage feeding back to another stage.

Considering that we have only shown three input stages, the circuit is beginning to look complicated, and if more than five independent inputs are required, another i.c. will be needed. Remember too, that we have not included delayed entry or exit, and so the keyswitch will have to be accessible from outside the house (or garden shed etc.).

At this stage the advantages of a PIC microcontroller start to beckon . . . plenty of inputs, ample current to drive an i.e.d. directly from each output, accurate timings without using electrolytic capacitors, and delayed entry and exit. So we shall now describe a simple PIC latching and timing system which improves upon the action of the circuits in Fig.9.11 and Fig.9.12.

### SIMPLE PIC SOLUTION

Why does the above heading say "simple"? There have been a number of excellent alarm systems based on PICs and published in *EPE*, including another in this issue (*Portable Mini-Alarm*) and there is no point in re-inventing the wheel. So we will develop a very simple system based on a PIC16F627, with a program written in a form of BASIC which also works with the version of this PIC known as PICAXE-18.

As detailed later, the BASIC version for use with the PICAXE-18, or the hex version for conventional programming of a PIC16F627, can be downloaded from the *EPE* website. PICAXE-18 devices were described in Part 5.

Our system is key-operated (numeric keypad decoding will be discussed later), and has the following features:

- 2 zones normally-open
- 2 zones normally-closed
- entry delay with pulsed warning buzzer
- exit delay with pulsed warning buzzer
- siren timer (10 minutes)
- zone indicator lights, to check which zone has been triggered

The schematic diagram is shown in Fig.9.13. Its test assembly breadboard layout is shown in Photo 9.7, but note that to simplify the circuit a little, the voltage regulator (IC2) has been omitted from the breadboard, so that the whole circuit is operated on a 4.5V or 5V supply. Also, all the 100nF capacitors have been omitted, since they are not essential to this test circuit.

The TB1 connector allows the PICAXE-18 version to be programmed directly in BASIC from the serial output port of a computer. TB1 may be omitted if this type of programming is not desired, but resistors R1 and R2 must be retained in order to hold IC1 pin 3 at 0V.

IC1 pin 4 must be held high to allow normal operation, but is pulled briefly to 0V in order to reset the i.c. This is rarely needed, and so two terminal pins are suggested, labelled TP1 and TP2. These may be bridged with a screwdriver blade or coin in order to reset the system.

Two input zones are controlled by normally-open switches, S1 and S2. These could be under-carpet pressure mats, suitably wired microswitches, or vibration switches etc.

The two other zones are sensed by normally-closed switches S3 and S4. These

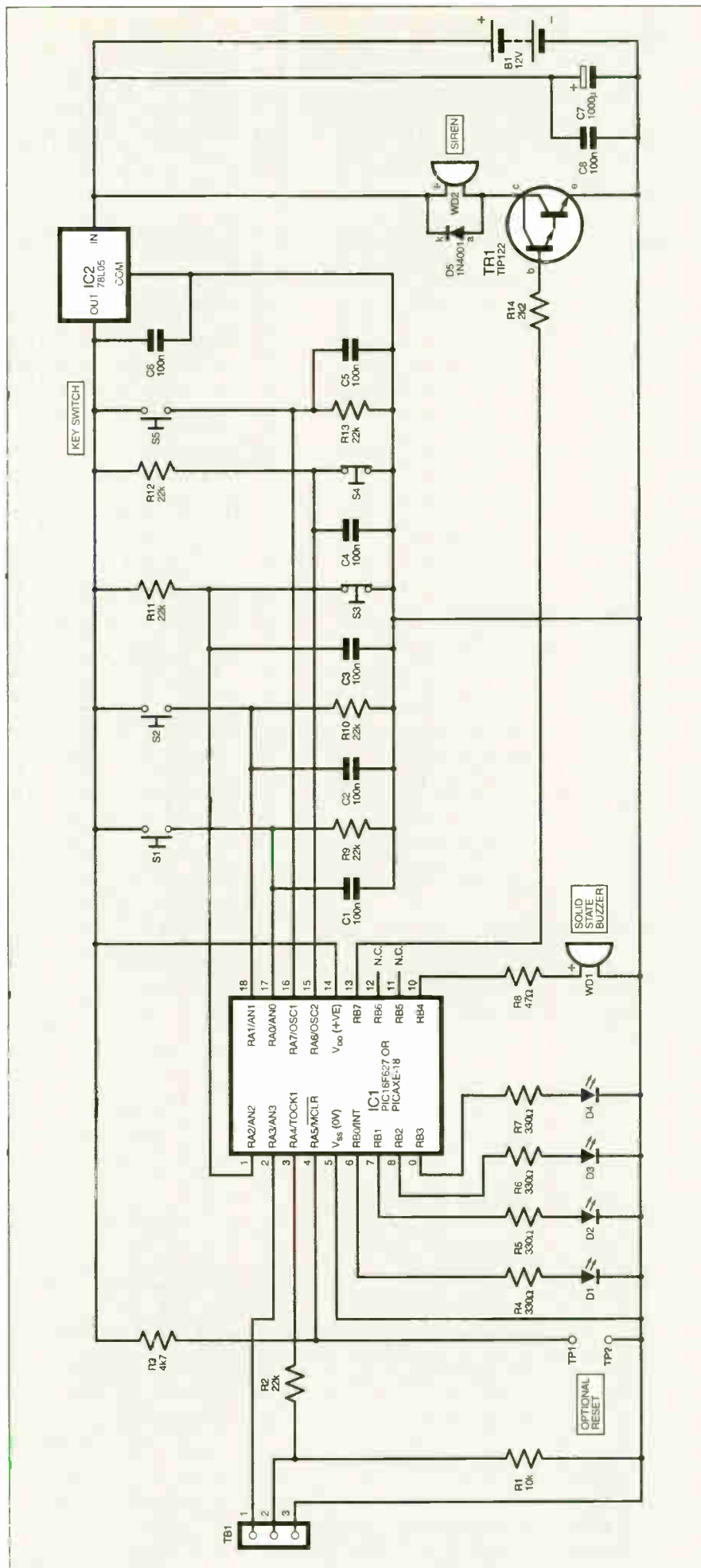


Fig.9.13. Circuit diagram for a simple PIC-based alarm system.

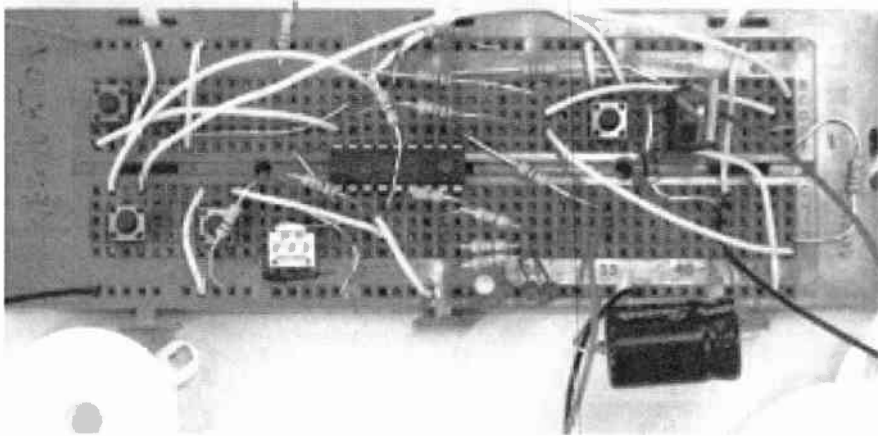


Photo 9.7. Breadboard layout of the circuit in Fig.9.13.

could be reed switches for door or window protection, or the alarm connections of PIR motion detectors. Remember that PIR units also require a power supply, generally 12V.

Each input is pulled high (positive) or low (0V), as required, by a 22kΩ resistor (R9 to R13). Since the wires connecting the zones to the circuit may be very long, capacitors of 100nF (C1 to C5) are used to bypass any interference which might cause a false alarm. The program also checks for and eliminates very brief pulses, so avoiding false alarms wherever possible.

Switch S5, which may be a keyswitch, is connected in a similar way to the zone switches, and is a normally-open circuit. The alarm is set by turning on the switch, and deactivated by turning it off; note that the switch also performs the function of resetting the zone indicator i.e.d.s D1 to D4. If any zone has been activated, the keyswitch must be switched off (silencing the siren, WD2. and/or buzzer, WD1, if triggered), then flicked on then off to reset the i.e.d.s.

## BASIC PROGRAM

The BASIC version of the program has been fully annotated in order to explain the program structure. The "pause 50" commands within it provide a delay of 50ms which eliminates the effect of voltage spikes at any input, and removes any switch bounce. However, capacitors C1 to C5 should be retained, since although they perform a similar function, they will also remove any continuous a.c. interference induced into the long wires.

Note that the program looks for logic highs at the alarm inputs, and so the circuit is arranged to provide the normally-open configuration for switches S1 and S2, and the normally-closed configuration for S3 and S4. The system is quite flexible, though, in that S1 can easily be interchanged with R9 to create another normally-closed input, and any of the other inputs

can be changed in a similar way to change from normally-open to normally-closed, and vice-versa.

A keyswitch alarm system is effective and easy to operate, providing you do not lose the key! We will now look at combination-code entry systems, so removing the need for a key.

## COMBINATION LOCKS

A simple type of combination-system is a hard-wired set of rotary switches, as shown in Fig.9.14 for example. Each switch, S1 to S4, is a single-pole 12-way rotary switch. If all four switches are at specific settings – in order of 7396 in this case – then the buzzer, WD1, will sound. It would take a long time to find the correct combination by random or sequenced movements of the switches.

The circuit could be combined with the previous alarm circuits, where a relay could replace WD1 in Fig.9.14. and the relay contacts used in a normally-closed or normally-open configuration as required.

You could use the four rotary switches to directly replace the keyswitch in Fig.9.13, except that the action needs to be reversed,

as you need the particular combination to switch off the alarm, not turn it on! So in Fig.9.13, a 22kΩ resistor could be fitted in place of S5, and the complete array of rotary switches connected in place of resistor R13.

The problem with this type of system is that it is quite difficult to change the correct combination number. However, if tags were used to push onto the switch contacts, the positions could be easily changed, at least by somebody electrically competent – the constructor of the circuit for example.

## PUSHBUTTON COMBINATION

A simple pushbutton switch system can be based upon the latches first examined in Part 4. The principle is that with, say, nine switches, four are used as "correct entries" and five are incorrect, as shown in block diagram form in Fig.9.15.

Each latch only works if its Enable input is held high. Hence the Enable input of the first latch is connected permanently high, so allowing a particular switch (Switch 1 in this case) to be active. Of course, Switch 1 will be any desired number on the keypad, not necessarily number "1".

When Switch 1 is pressed, the first stage latches, and its output enables the second latch, ready for Switch 2 to be pressed. If any wrong switch is pressed, the whole system is reset.

Note that if the correct switches are pressed in the wrong order, then the system does not reset, and this could be regarded as a flaw. It would be possible to solve this, but – as always – a single PIC could achieve this, and much more, and so at this stage we will keep the system simple. In any case, it would be easy to add more "incorrect switches" to make the chance of randomly pressing the correct sequence even more unlikely.

It would be possible to connect each "correct switch" in series between the output of a latch and the input of the next latch.

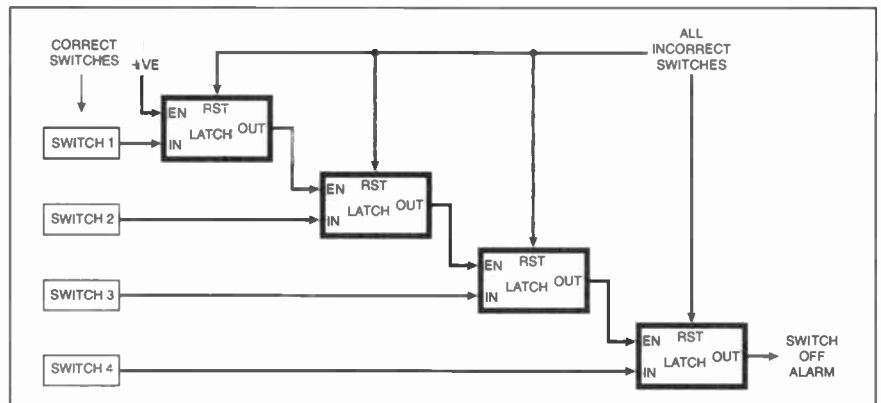


Fig.9.15. Schematic representation of a latch-based combination switch.

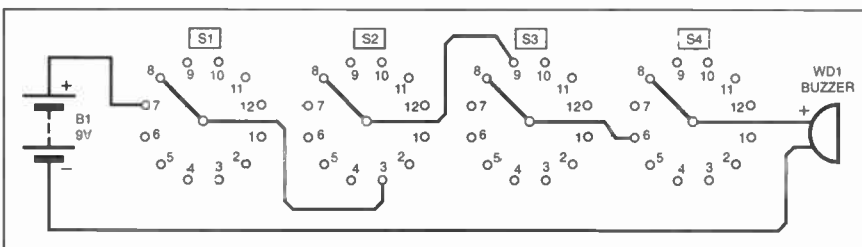


Fig.9.14. Example of using rotary switches to provide a combination-code buzzer control.

But employing the system shown allows all switches – correct or incorrect – to be connected to a common positive rail. It is therefore much easier to change the combination as required.

There are many ways of achieving the system using logic gates and ready-made latches. But we now describe a circuit that employs a single chip, the 4081B quad AND gate. An AND gate can be made to latch if its output is fed back to an input, and its other input is held at logic 1 (high).

