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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-purposeTV/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 49.7MHz-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 causing it to scan. The clips can be moved to adjust the span 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 80mm £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 infra-red 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 syem 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, back/neck 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
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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 o/p 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

8A solar regulator 12V, 96 watt, 150mm x 100mm x 25mm. £30 REF SOLREG2

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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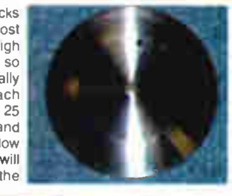


THE TIDE CLOCK. These clocks indicate the state of the tide. Most areas in the world have two high tides and two low tides a day, so the tide clock has been specially designed to rotate twice each lunar day (every 12 hours and 25 minutes) giving you a quick and easy indication of high and low water.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

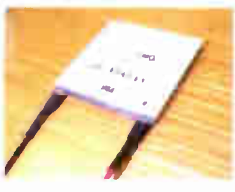
LINEAR ACTUATORS 12-36V D.C. BUILT-IN ADJUSTABLE LIMIT SWITCHES. POWER COATED 18in. THROW UP TO 1,000lb. THRUST (400lb. RECOMMENDED LOAD). SUPPL'ED WITH MOUNTING BRACKETS DESIGNED FOR OUTDOOR USE. These brackets originally made for moving very large satellite dishes are possibly more suitable for closing 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 4¼in. and comes complete with built-in alcohol burner. Red 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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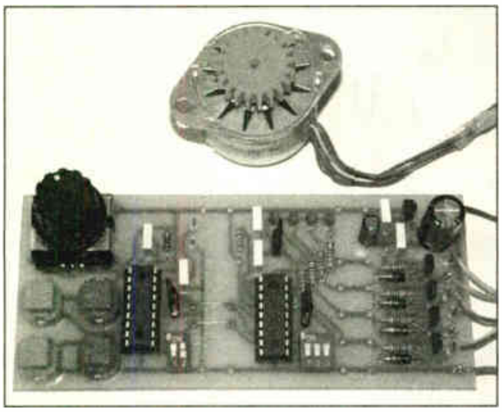

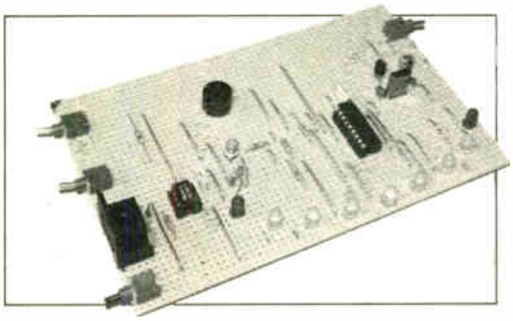

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Our July 2004 issue will be published on Thursday, 10 June 2004. See page 367 for details

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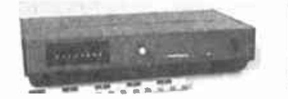
A bulk purchase enables us to bring to you these GIANT 7-segment digital displays at a now affordable price!! The **10" character size** gives exceptional readability at long distances and enables a host of applications including, score boards, **digital clocks, counters, event timers** etc. As the units 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.

Less than 30% of makers price — **Only £29.95**(B) Order RW44 **or 4 / £99.00**(D) Order PH26

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 STL 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***

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2½" to 3½" conversion kit for Pc's, complete with connectors	£15.95
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3½" **QUANTUM 40S Prodri** ve 42mb SCSI I/F, New RFE	£49.00
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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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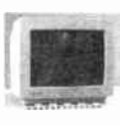

Mitsubishi FA3415ETKL 14" SVGA **Multisync** colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's in CGA, EGA, VGA & SVGA** modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE**. Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, in EXCELLENT little 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"	15"	17"
£59.00	**£69.00**	**£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 Dimensions: W14" x H12¾" x 15½" D. **Only £99.00** (E)

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 13½" D. 240 V AC mains powered. **Only £79.00** (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 QG36.