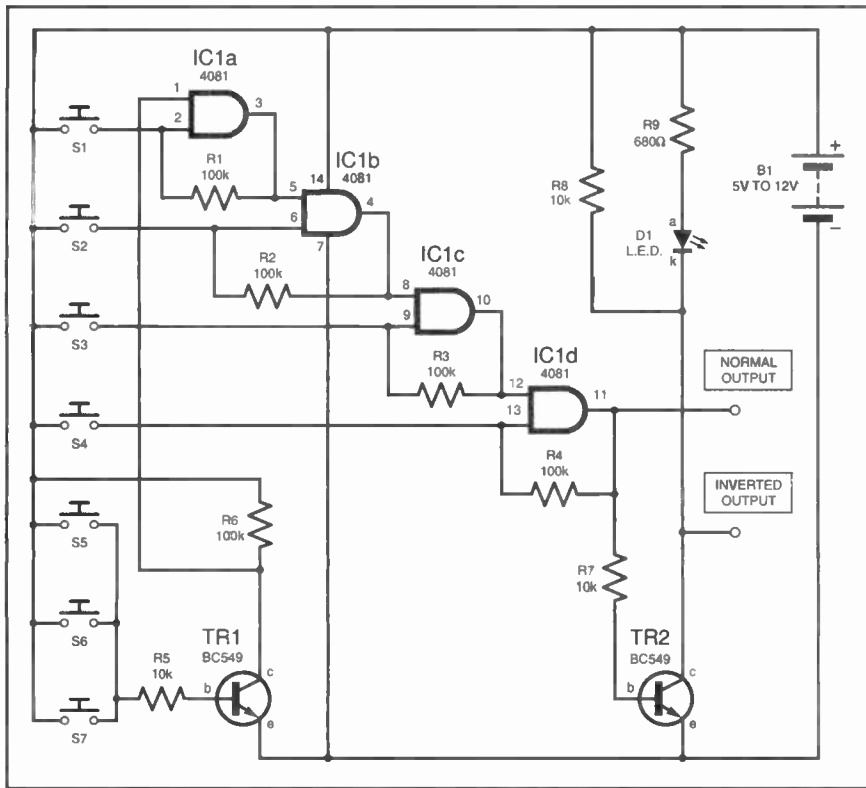


Fig.9.16. Combination switch system based on AND gates.

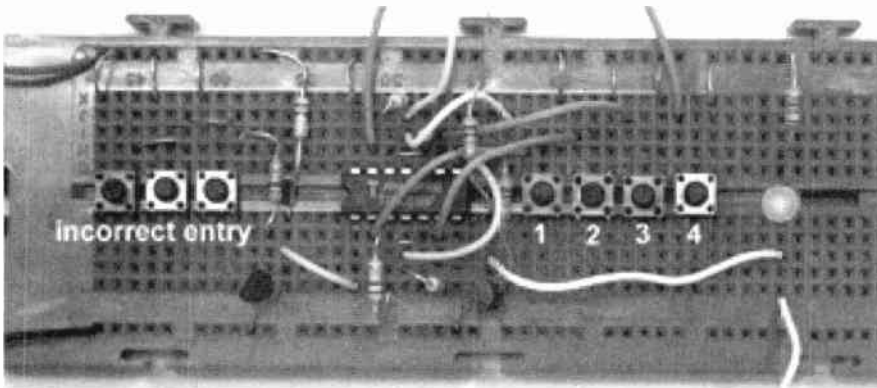


Photo 9.8. Breadboard assembly of the circuit in Fig.9.16.

The example circuit is shown in Fig.9.16 and in Photo 9.8. Transistor TR1 is normally in a "switched off" condition when switches S5 to S7 are unpressed (open-circuit), and so resistor R6 sets IC1 pin 1 high. Hence if S1 is pressed, IC1a pin 2 is made high, and the output at IC1a pin 3 also goes high (see Part 4 for logic gate input-output rules).

Resistor R1 feeds this logic level back to IC1a pin 2, so that if S1 is now released, the gate latches with its output high. Note that resistor R1 is needed (rather than a directly wired connection) otherwise the current from S1 would short-circuit into the output.

Since IC1a pin 3 is now high, IC1b pin 5 will copy, and if S2 is pressed, IC1b will latch, setting its output pin 4 high. In a similar way, pressing switch S3, then S4 will cause IC1c and IC1d to latch, and IC1d pin 11 will be high. Hence the "normal output" (directly from IC1d pin 11) will be high, and this can be used to trigger an alarm circuit into its "off state".

Alternatively, an "inverted output" can be obtained via transistor TR2. This is employed as a logic inverter, and when it

switches on, its collector (c), buffered by resistor R8, switches from high to low (0V). The transistor can also be used to drive the optional l.e.d. D1, ballasted by resistor R9, both in parallel with R8. Remember that the l.e.d. will be lit when the "normal output" is high, i.e. the correct combination has been entered.

### RESETTING

If switch S5 is pressed, transistor TR1 will be switched on, and so the voltage at its collector will fall to zero, hence IC1a will unlatch. Since IC1a must be latched in order that IC1b, IC1c and IC1d remain latched, the whole system will be reset, like a pack of cards collapsing.

Any number of switches may be connected in parallel with S5, not just S6 and S7 shown in Fig.9.16 and Photo 9.8. Of course, in a real system, the "incorrect switches" i.e. S5, S6 etc., will be interspersed with the correct switches so that the correct combination is not obvious.

When testing the circuit, any supply from 5V to 12V may be employed. No decoupling capacitor is shown since the

circuit is likely to be driven from the main alarm circuit, which will already have decoupling. The circuit should be very stable and is unlikely to suffer by the absence of decoupling, unless a buzzer is used.

Resistor R8 may appear redundant if an l.e.d. is used, but it will ensure that the inverted output will rise fully to the supply voltage when TR2 is switched off. Without R8, l.e.d. D1 will cause a loss of about 2V at TR2's collector.

### SHORTCOMINGS

The circuit does not reset if the "correct switches" are pressed in the wrong order, and there is no limit to the number of attempts allowed. Both these shortcomings are solvable, but further i.c.s would be required, and further points would arise.

The system would look much neater if a proper keypad was used, but virtually all keypads are "matrixed" (explained later), and the complex output will need decoding. Furthermore, the user would probably expect a short bleep each time a button is pressed. This is again solvable but the circuit will begin to be cumbersome and expensive, so again a PIC beckons!

### MATRIXED KEYPADS

If you need to connect up 12 switches representing, say, digits 0 to 9, \* and #, you would need 12 connecting leads, one per switch, and a common wire connecting all the switches to positive (or 0V). In other words, a total of 13 wires.

The same number of switches can be connected using only seven wires if a matrixed arrangement is employed. This is much more complicated to electronically decode, but the appearance of cheap microcontrollers such as PICs has made the decoding more straightforward, and if a circuit is mass produced, the saving of five connections per unit will make the system much cheaper to manufacture, and more reliable.

Matrixed keypads are readily available, and a common type is shown in Fig.9.17, with its internal connections illustrated in Fig.9.18. Notice how the switches in Fig.9.18 are arranged in three columns and four rows. Hence, if you press key 1, column A will be connected to row 1. Pressing key 2 will connect column B to row 1, and pressing key 9 will connect column C to row 3, etc. So each key when pressed will connect a unique combination of columns and rows. Your electronic circuit will need

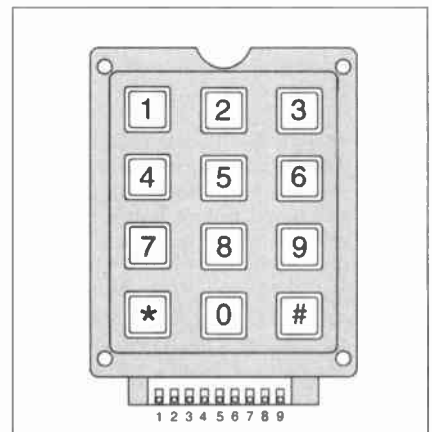


Fig.9.17. A common type of matrixed keypad.

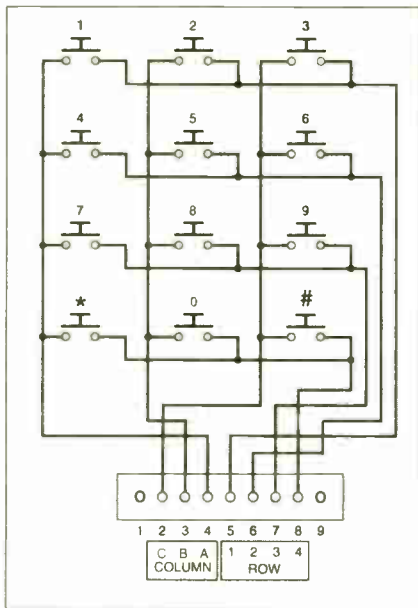


Fig. 9.18. Arrangement of the switches in a matrix keypad.

to look for each combination and translate it into a number.

Note, however, that there is no agreement about the labelling of rows and columns between different makes of keypad, and the arrangement of pins is often misprinted in catalogues. The information provided in Fig. 9.18 is correct for all the keypads which have the same appearance as the one illustrated. Note that pin 1 is not used, nor is pin 9 if fitted.

The "pins" are actually pads, which are easily damaged when soldering. Always fit the wires through from the back, and solder on the front, so that if a wire is pulled, the copper will not be pulled away from its base.

### STROBING

Imagine that row 1 has a positive (high) voltage applied to it. If key 1 is pressed column A will go high, key 2 will make column B high, and key 3 will make column C high. So your circuit will know which key is pressed if it records which column is high at the moment row 1 is high.

Suppose now that row 1 is returned to 0V and row 2 is made high. Again, the circuit checks which column is high, and determines which key (4, 5 or 6) is pressed.

The circuit moves on to row 3, and then row 4, and back to row 1. It moves (scans) through the rows many times a second, so that any pressed key will be decoded with considerable speed.

This system is known as *strobing*, and is used in virtually all systems such as calculators, computer keyboards etc., and in display systems such as liquid crystal displays. It dramatically reduces the number of connecting leads required, and hence the cost to mass-produce the circuit.

### PIC COMBINATION LOCK

The schematic of a PIC-controlled combination lock circuit is shown in Fig. 9.19. Again the PIC may be a PIC16F627 or a PICAXE-18, but the latter must have the "X" suffix (PICAXE-18X) because the program code is too lengthy to fit in the standard device.

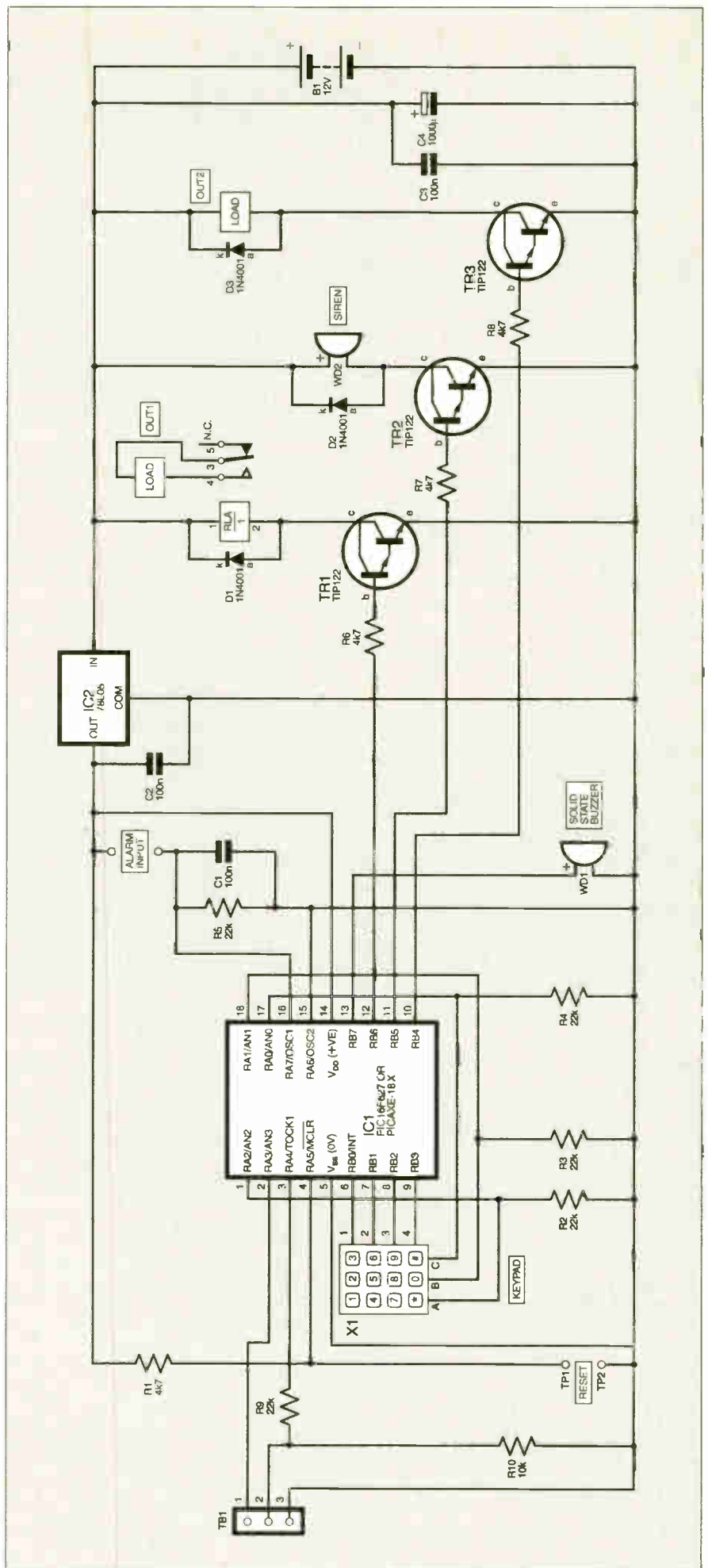


Fig. 9.19. Circuit diagram for a PIC-controlled combination-lock alarm monitor.