100's of applications inc: firewall, routers, robotics etc **Only £99.00** (D)

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Made by **Eurocraft Enclosures** Ltd to the **highest possible spec,** rack features **all steel construction** with removable side, front and back doors. Front and back doors are **hinged for easy access** and all **lockable with five secure 5 lever barrel locks.** The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members to **take the heaviest of 19" rack equipment.** The two movable vertical **fixing** struts (extras available) are pre punched for standard 'cage nuts'. A **mains distribution panel** internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin **switched utility socket.** Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvres. The top panel may be removed for fitting of **integral fans** to the sub plate etc. Other features include: fitted castors and floor levelers, prepunched utility panel at lower rear for cable / connector access etc. Supplied in **excellent,** slightly used condition with keys. Colour Royal blue. some grey available – CALL – Can be supplied in many other configurations.

33U	42U	47U
Order as BC44	Order as DT20	Order as RV36
External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)	External dimensions mm=2019H x 635D x 603 W. (79.5" H x 25" D x 23¾" W)	External dimensions mm=2019H x 635D x 603 W. (88" H x 25" D x 23¾" W)
Only **£245**	Only **£345**	Only **£410**

Call for shipping quotation

COLOUR CCD CAMERAS

BIG £ SAVER

Undoubtedly **a miracle of modern technology** & our special buying power ! **A quality product** featuring a fully cased **COLOUR** CCD camera at a give away price ! Unit features full autolight sensing for use in **low light & high light applications.**

A 10 mm fixed focus wide angle lens gives **excellent focus and resolution** from close up to long range. The **composite video** output will connect to any composite monitor or TV (via SCART socket) and most video recorders. Unit **runs from 12V DC** so ideal for security & **portable applications** where mains power not available. Overall dimensions 66 mm wide x 117 deep x 43 high. Supplied BRAND NEW & fully guaranteed with user data, 100's of applications including Security, Home Video, Web TV, Web Cams etc, etc.

Order as LK33 ***ONLY £79.00 or 2 for £149.00*** *(B)*

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NT4 WorkStation, complete with service pack 3 and licence - OEM packaged. ***ONLY £89.00*** *(B)*

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Wordperfect 6 for DOS supplied on 3½" disks with manual	**£24.95**

SOLID STATE LASERS

Visible red, 670nm laser diode assembly. Unit runs from 5 V DC at approx 50 mA. Orginally made for continuous use in industrial bar-code scanners, the laser is mounted in a removable solid aluminium block, which functions as a heatsink and rigid optical mount. Dims of block are 50 w x 50 d x 15 h mm. Integral features include over temperature shutdown, current control, laser OK output, and gated TTL ON / OFF. Many uses for experimental optics, comms & lightshows etc. Supplied complete with data sheet.

Order as TD91 ***ONLY £24.95*** *(A)*

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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 Suppy	£1850
KINGSHILL CZ403/1 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
ALLGON 8360.11805-1880 MHz hybrid power combiners	£250
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 020 300 MHz pulse generator, GPIB etc	£7900
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HP DRAFTMASTER 1 8 pen high speed plotter	£750
EG+G Brookdeal 95035C Precision lock in amp	£1800
Keithley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel voice recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS – New batteries	£4500
Emerson AP130 2.5KVA industrial spec.UPS	£1499
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Perkin Elmer 597 Infrared spectrophotometer	£3500
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3250
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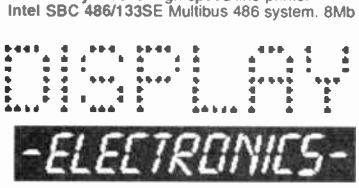
CLAUDE LYONS 12A 240V single phase auto. volt. regs	£325



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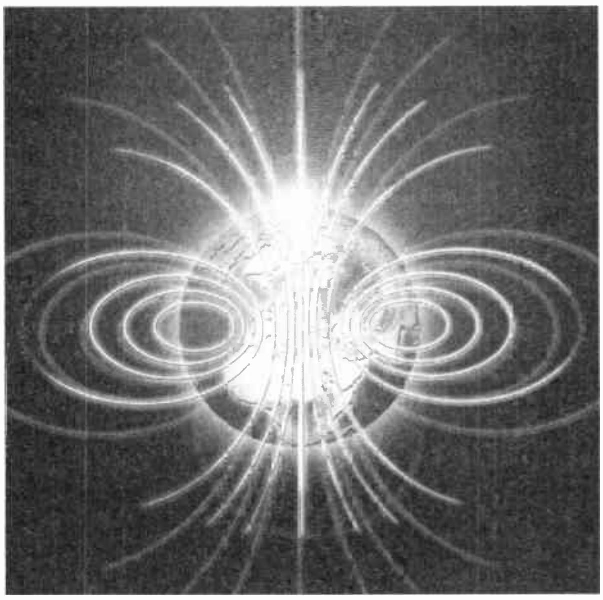
NEXT MONTH

EPE PIC MAGNETOMETRY LOGGER

Magnetometers 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.
This design is PIC-controlled and uses two FGM-3 fluxgate sensors from Speake & Co who describe them as "very high sensitivity magnetic field sensors operating in the ±50 microtesla range", which covers the Earth's magnetic field. Their applications include conventional magnetometry, ferrous metal detectors, magnetic material measurement and archaeological artifact assessment.
Data is recorded by the PIC to on-board memory, from where it can later be downloaded to a Windows-based PC for visual analysis.



PORTABLE MINI ALARM

This 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.

FRONT PANEL FINISHING

Adding 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.

BONGO BOX

The Bongo Box is for budding drummers everywhere who like to tap out a rhythm with their fingertips 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 and linking it to a PC. 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 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!

PLUS **TEACH-IN 2004 – PART 9 LOCK AND ALARM SYSTEMS**

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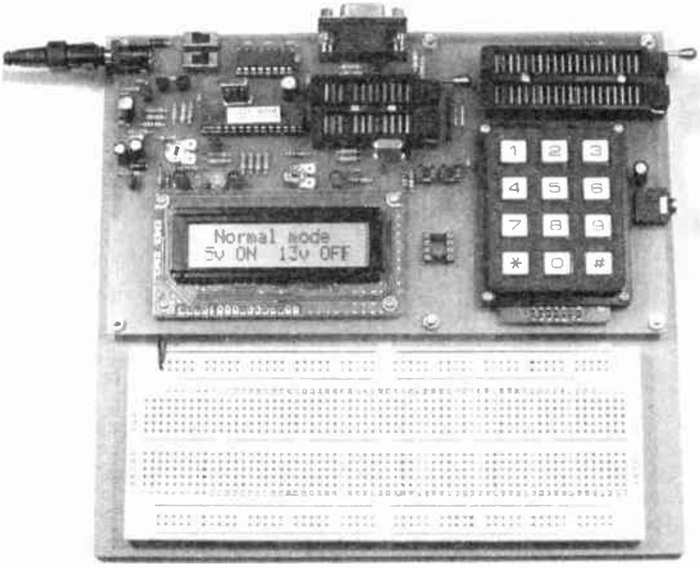

PIC Training & Development System

The best place to start learning about microcontrollers is the PIC16F84. This is easy to understand and very popular with construction projects. Then continue on using the more sophisticated PIC16F877 family.

The heart of our system is two real books which lie open on your desk while you use your computer to type in the programme and control the hardware. Start with four very simple programmes. Run the simulator to see how they work. Test them with real hardware. Follow on with a little theory.....

Our complete PIC training and development system consists of our universal mid range PIC programmer, a 306 page book covering the PIC16F84, a 262 page book introducing the PIC16F877 family, and a suite of programmes to run on a PC. The module is an advanced design using a 28 pin PIC16F870 to handle the timing, programming and voltage switching requirements. The module has two ZIF sockets and an 8 pin socket which between them allow most mid range 8, 18, 28 and 40 pin PICs to be programmed. The plugboard is wired with a 5 volt supply. The software is an integrated system comprising a text editor, assembler disassembler, simulator and programming software. The programming is performed at 5 volts, verified with 2 volts or 3 volts applied and verified again with 5.5 volts applied to ensure that the PIC is programmed correctly over its full operating voltage. DC version for UK, battery version for overseas. UK orders include a plugtop power supply.

Universal mid range PIC programmer module
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+ Universal mid range PIC software suite
+ PIC16F84 and PIC16F870 test PICs. £159.00
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Experimenting with PIC Microcontrollers

This book introduces the PIC16F84 and PIC16C711, and is the easy way to get started for anyone who is new to PIC programming. We begin with four simple experiments, the first of which is explained over ten and half a pages assuming no starting knowledge except the ability to operate a PC. Then having gained some practical experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Für Elise*. Finally there are two projects to work through, using the PIC16F84 to create a sinewave generator and investigating the power taken by domestic appliances. In the space of 24 experiments, two projects and 56 exercises the book works through from absolute beginner to experienced engineer level.