The keypad is shown with seven connections, with the columns labelled A, B, C, and the rows labelled 1 to 4. This labelling will enable any keypad to be used, regardless of its pinout arrangement, providing the constructor has data for the arrangement of rows and columns within the pinout. You could of course use separate buttons, connected as shown in Fig.9.18.

The PIC microcontroller, IC1, scans the keypad by making each row positive in turn, using pins RB0 to RB3. The columns are connected to PIC pins RA0 to RA2, with resistors R2 to R4 maintaining the inputs at 0V, unless forced high by pressing a button on the keypad to make connection with any of RB0 to RB3 when they are held high.

Three outputs are provided, the one from pin RB5 simply toggles high at each correct entry of the keypad number, turning on transistor TR1 via resistor R6. In other words, if TR1 is connected to a relay as shown (RLA1), the relay contacts will stay open until the correct keypad entry is made, then close and remain closed until the correct entry is made again. Hence the relay contacts can be wired in place of any keyswitch (labelled "OUT1") for any alarm system.

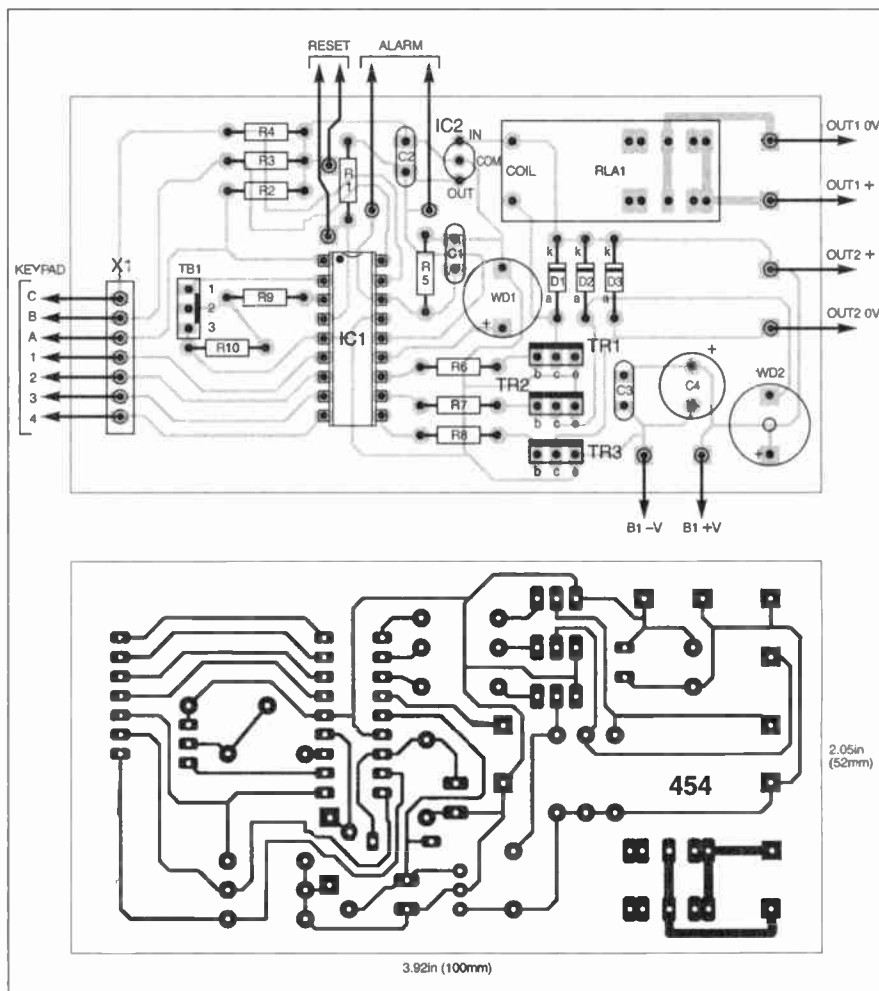


Fig.9.20. P.C.B. component and track layouts for the circuit in Fig.9.19.

## COMPONENTS

**Combination Lock, Fig.9.19**

<b>Resistors</b>		<b>See SHOP TALK page</b>
R1, R6 to R8	4k7 (4 off)	
R2 to R5, R9	22k (5 off)	
R10	10k	
<b>Capacitors</b>		
C1 to C3	100n ceramic disc (3 off)	
C4	1000µ radial elect. 16V	
<b>Semiconductors</b>		
D1 to D3	1N4001 rectifier diode (3 off)	
TR1 to TR3	TIP122 n-channel MOSFET (3 off)	
IC1	PICAXE-18X or PIC16F627, preprogrammed (see text)	
IC2	78L05 +5V 100mA voltage regulator	
<b>Miscellaneous</b>		
RLA1	s.p.c.o. relay, 12V, contact rating to suit application (see text)	
X1	12-key matrixed keypad (see text)	
TB1	3-pin header connector to suit PICAXE-18 programming lead (see text)	
WD1	solid state buzzer	
WD2	siren	

Printed circuit board, available from the *EPE PCB Service*, code 454; 18-pin d.i.l. socket; plastic case to suit application (see text); 12V battery and clip; connecting wire; solder, etc.

Approx. Cost Guidance Only **£24** excl. batts & hardware

The output from pin RB5 can be used to drive a siren (WD2, via resistor R7 and transistor TR2), and a timed output is provided if the wrong entry is made more than three times.

Pin RB4 switches high for a second or so each time the correct entry is made. This controls transistor TR3 via resistor R8, and provides a general purpose output, labelled "OUT2". This is ideal if a solenoid door release mechanism is required, for example, and the Darlington transistor type used as TR3 will switch an amp or more.

Pin RB7 drives a buzzer (WD1) which bleeps for a short period whenever an active button is pressed (see later).

Decoupling is provided by capacitors C3 and C4, and if large amounts of current are to be controlled by transistors TR2 and TR3 then the value of C4 could be increased to prevent the supply dipping. In practice this should not be a problem since the supply to the PIC is regulated down to 5V by IC2 and decoupled by C2, which should be fitted as physically close to IC2 as possible.

### CONSTRUCTION

All components, apart from the keypad and siren may be mounted directly on the printed circuit board (p.c.b.) whose layout details are shown in Fig.9.20. This board is available from the *EPE PCB Service*, code 454.

It is worth checking that the relay will fit into the pads provided, since there are slight variations between relay types. Double pads are provided for some of the

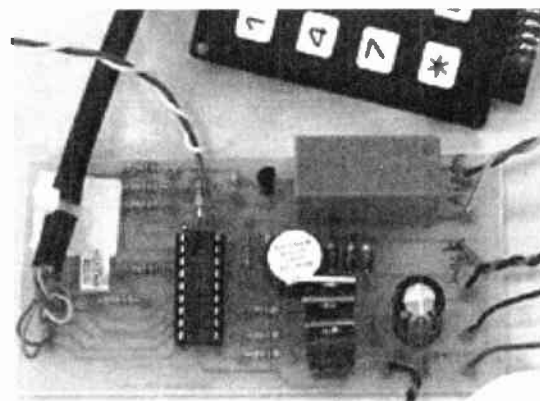


Photo 9.9. Completed p.c.b. of Fig.9.20.

relay pins, to accommodate the two main styles of relay.

After this begin by soldering in the socket for the PIC, followed by the resistors. Ensure that the diodes are fitted with their bands at the top (i.e. nearest the relay). Next fit the larger components such as the capacitors, ensuring that electrolytic capacitor C4 is fitted with its positive (longer) lead nearer the top of the p.c.b.

Regulator IC2 looks like a small transistor, and must be fitted with its flat side as shown. Transistors TR1 to TR3 are fitted with their metal tabs towards the top of the p.c.b.

If a PICAXE-18X is to be employed, the 3-pin header connector TB1 will allow programming directly from the serial connector of a computer. If a standard PIC16F627 is employed, then it will need to be

programmed in a programmer (or purchased ready-programmed), in which case TBI may be omitted.

Buzzer WD1 can either be a p.c.b. mounting type, or linked via wires. In either case, ensure that the correct polarity is observed. Siren WD2 (often called a "buzzer" in catalogues, but larger and louder than a normal buzzer), also needs to be linked the correct way round.

The relay should now be eased into position, ensuring that all the pins line up correctly. Attach wires to the power supply pads and outputs as required. The "Alarm" pads provide an alarm input as described earlier. The pads labelled "Reset" will rarely be required, but terminal pins could be soldered into these pads so that a metal object can be used to bridge the pins if a reset is ever needed.

## KEYPAD

The keypad shown in the photograph includes an unused pad (pin 1) on its left-hand side. Some keypads may omit this pad, so check to see how many solderable pads are included; a total of seven are required.

Be warned that the solder pads on the keypad are easily pulled away, and so take care by inserting the wires from the underside. This will ensure that if the wires are accidentally pulled, the copper pads will not be pulled off. If possible, the multicore cable should be fixed to the back of the keypad by a cable tie and self-adhesive pad.

The connection pads on the p.c.b. are in the correct order relative to the keypad, so that "C" on the p.c.b. connects with pin 2 on the keypad, with the other connections following in sequence.

Having thoroughly checked your assembly, and its 5V regulated supply, the circuit can be operated with the preprogrammed PIC installed.

## PROGRAM OPERATION

The program is quite long and complicated because it has to scan the keyboard, and make provision for storing and checking the numbers entered. In fact the numbers are stored within the PIC's own non-volatile memory, so that the number set by the user as the correct entry is retained even if the circuit is powered down.

When power is first applied to the circuit, the keypad will appear "dead" i.e. pressing the buttons will not produce a bleep sound. You first have to press the "#" key. This must be followed by the "correct" entry number, which has been set at the default of "1234". At this point you either press "#" again to trigger the system into firing (for instance) a solenoid lock and toggling the relay, or you press the "\*" key to change the entry number.

Having typed in your preferred entry number, this will be retained by the PIC indefinitely, until you wish to change it, if ever. If you forget the number, the only way of resetting the system to 1234 is by re-programming the PIC.

If a wrong number is entered more than three times, the siren sounds for around one minute. However, entering the correct number will silence the siren.

## RESOURCES

Preprogrammed PICAXE-18X micro-controllers for the circuits in Fig.9.13 and Fig.9.19 can be obtained from: M. P. Horsey, Electronics Dept., Radley College, Abingdon, Oxon OX14 2HR. The price is £5 per PIC, including postage. Specify that the PIC is for *Teach-In 2004* Part 9 and quote the figure number for which the device should be programmed. Enclose a cheque payable to Radley College.

The software for the PIC program (except for the PICAXE programming software) is available on 3.5in disk (*EPE* Disk 7), for which a nominal handling charge applies, from the Editorial Office, see the *EPE PCB Service* page. It is also available for free download via the click-link on the *EPE* home page at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk).

PICAXE programming software can be obtained from: Revolution Education, Dept. *EPE*, 4 Old Dairy Business Centre, Melcombe Road, Bath BA2 3LR. Tel: 01225 340563. Web: [www.rev-ed.co.uk](http://www.rev-ed.co.uk).

## NEXT MONTH

Our *Teach-In 2004* series concludes next month with Part 10, in which we examine motor control and present an example of a PIC-based curtain winder.

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# PIC N' MIX

ANDREW JARVIS

Our periodic column for your PIC programming enlightenment

## Hello World For PICs: Instruction Cycles, Masks and Clockwork L.E.D.s

THE first *PIC n' Mix* column opened with a light-hearted remark about the importance of having PICs flash an l.e.d. It was intended for the detractors who would say this is over-engineering – but it is a great way to illustrate some of the most fundamental PIC concepts, and an easy way to get up and running.

### Hello World

Using a high level language like “C” or Visual Basic you would usually start with “hello world”, not just as a nod to tradition, but for two real reasons. First, it should be one of the easiest programs you can write, but second and more importantly, it provides immediate visual feedback – confirmation that your program is working.

If you've ever programmed a PIC with a rush of excitement waiting for your circuit to explode into life, only to find yourself still staring at it a couple of minutes later, willing something to happen, then you'll understand how important this is.

In the absence of a pop-up message box, the l.e.d. is the best way to provide the warm feeling that goes with knowing that everything is OK. A PIC pin configured as an output can source or sink sufficient current to drive l.e.d.s directly (via a suitable ballast resistor, of course), making the circuit very simple indeed, and for me it is why l.e.d. flashing is commonly acknowledged as the “hello world” for PICs.

### Trains and Delays

Using a circuit like the one shown in Fig. 1a (which can be easily arranged without extra components if you are using TK3), flashing the l.e.d. is a simple matter of alternating the digital output between logic 1 and 0 with an appropriate delay between states.

The simple scenario we'll start with is that the delay is always the same, generating the pulse train shown which is said to have an equal mark-space ratio – the amount of time for which the output is high and low is equal. An alternative description would be to say it has a 50% duty cycle. While the output is high (mark), the l.e.d. is lit, and when low (space), the l.e.d. is off.

If you instead chose the circuit configuration of Fig. 1b then the behaviour would be reversed. You can exploit this principal to drive more than one l.e.d. from the same digital output. Microchip application note AN234 shows you how to multiplex up to 12 l.e.d.s with only four I/O (input/output) pins.

### First Timer

A first (intuitive) attempt at code to do this might be as shown in Listing 1. Port B pin RB4 (PORTB.4) has been used in these examples, but you can just as easily substitute your own I/O port in the code. Listing 1, however, is unsatisfactory for a number of reasons. First and foremost, there is an uneven delay between the changing output states, which would mean that the mark-space ratio of a waveform generated by this code would be unequal.

```

LISTING 1
LOOP    BSF PORTB,4
        BCF PORTB,4
        GOTO LOOP
    
```

To understand why, we need to look at the relationship between the oscillator, clocking scheme and instruction cycles. I was surprised to learn recently that this area actually exposes a few gaps in some of

the popular tutorials. Since this is, quite literally, what makes the whole thing tick – it deserves a closer look.

### Clockwork

The mid-range PIC family supports up to eight different oscillator modes, depending on whether an internal RC oscillator is present, and selected by the device configuration bits set during programming. Most *EPE* projects use an external crystal resonator connected between pins OSC1 and OSC2 and set the mode to XT or HS, for “normal” (up to 4MHz) or high-speed crystal (4MHz upwards) respectively.

Some PICs however, including the PIC16F628 and the newer flash types like the 12F6xx, provide an internal 4MHz system clock that is not only cheaper (fewer parts required), but also frees up pins for general I/O – especially important on the low pin count devices. The internal RC oscillator is not as accurate as a crystal (and so not recommended for time critical applications or anything that uses RS232 serial interfacing), and may require calibration. This particular characteristic makes for an interesting study when we introduce the 8-pin PICs to TK3 in the near future, it certainly complicates the programming algorithm.

The choice of oscillator mode and component values you use set the frequency ( $F_{OSC}$  in datasheet terminology) and period ( $T_{OSC}$ ) of the oscillator. The relationship is given by  $F_{OSC} = 1 / T_{OSC}$ . You might reasonably think therefore that if you opt for a 4MHz crystal, each instruction would take  $0.25\mu s$ , but this is not the case.

### Four-To-One

It takes four clock periods to generate one instruction cycle ( $T_{CY}$ ), which the PIC needs to sequence internal operations that control how your program instructions and data are fetched from memory, decoded, executed and written back. This effectively means that the PIC will execute each instruction at a frequency one quarter of the clock input you specify, so with the 4MHz crystal, each cycle takes  $1\mu s$ . A 20MHz crystal will yield a  $T_{CY}$  of  $0.2\mu s$ .

If you look at an extract from a PIC instruction set summary (located in the appropriate datasheet), you'll notice that instructions are listed together with the number of cycles needed to complete (see Table 1). In most cases, this is stated as “1” – as you might expect, but some are “2” and others written as “1(2)”, which means that usually it is “1”, but sometimes “2”!

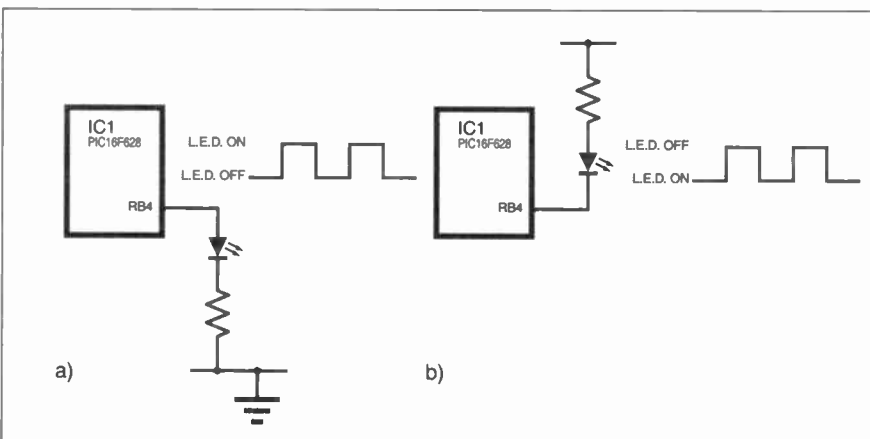


Fig. 1. Example techniques for connecting an l.e.d. to a PIC pin used in output mode.

**Table 1. Command cycles example**

Command	Cycles
ADDWF	1
ANDWF	1
CLRF	1
CALL	2
DECFSZ	1(2)
GOTO	2
INCFSZ	1(2)
RETURN	2
XORWF	1

Closer inspection reveals that this happens with conditional statements like DECFSZ and INCFSZ. In the "usual" case the instruction takes one cycle, but if the condition is met the instruction modifies the contents of the Program Counter, which makes it a 2-cycle instruction. All instructions that modify the Program Counter take two cycles as with, for example, CALL, GOTO and RETURN.

The reason for this is because the PIC overlaps the execution of the current instruction with the fetching of the next one as a way of improving performance. So in each instruction cycle there is actually a fetch *and* an execute happening. The problem when the Program Counter is changed, however, is that the next instruction already fetched is suddenly incorrect because it has been brought from the wrong address, so the "pipeline" has to be flushed, which takes one additional cycle and is implemented as an NOP.

### Balancing Act

Knowing exactly how long instructions take to execute puts us in a good position to return to the l.e.d. code. Since GOTO takes two instruction cycles, a reasonable solution to maintain the equal mark-space ratio is to introduce a balancing 2-cycle delay after switching on the l.e.d. Listing 2a shows an obvious way to do this, while Listing 2b shows a trick to achieve the same thing where program memory is tighter, using one instruction that needs two cycles, instead of two instructions that need one. If you're using MPLAB, the slicker alternative is GOTO \$+1, removing the requirement for a dummy label.

There are still improvements to be made. Listing 2c introduces a little more elegance and cuts the instruction count further. The need to specifically set and clear the port is

#### LISTING 2A

```
LOOP    BSF PORTB,4
        NOP
        NOP
        BCF PORTB,4
        GOTO LOOP
```

#### LISTING 2B

```
LOOP    BSF PORTB,4
        GOTO NEXT
NEXT    BCF PORTB,4
        GOTO LOOP
```

#### LISTING 2C

```
LOOP    MOVLW 16
        XORWF PORTB,F
        GOTO LOOP
```

**Table 2. PORT B Register – Isolating RB4**

	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0
Bit	7	6	5	4	3	2	1	0
Mask	0	0	0	1	0	0	0	0
Mask	RB4			Result				
0	0			0				
0	1			1				
1	0			1				
1	1			0				

eliminated by using XORWF (Exclusive OR W with F). This instruction causes the l.e.d. output to be toggled, leaving the others unchanged so long as we are careful to "mask" them out. Table 2 shows that the mask for this example (we only want to change RB4) has a binary value of 0010000, decimal 16.

To see *why* this works, rather than *how*, it helps to consider the truth table for XOR. Look at the values for the mask and those of RB4, the digital output in this example. Where the mask is 0, the result is RB4 unchanged. Where the mask is 1, the result is the opposite of RB4 (i.e. RB4 toggled), which is exactly the behaviour we want. It's important to store the result of the XOR back to the Port B register, otherwise nothing will happen! That's why F (file) is given as the destination.

### Slow Down

The code of Listing 2c changes the state of the l.e.d. every 2µs as it stands (still assuming 4MHz), which isn't particularly useful as a visual reference. At this speed the l.e.d. looks like it's on all the time. To make it appear to flash we need a longer delay.

It's not practical to simply pack the loop with NOPs, you would need half a million of them for a half second delay! Instead, carefully controlled loops are used to achieve the timings required (actually, for "hello world" it doesn't have to be that accurate of course, but if, for example you're flashing an infra-red (IR) l.e.d. with respect to a protocol like SIRC (Serial Infra-Red Control) that requires pulses with durations in the order of 1.2ms and 0.6ms, then precision does become more important).

Listing 3a introduces a delay loop of 769 instruction cycles (769µs), using a

#### LISTING 3A

```
CLRF DELAY1
MOVLW 16
XORWF PORTB,F
DECFSZ DELAY1
GOTO WAIT
GOTO LOOP
```

#### LISTING 3B

```
CLRF DELAY1
MOVLW 16
XORWF PORTB,F
DECFSZ DELAY1
GOTO WAIT
NOP
GOTO LOOP
```

single loop counter, DELAY1. The counter is decremented until it reaches zero, whereupon the l.e.d. is toggled and the loop starts over. The decrement is done before the zero condition is tested, so by starting from 0 each time, we actually get a loop with 256 iterations of three instruction cycles (one for DECFSZ plus two for GOTO).

However, as we have already seen, the last iteration in which the zero condition is met takes one less cycle because the skip is executed, that's why we subtract one. An additional two cycles is added for the outermost GOTO (LOOP):

$$\text{Delay} = (256 \times 3) - 1 + 2 = 769 \text{ cycles}$$

An alternative is shown in Listing 3b, which makes the maths slightly more straightforward at the expense of another cycle, by using an NOP to effectively eliminate the conditional timing characteristic of DECFSZ:

$$\text{Delay} = (256 \times 3) + 2 = 770 \text{ cycles}$$

The delay can be varied in one of three ways:

- Change the value of DELAY1
- Pad the delay loop with more instructions
- Change the instruction cycle time by using a different oscillator mode or crystal

Even so, it's still too fast for "hello world".

#### LISTING 4

```
CLRF DELAY1
CLRF DELAY2
MOVLW 16
XORWF PORTB,F
LOOP    DECFSZ DELAY1
        GOTO WAIT
        DECFSZ DELAY2
        GOTO WAIT
WAIT    GOTO LOOP
```

Listing 4 introduces another loop, controlled by DELAY2, to bring the delay up to an acceptable (i.e. noticeable) level. Using the same methods as previously, we now have:

$$\text{Delay} = (256 \times (767 + 3)) - 1 + 2 = 197121 \text{ cycles, or } 0.197\text{s}$$

Note that 767 isn't a magic number, it's the value of the innermost loop calculated above,  $(256 \times 3) - 1$ .

### Jumping Through Hoops

As you might be starting to realise, it all begins to get jolly complicated very quickly if we use three or more nested loops. Next time, we'll look at some ways to calculate the precise loop counter values and code needed for an exact delay or frequency. Also, how the delays can be verified without going anywhere near a PIC, and a look at unequal mark-space ratios. Finally we'll ask – "Is there a better way to do this sort of thing anyway?"

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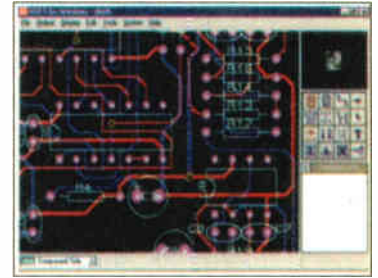


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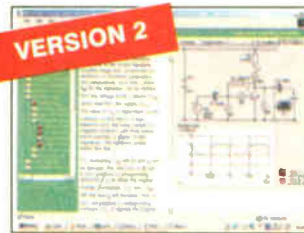
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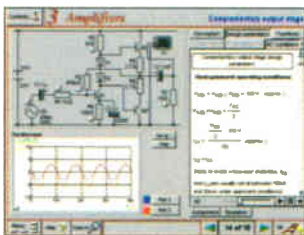
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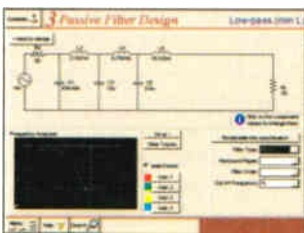


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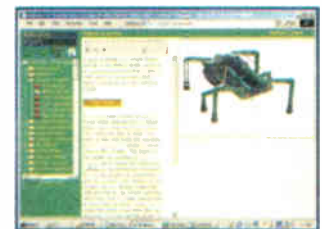
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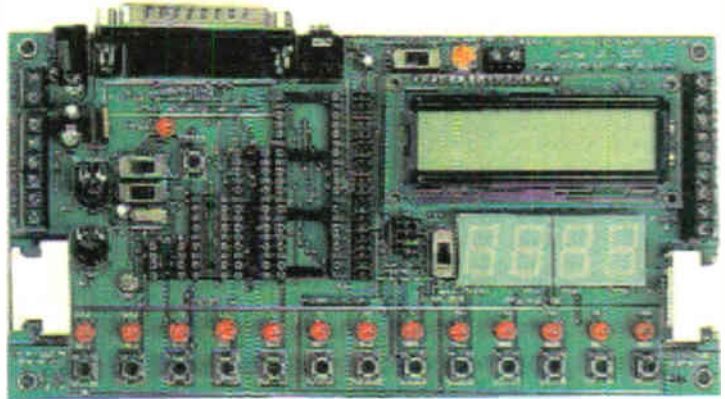
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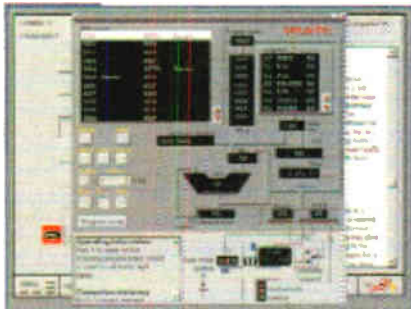
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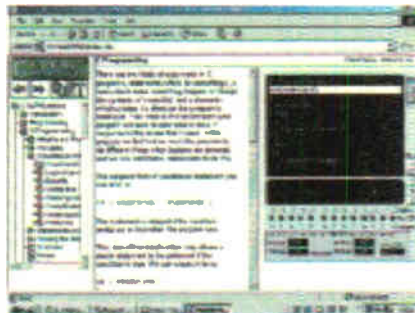
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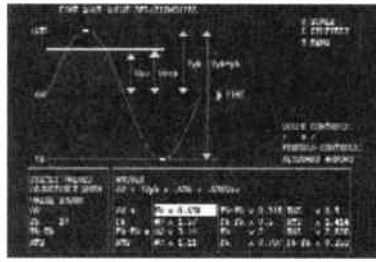
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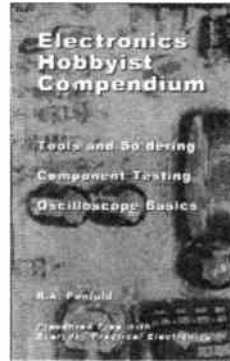
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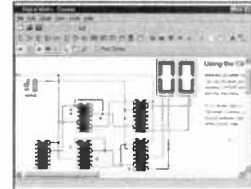
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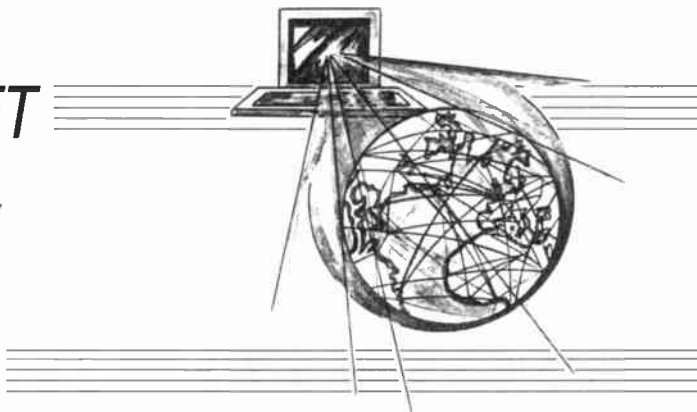
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# SURFING THE INTERNET

# NET WORK

# ALAN WINSTANLEY



## A Fourth Engine

LAST month I examined the current search engine market, looking at Google, Yahoo and MSN. Ask Jeeves is a popular web search engine which is easy to use and tries to answer search requests that are entered in plain English. Internet users may not know that it is powered by Teoma ([www.teoma.com](http://www.teoma.com)) which is a minimalistic-looking engine that can deliver very accurate results.

It uses "Subject-Specific Popularity" to rank a site based on the number of same-subject pages that reference it, not just general popularity. Unlike either Yahoo or MSN, it correctly listed the National Semiconductor site when we searched for the LM12 amplifier. Teoma offers a downloadable toolbar and it's definitely worth a try, especially if you're a Jeeves fan.

## A Gander at Gmail

News continues to trickle in concerning the proposed Gmail web mail service from Google that I mentioned last month. At the time of writing, this web-based email service is still being tested (see [gmail.google.com](http://gmail.google.com)), and one of its major attractions is the offer of a mammoth 1GB of online storage space, so that "you need never delete an email again", presumably because the disk space is so vast that it will no longer be a consideration for users.

A number of concerns arose early on, one of the main ones being the implications on the users' right to privacy. A few weeks down the line, Google has been stung by comments made by privacy lobbyists concerning the fact that Gmail would be "sniffed" by Google in search of keywords, in order to deliver advertising to the recipients. Commentators, who were worried that it may be impossible to delete one's Gmail permanently from Google's servers, also initially questioned the apparently perpetual "shelf life" of Gmail email messages. The search engine giant argues that any concerns were premature and unfounded.

Firstly, many if not most users' email is already scanned by their ISP, argues Google, because ISPs usually search for viruses or spam, in order to deliver a filtered email feed to their customers. So what's wrong with sniffing the contents for keywords that could trigger some advertising as well, they imply. (To clarify a point made last month, I would add that there is no suggestion that separate

advertising emails would be generated through the use of Gmail webmail.)

Gmail will not only filter spam and viruses but will also generate some online advertising in the webmail window, similar to the AdWord adverts often seen in Google search results. "When email messages are fully protected from unwanted disclosure (to third parties), the automatic scanning of email does not amount to a violation of privacy," declares Google, though they ended by admitting that they are still learning what the privacy issues related to email really are anyway.

Regardless of what Google would have us believe, there is always a distinct feeling of privacy "invasion" when someone or something has "physically" scanned your "private" mail in search of certain words. No-one likes the feeling that their mails are being "read" (especially not at work: a number of large firms do scan mail, instant messages and the web surfing habits of their employees) but individuals are justifiably happy when spam and viruses are spirited away by their ISP.

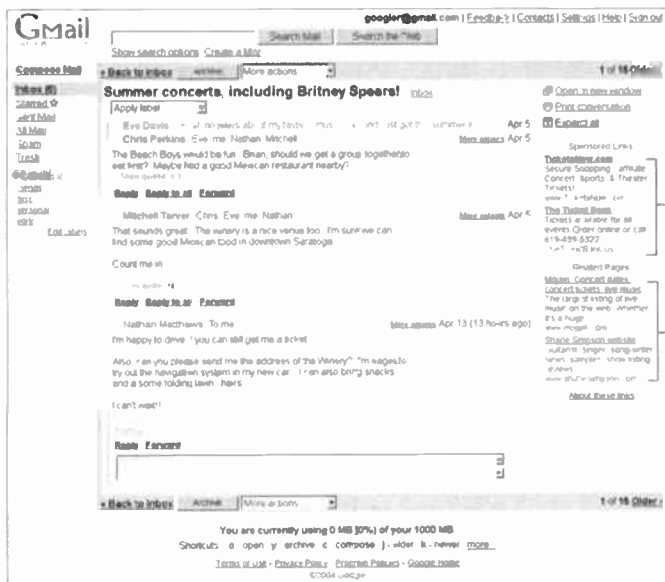
Google uses rather a perverse rationale to explain away the fact that your Gmail will indeed be "read" by their system when they argue that the user will "benefit" from the inclusion of related adverts in his online Gmail. This is the same sort of marketing-speak that implies that people "benefit" from junk mail being shoved through their letterbox.

## A Word From Our Sponsors

Google's advertising-related scanning can be remarkably efficient in practice: a village web site that the author runs, uses a freeware classified advert system (see [www.bravenet.com](http://www.bravenet.com) for a huge range of pop-up powered web site add-ins like that), and remarkably enough, a For Sale advert placed online for a Flymo electric hover lawnmower triggered a number of Google Adverts on the same web page for Flymo lawnmowers and electrical appliances. The same effect will undoubtedly be seen in a Gmail window: users will "benefit" in a distorted sort of way from targeted advertising generated by the world's most sophisticated search engine. Never-the-less, it will be free, and there will be lots of disk space (far more than e.g. Hotmail) so provided that users are fully aware of such issues when they sign up, then there isn't a problem.

Any early suggestion that mail will be retained indefinitely was also wrong, says Google, who have clarified that it will erase deleted mail as soon as reasonably practicable, only storing mail just like any other ISP does - to ensure that systems can be restored from backups if necessary, in the shorter term. Conversely, Google also states that Gmail "quickly recalls any message an account owner has ever sent or received" which implies some form of perpetuity. No wonder they confuse commentators.

Taking a balanced view, it is reasonable that a free service such as Gmail should be supported by some form of advertising. In practice, if Gmail performs as quickly and efficiently as the Google search engine does, then it is highly likely that Gmail will explode onto the mass market in the same way that AOL did. Gmail users will soon forget that their mail is being "read", and they will doubtless "benefit" from those keyword-related adverts. You can email comments to [alan@epemag.demon.co.uk](mailto:alan@epemag.demon.co.uk).

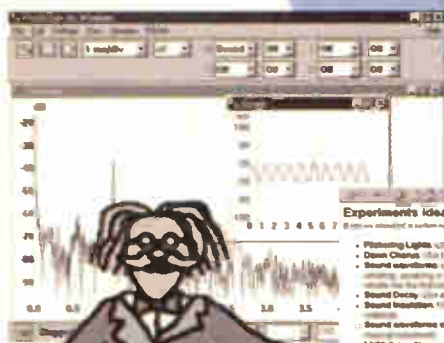


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# Hard Drive Warbler

Terry de Vaux-Balbirnie

Monitor your hard drive activity – at a distance!

**T**HERE was a time when most computer users placed their machine on the worktop. The monitor could then be sited on top of the “desktop” style case so little space was wasted.

However, today’s tower cases tend to waste space and many people avoid this by putting the computer on the floor. The user may need to buy some extension leads for the keyboard, mouse and monitor. However, apart from also having to fumble under the desk to reach the floppy and CD-ROM drives, this method is usually convenient.

## Little Problem

Unfortunately, it leaves the problem of not being able to see the hard drive activity l.e.d. very easily. This light is very useful – after all, it has persisted in computer design for many years. It informs the user that the system is active – whether a long document has finished being opened or saved, for example.

It also serves to inform when the machine has stopped responding. When there is a lot of hard drive activity creating swap files, this fact may prompt the user to install more memory chips.

Note that the hard drive l.e.d. on a modern machine is usually connected to the HDD controller on the motherboard. This circuit will therefore monitor the activity of

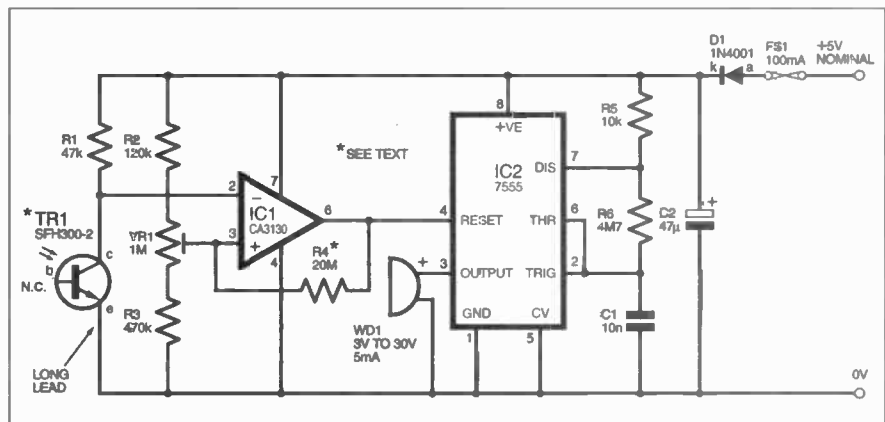
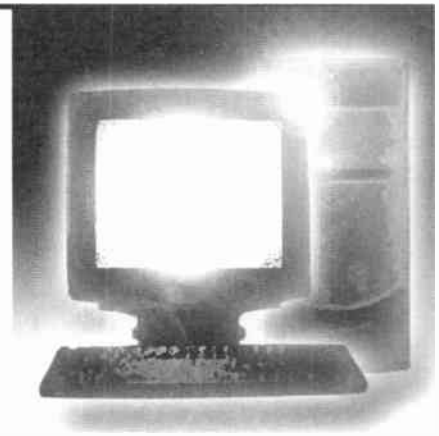
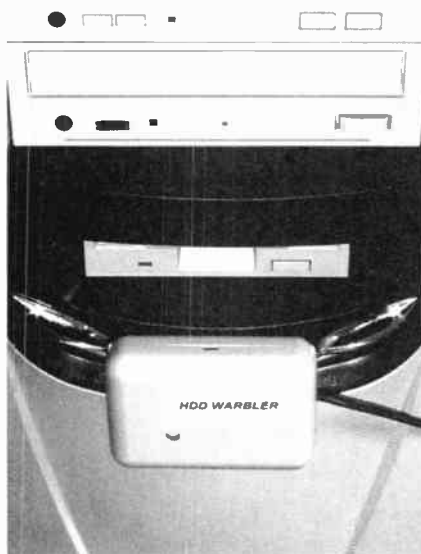


Fig. 1. Complete circuit diagram for the Hard Drive Warbler.

any hard drive if you have more than one installed in your computer.

## Disk Activity

The Hard Drive Warbler provides hard-drive activity checking without being able to see the warning light. It does this by monitoring the operation of the existing l.e.d. and “warbling” in sympathy with its flashes. The unit does not require any modifications to the computer itself so there are no warranty implications. The new unit is simply attached over the existing l.e.d. using adhesive fixing pads or a similar method.

The prototype draws only 650µA from a 5V or 6V supply rising to some 1.5mA when the buzzer is sounding. Such a small current may be obtained in various ways. The best method is to draw it from a USB port. This method has the advantage of costing very little (just a USB plug and a piece of twin wire). Also, the circuit will switch off automatically when the computer session is over. However, older machines do not have a USB facility. Also, some users will not have any free ports and might not wish to buy a hub to provide extra ones.

You could use a 6V battery as a supply. A pack of four AA size alkaline cells placed externally would give excellent service. Alternatively, you could use a small internal 6V battery with a corresponding reduction in service life. With any battery supply, you would need to fit an on-off switch and remember to switch off the unit at the end of a session

The “warbler” circuit may be found useful for monitoring other l.e.d.s – that is on non-computing devices such as household appliances. You will even find that it “chirps” when a TV or similar infra-red remote control is pointed at it so the device could be used to check that one of these is working.

## Circuit Description

The full circuit diagram for the Hard Drive Warbler, except power source, is shown in Fig. 1. Fuse FS1 protects the supply in the event of a short-circuit. Diode D1 provides reverse-polarity protection. Thus, if the supply were to be connected in the wrong sense, the diode would not conduct and nothing would happen.

Current flows through diode D1 to capacitor C2 which provides a small reserve of energy. This is especially useful if a battery supply is used.

A phototransistor, TR1, is particularly sensitive to light in the red and infra-red region of the spectrum and therefore responds well to light from the red l.e.d. that is usually used to monitor the hard drive. However, the phototransistor chosen must NOT be an infra-red type as such. These are recognized by having an opaque black body to filter out visible light. One of these will not work.

The phototransistor must be of a type housed in a clear package so that it will admit visible light. Various phototransistors would be suitable – not just the one used in the prototype. Resistor R1 is the load resistor.

Unlike an ordinary transistor, a photo-transistor does not usually have an external base connection. This is because it is activated by light falling on its sensitive surface rather than by base current entering. There are therefore only two leads – collector (c) and emitter (e).

In the absence of any light (or only a small amount of light) reaching TR1, the phototransistor will be *off* and a high resistance will exist between collector (c) and emitter (e). The collector will then be *high* (close to positive supply voltage) via resistor R1. Under these conditions, very little current (only the “dark current”) will flow from collector to emitter.

### Falling Resistance

When light reaches TR1, the resistance between its collector and emitter falls and the collector voltage falls in sympathy. With sufficient light, TR1 will be turned completely “on” and the collector voltage will be near to 0V. With the small amount of light picked up from an l.e.d. the voltage is likely to fall to around one-half that of the supply when it flashes.

## COMPONENTS

### Resistors

R1	47k
R2	120k
R3	470k
R4	10M (2 off – see text)
R5	10k
R6	4M7

All 0.25W 5% carbon film.

### Potentiometer

VR1	1M min. enclosed carbon preset, vertical
-----	--

### Capacitors

C1	10n metallised polyester.
C2	47µ radial elect. 10V.

### Semiconductors

D1	1N4001 rect. diode.
TR1	SFH300-2 or other phototransistor having a clear case – see text
IC1	CA3130 op.amp
IC2	7555 low power timer

### Miscellaneous

WD1	3V to 30V low-profile d.c. buzzer, 5mA maximum.
FS1	100mA 20mm quick-blow fuse and chassis-mounting fuseholder

Printed circuit board, available from the *EPE PCB Service*, code 450; small plastic box, size and type to choice; 8-pin d.i.l. socket (2 off); USB Type-A plug (if used – see text); twin wire for supply leads; nylon nuts, bolts and spacers; cable strain relief tie; solder etc.

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The voltage existing at TR1 collector is applied to the inverting input (pin 2) of operational amplifier (op.amp) IC1. Meanwhile, its non-inverting input (pin 3) receives a voltage which may be varied using preset potentiometer VR1. Fixed resistors R2 and R3 narrow the range of VR1 adjustment to between 1.5V and 4.6V approximately (using a 5V supply) and with the specified component values.

When preset VR1 has been set up correctly at the end of construction, the inverting input voltage will fall below the non-inverting one when the hard drive activity light flashes on. The output of IC1, pin 6, will then go high.

When the activity l.e.d. is off, the op.amp input conditions are reversed and the output reverts to a low state. Note that if the supply voltage varies, this does not affect correct operation of the circuit because it is the *relative* states of the op.amp inputs that are important, not their absolute values.

### Feedback

Resistor(s) R4 apply some positive feedback to the system and this ensures that the on-off transitions are sharp. In fact, R4 comprises two 10 megohm resistors connected in series. This is because 10M is the highest easily-available resistor value.

While op.amp IC1 is on, with pin 6 high (due to sufficient light being detected by the phototransistor), a high state will be applied to CMOS timer IC2 Reset input, pin 4. This enables the device, which runs as an astable (pulse generator). The output of IC2 (pin 3) then switches rapidly between high and low states. While no light (or only a little light) is detected, the low

state of IC2 pin 4 disables the device and it has no further effect.

The frequency and mark-space ratio of the astable is determined by the values of fixed resistors R5 and R6 in conjunction with that of capacitor C1. With the values specified, this will be some 16Hz and having a mark-space ratio close to 1:1 – that is, more-or-less equal on and off times.

The output of IC2 (pin 3) is connected to solid-state buzzer, WD1, which therefore emits a “warbling” sound whenever the activity l.e.d. is on. This is because its natural operating frequency (3.5 kHz approx.) is modulated by that of the astable.

### Construction

Construction of the Hard Drive Warbler circuit is based on a single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 450. The topside component layout and actual-size copper master pattern are shown in Fig. 2.

Begin construction by drilling the single fixing hole and soldering the two i.c. sockets in place. Add all resistors (including preset VR1) – note that both feedback resistors are labelled “R4”.

Add the capacitors taking care over the polarity of electrolytic C2. Note how the latter capacitor is placed flat on the p.c.b. (see photograph). Solder buzzer WD1 in position, again, taking care over its polarity (which is indicated on the underside).

Solder phototransistor TR1 on the *copper track* side of the p.c.b. taking care over its orientation – the short lead is the collector. Do not cut its end leads to a length of less than 10mm or the heat could damage it. Even so, use minimum heat while soldering and grip the leads between the joint and the body using a pair of fine-nose pliers. This will give a simple “heat shunt” effect.

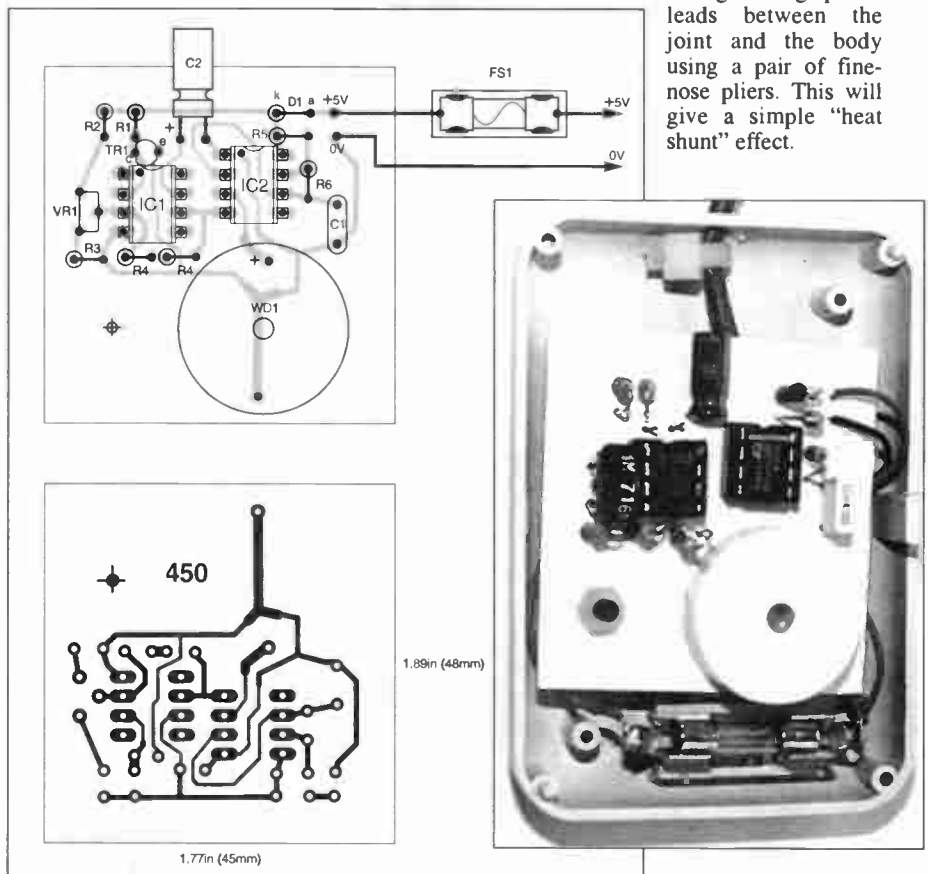
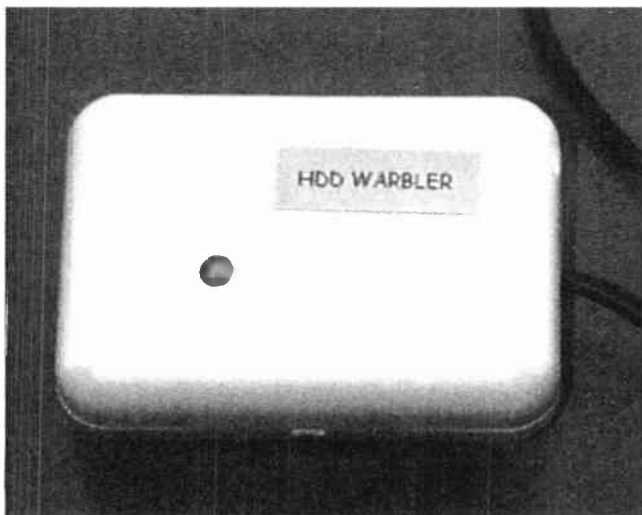
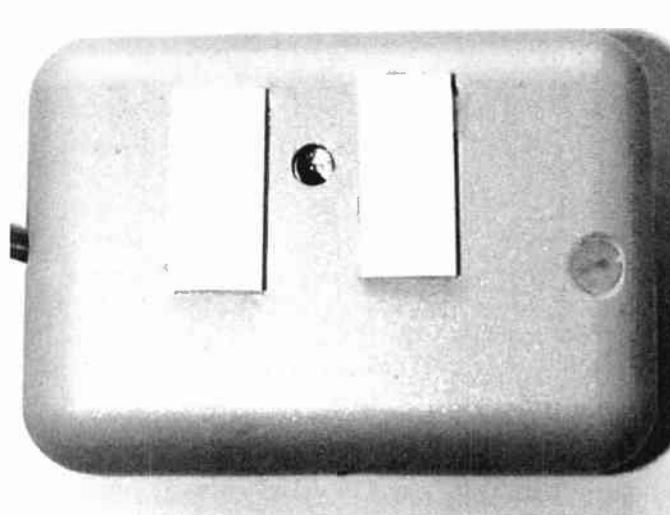


Fig.2. Printed circuit board topside component layout, wiring and full size copper foil master for the Hard Drive Warbler. Note, the phototransistor is soldered on the trackside. The photograph shows the p.c.b. mounted in the small case.



Completed "warbler" showing the sound exit hole in the case lid and USB plug.



Rear of case showing fixing pads and phototransistor window.

Gently "zigzag" the leads so that the phototransistor body stands close to the p.c.b. Take care to avoid short-circuits either between the leads or between the leads and p.c.b. tracks. If necessary, use some insulation sleeving.

Adjust preset VR1 sliding contact to approximately mid-track position. Solder pieces of light-duty stranded connecting wire to the +5V and 0V pads. These will be used for testing purposes.

Insert IC1 and IC2 into their sockets. However, before doing this observe some simple anti-static precautions (for example, touch a metal water tap before handling their pins). This precaution is necessary because these are CMOS devices which will be damaged by excessive static charge on the body.

## Testing

Connect a 6V battery (say, 4 AA cells in a suitable holder) with the correct polarity to the supply input wires. The buzzer WD1 might sound with a warbling tone because the phototransistor is picking up sufficient ambient light to operate the circuit. If not, point it towards the light from a filament lamp. Cover the phototransistor with the hand to shield it from light and the sound should stop. If necessary, adjust preset VR1 so that this works properly.

Check that the circuit operates satisfactorily with light from the hard drive i.e.d. To do this, hold the phototransistor as close as possible to the i.e.d. You will find that any adjustments needed to VR1 are not particularly critical. The circuit becomes more sensitive as VR1 sliding contact is rotated anti-clockwise (as viewed from the left-hand edge of the p.c.b.).

You may change the warbling frequency if this is thought necessary. Reducing the value of resistor R6 will increase the frequency and vice versa. If you do this, remember to remove the i.c.s first, observing the anti-static precautions mentioned earlier.

## Power Supply

If you intend using a USB supply, you will need to make a connection to a "Type-A" (flat) USB socket on the computer. You

will therefore need a Type-A plug to fit it. If one of these is not readily available, you could buy a ready-made USB lead and cut the Type-B plug off the other end.

Using a suitable length of light-duty twin-stranded wire, make up the power supply lead. There are four pins on USB connectors and these may be of the solder or crimp type. Pins 2 and 3 (which are not used here) are used for the data signal. Pin 1 is for +5V and Pin 4 is 0V ("earth").

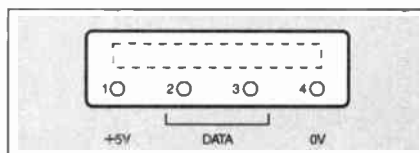


Fig.3. Solder tag view for a USB Type-A plug.

The pinout details of a Type-A plug are shown inset in Fig.3. This is a view looking at the soldered connections with the tags nearer the lower edge. The "slot" shown dotted (and which is visible from the front of the plug) will then be at the top. If the polarity seems confusing, see if the lead works and interchange the +5V and 0V wires if it does not. *Make certain that no short circuits are formed between adjacent pins or between a soldered connection and the metal body.*

## Boxing Up

Choose a small plastic box in which to house the circuit panel (and battery if this is to be placed internally). Any type will be satisfactory as long as everything fits. A "soap bar" style case was used for the prototype.

Drill a hole in the base to correspond with the fixing hole in the p.c.b. Drill a small hole above the

phototransistor position and another, larger, one in the lid for the sound to pass out from the buzzer. Drill a hole for the power supply lead to pass through and a further one for the fuseholder. Attach the fuseholder.

Referring to Fig.2, you should be able to use the positive power supply wire already in place to make the connection to the fuseholder. If you are using a battery supply, connect also a small on-off switch in line with this wire. The 0V one will need to be de-soldered but remove the i.c.s before doing this. Pass the new wire through the hole drilled for it and solder the ends to the fuseholder and the 0V pad on the p.c.b. observing the polarity.

Leaving a little slack inside the box, apply strain relief to the wire. This may be done by applying a tight cable tie to it. Attach the p.c.b. using a thin nylon fixing and a plastic spacer to hold the circuit panel clear of the base of the box. Arrange for the phototransistor to lie behind, or slightly protrude, through the hole drilled for it.

Attach the unit over the hard drive activity i.e.d. using adhesive fixing pads so that the maximum amount of light from it will reach the phototransistor. Connect the power supply and test the circuit. Make further adjustment to preset VR1 and the position of the unit, as necessary, so that operation is reliable. □

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# Making Front Panel Overlays

Andrew Martell

Making low-cost, professional looking, front panel overlays using your PC

**A**DDING the finishing touches to your project can be a time consuming and laborious task, and the results may not be as professional as you would have liked! However, with the use of a home PC, professional looking front panel overlays can be quickly and easily produced. This article shows you how.

The author's project shown in Fig.1 is based on John Becker's *Pic-Gen Frequency Generator/Counter* from the July 2000 issue of *EPE*. Note that a few changes have been made to the design to assist with the front panel layout.

## You Will Need

To complete the front panel overlay as shown in the photographs, the following equipment is required:

- A PC equipped with a printer capable of printing on Over-Head Projector (OHP) acetates. The author uses an inkjet printer.
- A basic Computer Aided Design (CAD) drawing package which is capable of producing images at 1:1 scale on the printer.
- A supply of good quality OHP acetates and ordinary white paper.
- Aerosol spray mount adhesive.
- Scissors, art scalpel (and a paper guillotine if available) to make the cut-outs in the overlay for switches etc.

It is advantageous to use a CAD package for the design (rather than a package such as Microsoft Powerpoint) which allows a 1:1 scale drawing to be produced. The mounting holes for the components involved in the layout can simply be measured and drawn up in their normal size.

The drawing is made in simple 2D mode so producing front panel overlays as described is unlikely to challenge a modern CAD package too greatly! The author uses TurboCAD by IMSI Ltd although any package that the constructor feels comfortable with is OK.

The spray mount adhesive is used to bond an OHP acetate to the plain paper. As the acetate will be transparent in certain areas, the adhesive used must also be transparent when dry. Use of a spray adhesive achieves this.

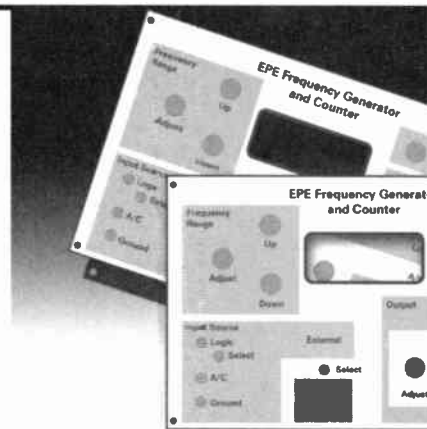


Fig. 1. Front panel of the author's Frequency Generator and Counter case.

## Designing the Layout

The first step in designing the overlay is to measure the corresponding area on the enclosure and draw this on the computer. In the example, the front panel is an aluminium rectangle with four fixing holes in the corners.

Then the mounting holes for the front panel components can be laid out in a logical manner. Use the CAD package's alignment and snap functions to line up the holes, remembering to allow enough space in front of and behind the panel for the components themselves. Rectangles and other shapes can be used to group the components and text labels added as shown in Fig.1. You can be as colourful as you like!

When the design is printed, the white paper is used to provide the background so there is no need to completely fill in the overlay, saving printer ink.

In the example panel, an l.c.d. display is used. It has been mounted behind the aluminium front panel using countersunk screws that are subsequently hidden when the overlay is put in place. A window drawn on the overlay aligns with a window in the background so the l.c.d. is visible.

When you are happy with the layout, it needs to be copied and modified several times to make up the components for the

finished product, as shown in Fig.2a. The method of procedure should be as follows:

Copy and mirror the overlay, Fig.2b. It can then be printed on the rough side of the OHP acetate and then turned over so that the colours are solid, the final finish is shiny and the ink will not be affected by moisture!

Copy the overlay and use the CAD package to place points at the centre of all of the holes. This image can be used as a drilling guide, Fig.2c.

Copy the overlay again to make the layout for the white paper background, Fig.2d. Delete everything except for the shapes that require cutting out of the background. In the example, this is the window for the display.

Note that on the overlay image, the border of the window is 2mm thick and on the background it is minimum thickness. This results in the background window being 1mm larger all the way round so that the cutting out does not have to be really neat – its hidden by the border on the OHP. It is worth experimenting with this effect.

## Making the Overlay

Print the mirrored overlay, the drilling guide and the background using appropriate settings on the printer. Make the cut outs in the background if required.

It is recommended that the OHP slide and the background are bonded before they are trimmed, as this makes alignment of the images easier. Spray the background with the adhesive, using newspaper to protect the surface underneath.

Move it to some fresh newspaper (or the l.c.d. window will get glue on it) and then lay the OHP slide over the top – see Fig.3. Once the glue is dry, trim the outside shape using scissors or a guillotine if available.

Next, tape the drilling guide to the enclosure panel and use it to drill the holes for the components. Deburr the holes using a file or oversize drill as appropriate.

### Mounting Holes

The mounting holes in the overlay can now be cut out. It is worth offering up the overlay to the enclosure and checking from behind that the drilled holes line up completely with the overlay markings. Use a leather punch or sharp instrument pressed into a scrap piece of wood to start the holes and then cut them out using scissors or scalpel. Check using the components themselves that the holes have been opened out sufficiently. The completed overlay is shown in Fig.4.

Finally, put the countersunk screws in position for any rear mounted components and then fix the remaining components to the enclosure with the overlay in place. The spray mount adhesive can be used again if preferred to prevent the overlay from distorting but remember to apply it to the enclosure surface and not the overlay to prevent any clear windows from getting adhesive on them. If this is not possible (when the overlay fits into a recess on the enclosure for example), use a mask cut from plywood to prevent the adhesive getting in the wrong place.

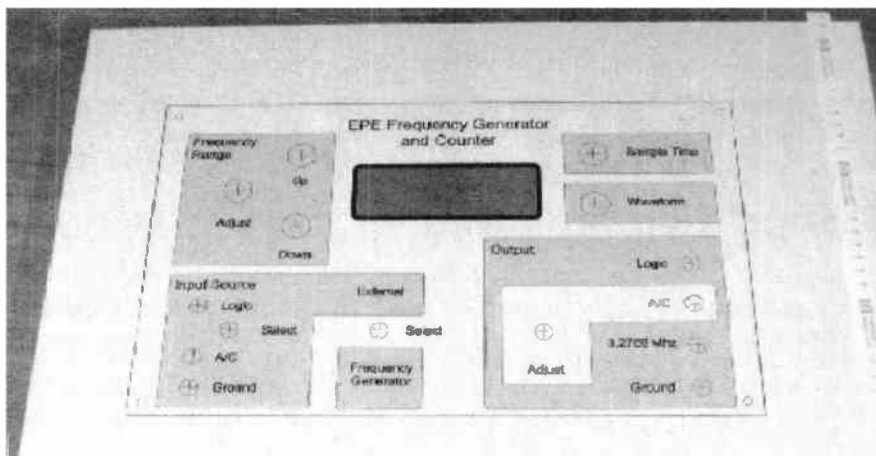


Fig.3. Completed overlay ready for trimming.

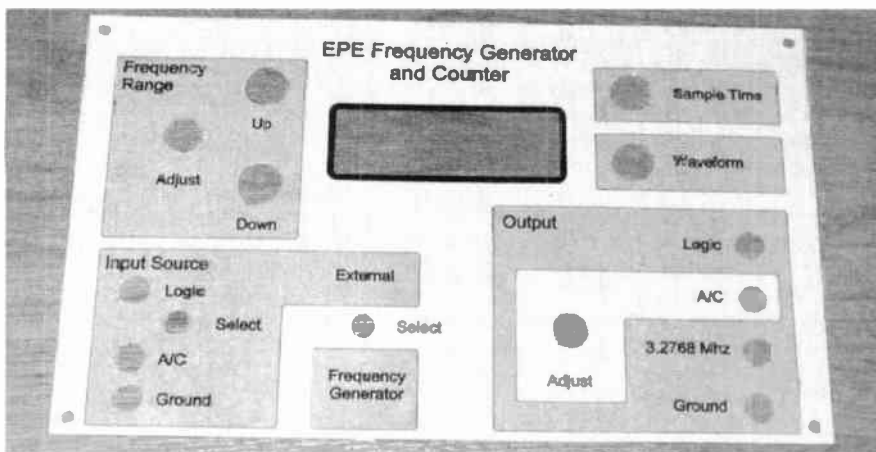


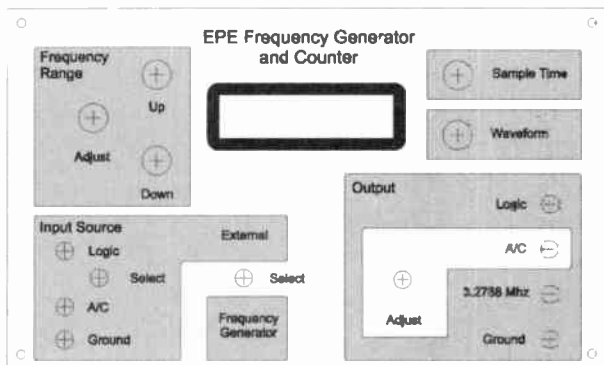
Fig.4. Finished overlay ready for mounting on the front panel.

### Other Ideas

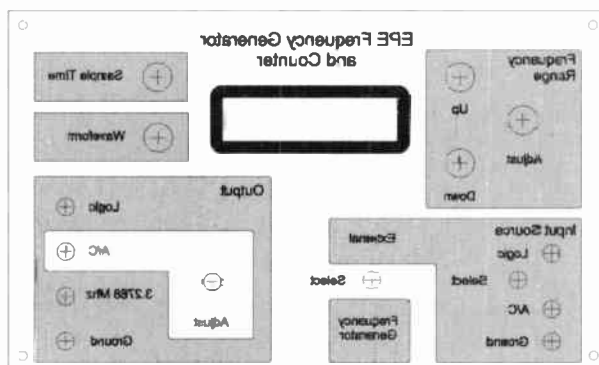
As an extension to the above technique, a membrane keyboard effect can be generated by fixing suitable switches on a circuit board behind the overlay using countersunk

screws. The keyboard can then be drawn on the overlay to the user's specification.

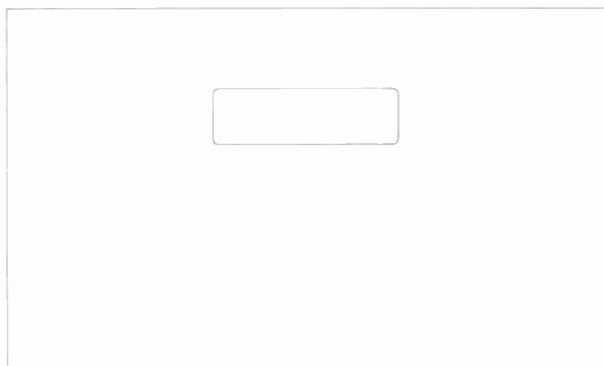
This article has shown how front panel overlays can be produced with minimal cost to achieve professional results. Happy constructing! □



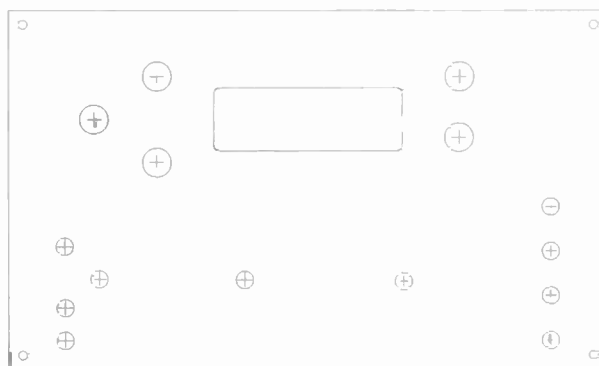
a)



b)



c)



d)

Fig.2. CAD drawings (clockwise from top left), a) final layout, b) mirrored layout, c) drilling guide and d) background.

# PRACTICALLY SPEAKING

*Robert Penfold looks at the Techniques of Actually Doing It!*

**P**ROBABLY the biggest worry for newcomers to electronic project construction is the possibility of the first project or two failing to work. If you are not suitably diligent at checking everything during construction, and again before switching on, you may well find that the number of failures substantially outnumbers the successes.

This is not to say that a project that fails to work first time will never work. Fortunately, when a project fails to work first time there is usually a very simple solution to the problem. A few minutes of belated checking and correction are sufficient to get most faulty projects "up and running".

When things go wrong it is important to be positive in your approach, and to set about finding the mistake (or mistakes) that you have probably made. Passing the buck by telling everyone that it is the fault of the project designer or publisher is the easy way out, but it will not get the project working.

If a few basic checks fail to locate a problem, then it might then be worthwhile contacting the publisher of the project to see if there is a known error in the article in question (*in the case of EPE, look out for any "Please Take Note" entries in the mag. - Ed.*). In most cases though, it is a construction fault that is responsible for the problem.

## Deja Vu

Faultfinding is relatively easy for "old hands" at project construction. It would be an exaggeration to say that they have seen it all before, but you do seem to get certain errors occurring time and time again.

Experienced project builders know the telltale signs, and, as a result, can often home straight in on a problem. Here are some of the most common classic symptoms together with the likely causes.

## Hot Stuff

Most project builders soon develop a keen sense of smell that will detect any hot components. Where a project uses power semiconductors this smell is quite normal, but if the project is not working properly it is vital to switch it off at once. The quicker you get to the off switch, the better the chances of the heated components surviving the experience.

When overheating does occur it is usually a semiconductor that has become heated. The most likely cause of the problem is an integrated circuit that has been fitted into its holder with the wrong orientation. When dealing with integrated

circuits try not to get fazed by extraneous marks and indentations in the cases.

With the vast majority of devices, getting the orientation wrong causes a high supply current to flow which quickly heats the component. Surprisingly perhaps, most semiconductors seem to withstand this high current for short periods. There will usually be no damage provided the power is switched off before something gets seriously overheated.

Integrated circuits should be fitted in holders. If a mistake is made it is then easy to remove the device and fit it the right way round.

## Tight Squeeze

Ideally a special integrated circuit removal tool should be used, and the simple tweezers type (Fig.1) is sufficient. It is otherwise a matter of gently prising out the chip using the blade of a small screwdriver, being careful not to bend any of the pins.

Do *not* remove integrated circuits using your fingers. They nearly always come free at one end while the other remains in the socket. This bends some of the pins (Fig.2), and there is a risk of the pins breaking off when they are pushed back into place.

Even if you have the right tools, removing an integrated circuit that is soldered to the board risks damaging both the component and the copper tracks on the board. Should all the integrated circuits get hot it is likely that they are fitted correctly but the battery is connected with the wrong polarity.

## Smoke Signals

Do not assume that components will heat up slowly, and that you will have an opportunity to switch off before there is any serious damage. A fault can cause

such a large current flow that a component is "zapped" almost immediately.

This usually occurs in the form of a bursting electrolytic capacitor. Large electrolytic capacitors are often used for supply decoupling, and are therefore connected straight across the supply rails. Getting one of these connected with the wrong polarity often causes a large current to flow and the component almost immediately bursts. Fitting a replacement is easy enough, but this is definitely something where "prevention is far better than cure". Always double-check the polarities of electrolytics before powering up a project, and be especially careful with the larger and higher voltage types.

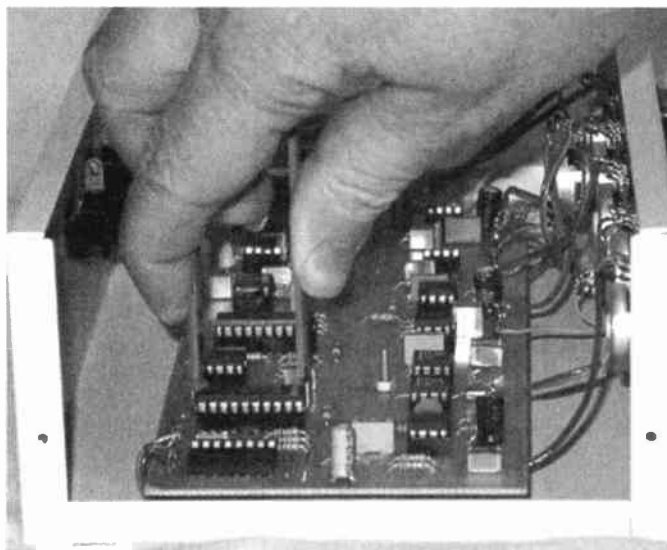
Diodes and small transistors are also vulnerable to this problem. In the case of a diode the most likely cause is that it was connected the wrong way around. Simply replacing it with one connected with the correct polarity should cure the problem.

With an "exploding" transistor it is likely that the cause will be found elsewhere in the circuit. Replacing the damaged component will probably just result in another "zapped" transistor. Try to determine the cause before fitting a replacement. Is there a solder splash producing a short circuit between two of the board's copper tracks?

## Backwards Control

A volume control or other control that uses a potentiometer will sometimes operate "backwards". There are three terminals on a potentiometer. The outer two are the track terminals and the middle one is the wiper terminal. The project will still work if you get the connections to the track terminals swapped over, but the control will work "backwards". For instance, advancing a volume control will actually reduce the volume. Simply swap the two track connections and it should work normally.

There can be other problems with potentiometers, and a typical example would be a volume control that works after a fashion, but with a very odd control characteristic and (possibly) distortion at low volume levels. This is often indicative of the connections to the wiper and one of the track terminals being transposed. In a volume control application it might actually provide control of the volume by loading down and virtually short circuiting the output of the preceding stage. This heavy loading will usually produce heavy distortion at very low volume settings. Reverse the



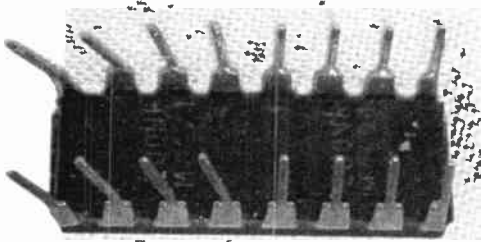
*Fig.1. Integrated circuits must be removed carefully, preferably using a special tool such as these tweezers that hook under the body of the device.*



wrong connections and the control should work properly.

A control that uses a dual-gang potentiometer will sometimes work plausibly at middle settings, but behave erratically towards the ends of its adjustment range.

This is usually the result of getting the track connections to one gang of the potentiometer swapped over. At middle settings this usually makes little difference, but things go awry as the control is adjusted away from the midpoint. This is due to the two gangs going further and further out of balance, giving the circuit little chance of working properly. Reverse the incorrect connections and normality will be restored.



*Fig.2. This is often the result of removing an integrated circuit using your fingers. The pins can be carefully pushed back into position, but could break off.*

### L.E.D. Astray

I think it is fair to say that l.e.d.s have tended to be troublesome ever since they were first introduced. These days most l.e.d.s, including many of the more fancy types, have the cathode (k) lead shorter than the anode one. Also, there is usually a "flat" on the cathode side of the body.

However, I have encountered l.e.d.s which do things the other way around. Some of them seem to be completely symmetrical, giving no clue as to the correct method of connection. The larger electrode inside the component usually connects to the cathode leadout, but there are exceptions, and with some l.e.d.s it is not possible to see inside the encapsulation properly anyway.

The most likely cause of an l.e.d. failing to work is that it is connected with the wrong polarity. Even if a check of the wiring suggests that an inoperative l.e.d. is connected correctly, it is still worthwhile trying the opposite method of connection. There always seem to be a few l.e.d.s that do things differently, and you might be using one of them. Getting the polarity of an l.e.d. wrong should not do any harm, so it is quite acceptable to adopt a "suck it and see" approach with these components.

### Stripped For Success

My success rate using stripboard used to be extremely low, with few projects working first time. By far the most frequent fault was an accidental short circuit between adjacent copper strips due to some excess solder. The solution to the problem was to clean the copper side of the board and then carefully check for excess solder. Vigorously

brushing the strips using an old toothbrush is sufficient to remove excess flux and other dirt.

This permits a clearer view of the board, but some of the pieces of excess solder are very small. They are more easily seen with the aid of a magnifying glass or even a loupe. A few seem to defy visual detection. Using a sharp modelling knife to score between the strips should remove minute solder blobs.

### Sound of Silence

Problems with a lack of signal from an audio project are often due to minor problems with the plugs and sockets. It is likely that everything is alright on the output side of the circuit if there is some background noise such as the usual "hiss". Making an error with the connections to the input socket can short circuit the input of the project, giving no significant output signal. Sometimes getting these connections swapped-over will result in a lot of "hum" and other noise such as breakthrough from strong radio transmissions.

Cables with broken wires or bad internal connections are not exactly a rarity. If possible, check the leads using a continuity tester. Also check for short circuits between the wires, as well as checking for a lack of continuity through each lead. The "hum" and noise problem mentioned previously can be caused by a bad connection between the screen of the cable and the plug.

When there is genuinely no detectable output signal at all from an audio project, start by checking the output socket. If the output socket of a power amplifier is an insulated type, such as a plastic jack or a two-way DIN loudspeaker socket, it will work with the socket connected either way round. With a stereo amplifier the phasing of the speakers will be wrong if one socket is connected the wrong way round. This will give a poor stereo image, but in other respects it will work properly.

If an output socket is not an insulated type and has one tag connecting to the amplifier's chassis, getting the connections round the wrong way will short circuit the output. Damage is unlikely to occur if the project is something like a signal processor that has a low power output stage. There could be disastrous consequences with a project that has a power amplifier at the output. Great care has to be taken with any project that provides significant output powers, and the output wiring should be thoroughly checked before switching on. Output leads are no more reliable than the input variety, so check that the output cables are functioning properly.

### Sort of Works

Sometimes a project works after a fashion, but (say) the ranges of a piece of test gear seem to be here, there, and everywhere. Is it simply that you have misinterpreted things, and that (say) the high setting is actually the low one and vice versa? With a rotary switch are what you think are ranges 1 through 5 actually ranges 5 through 1?

When wiring up rotary switches it is easy to make mistakes. In particular, it

is very easy to get all the connections to the outer ring of contacts shifted one tag away from their correct placement. The pole tags are normally marked "A", "B", "C", etc., and the wiper tags are marked "1" to "12". With a six-way two-pole switch for example, tag "A" is grouped with tags "1" to "6", and tag "B" is grouped with tags "7" to "12".

Unfortunately, it is difficult to see these markings when you are making the connections to the tags, and it is easy to get every connection shifted one tag out of position. The other easy mistake is to wire the switch in reverse so that ranges 1 to 5 really would become ranges 5 to 1. A close visual inspection should soon reveal any errors.

### Absolutely Zero

The possible causes for a project doing absolutely nothing are practically endless, but it is best to start with the most simple of the likely causes. Check the battery and battery clip first. Often problems occur with battery clips where one press-stud does not make good contact with its counterpart on the battery. Carefully squeezing the female connector inwards using some pliers will usually clear the problem.

Some battery clips appear to be perfectly all right, but a lead has actually come adrift internally. Pulling firmly on the leads should detach a lead that is not actually connected to anything. Most battery connectors can be cut open and repaired quite easily, but it is best to fit a replacement at the earliest opportunity.

Is the battery in a usable state? If possible it should be checked with a multimeter or battery tester, especially if it is something less than new. Alternatively, try it in another gadget that uses the same type of battery. Bear in mind though, that some devices work quite well using batteries that are virtually flat while others need one that still has plenty of life left in it. When in doubt it is best to try a new battery.

What could be termed the classic mistake is to forget to switch on. It may sound ridiculous, but sooner or later everyone seems to somehow convince themselves that a project should be working when it is not actually turned on or it is not plugged in and switched on at the mains.

Miniature toggle and slider switches are not the most reliable of components. The quality has improved somewhat in recent years, but some of them still work rather intermittently, if at all. Switches are easily checked using the most basic of continuity testers. With a mains powered project you **MUST unplug** the unit from the mains before testing the switch.

### Last but Not Least

When project building, it is best to work on the basis that prevention is better than cure. Carefully checking a project prior to switch-on is time well spent. It is *essential* with projects that involve power semiconductors or are mains powered. A lack of checking could result in expensive damage and could even be dangerous.

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I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

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Third Edition

Morris Rosenthal

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Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. For non-specialists, there's even a graphical glossary that clearly illustrates technical terms. The author goes "under the hood" and shows step-by-step how to create a socket 7 (Pentium and non-intel chipsets) and a Slot 1 (Pentium II) computer, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows 98. The few existing books on this subject, although badly outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are eagerly looking for.

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# Theory and Reference

## BEBOP TO THE BOOLEAN BOOGIE Second Edition Clive (Max) Maxfield

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**Contents:** Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

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**Contents:** waves and pulses, passive components, active components and ICs, linear circuits, block and circuit diagrams, how radio works, disc and tape recording, elements of TV and radar, digital signals, gating and logic circuits, counting and correcting, microprocessors, calculators and computers, miscellaneous systems.

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S. W. Amos and Roger Amos

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Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.

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R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

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If you want to take your synthesiser – of the hardware or software variety – past the presets, and program your own sounds and effects, this practical and well-illustrated book tells you what you need to know.

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All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

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## 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.

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## THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN

Robert Charles Alexander

This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

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 thirtieth birthday.

420 pages

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## 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.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical video, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, push-button fader, computer control interface, 12 volt mains power supply.

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## PC MUSIC – THE EASY GUIDE

Robin Vincent

How do I make music on my PC? Can I record music onto my PC? What's a sequencer? How can I get my PC to print a music score? What sort of a soundcard do I need? What hardware and software do I need? How do I connect a keyboard to my PC?

Just a few of the questions you've probably asked. Well, you'll find the answers to all these questions, and many more, in this book. It will show you what can be done, what it all means, and what you will need to start creating your own music on your PC. It's an easy read, it's fully illustrated and it will help you understand how a computer can be used as a creative music tool.

It covers soundcards, sequencers, hard disk digital audio recording and editing, plug-ins, printing scores with notation software, using your PC as a synthesiser, getting music onto and off the Internet, using Windows, sample PC music setups, FAQs, a glossary, advice on hardware and software, and a list of industry contacts.

116 pages

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## HIGH POWER AUDIO AMPLIFIER CONSTRUCTION

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96 pages

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# Circuits, Data and Design

## PRACTICAL ELECTRONIC FILTERS

Owen Bishop

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

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

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

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There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

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Mike James

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R. A. Penfold

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The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

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While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

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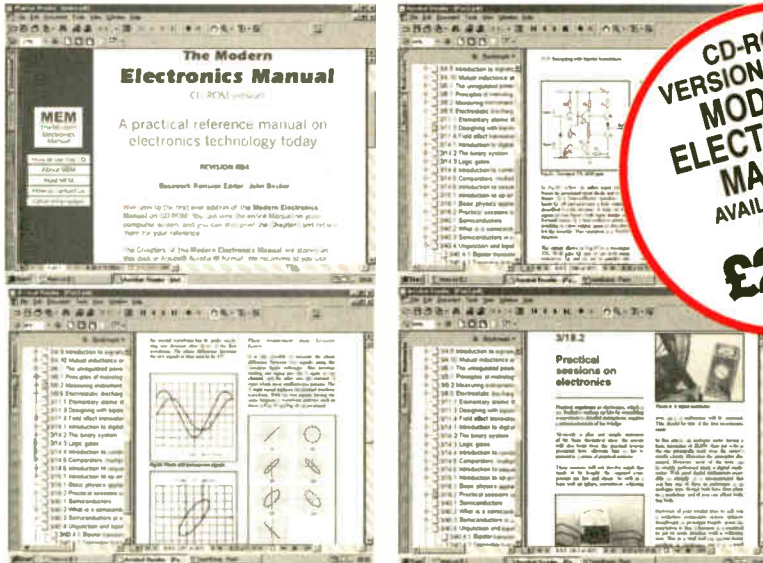
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## ADVERTISERS INDEX

N. R. BARDWELL	503
B.K. ELECTRONICS	Cover (iv)/460
BRUNNING SOFTWARE	443
BULL GROUP	Cover (ii)
CRICKLEWOOD ELECTRONICS	515
DISPLAY ELECTRONICS	438
ESR ELECTRONIC COMPONENTS	446
FOREST ELECTRONIC DEVELOPMENTS	468
JAYCAR ELECTRONICS	477
JPG ELECTRONICS	516
LABCENTER	Cover (iii)
MAGENTA ELECTRONICS	444/445
MATRIX MULTIMEDIA	460
MILFORD INSTRUMENTS	457
PEAK ELECTRONIC DESIGN	493
PICO TECHNOLOGY	500
QUASAR ELECTRONICS	440/441
SHERWOOD ELECTRONICS	516
SQUIRES	515
STEWART OF READING	515

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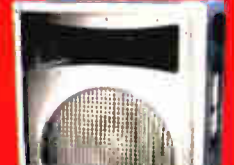
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