Hardware & Ordering Information

Our latest programmer module connects to the serial port of your PC (COM1 or COM2), which enables our PIC software to operate directly within Windows 98, XP, NT, 2000 etc.

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NEW 32 bit PC Assembler

Experimenting with PC Computers with its kit is the easiest way ever to learn assembly language programming. If you have enough intelligence to understand the English language and you can operate a PC computer then you have all the necessary background knowledge. Flashing LEDs, digital to analogue converters, simple oscilloscope, charging curves, temperature graphs and audio digitising.

Kit now supplied with our 32 bit assembler with 84 page supplement detailing the new features and including 7 experiments PC to PIC communication. Flashing LEDs, writing to LCD and two way data using 3 wires from PC's parallel port to PIC16F84.

Book + made up kit 1a + software........ £73.50
Book + unmade kit 1u + software......... £66.50
(PP UK £4, Europe £10, Rest of world £14)

C & C++ for the PC

Experimenting with C & C++ Programmes teaches us to programme by using C to drive the simple hardware circuits built using the materials supplied in the kit. The circuits build up to a storage oscilloscope using relatively simple C techniques to construct a programme that is by no means simple. When approached in this way C is only marginally more difficult than BASIC and infinitely more powerful. C programmers are always in demand. Ideal for absolute beginners and experienced programmers.

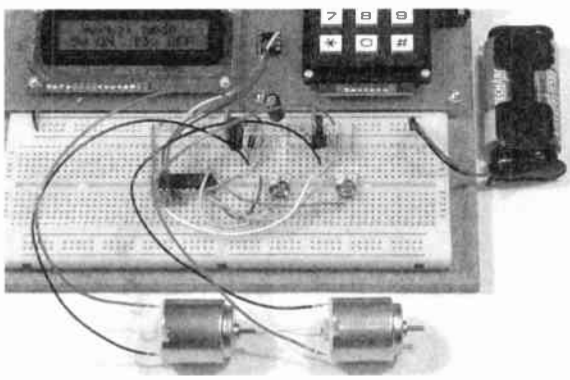
Book + made up kit 2a + software £57.50
Book + unmade kit 2u + software £51.50
Book + top up kit 2t + software £37.98
(PP UK £4, Europe £10, Rest of world £14)

The Kits

The assembler and C & C++ kits contain the prototyping board, lead assemblies, components and programming software to do all the experiments. The 'made up' kits are supplied ready to start. The 'top up' kit is for readers who have already purchased kit 1a or 1u.

Assembler and C & C++

Click on 'Special Offers' on our website for details of how to save by buying a combined kit for assembler and C & C++.



Experimenting with the PIC16F877

The second PIC book starts with the simplest of experiments to give us a basic understanding of the PIC16F877 family. Then we look at the 16 bit timer, efficient storage and display of text messages, simple frequency counter, use a keypad for numbers, letters and security codes, and examine the 10 bit A/D converter.

The PIC16F627 is then introduced as a low cost PIC16F84. We use the PIC16F627 as a step up switching regulator, and to control the speed of a DC motor with maximum torque still available. We study how to use a PIC to switch mains power using an optoisolated triac driving a high current triac. Finally we study how to use the PICs USART for serial communication to a PC.

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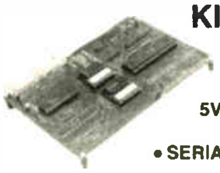

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Kit includes case, P.C.B., coupling coil and all components.
High coil current ensures maximum effect. L.E.D. monitor.

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Our latest design – The ultimate scarer for the garden. Uses special microchip to give random delay and pulse time. Easy to build reliable circuit. Keeps pets/pests away from newly sown areas, play areas, etc. uses power source from 9 to 24 volts.
- **RANDOM PULSES**
- **HIGH POWER**
- **DUAL OPTION**

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As featured in March '97 issue.

Set of 4 spare electrodes £6.50

Magenta have prepared a FULL KIT for this. excellent new project. All components, PCB, hardware and electrodes are included.
Designed for simple assembly and testing and providing high level dual output drive.

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Kit includes wound coil, cut-out case, meter scale, PCB & ALL components.

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Full set of top quality *NEW* components for this educational series. All parts as specified by *EPE*. Kit includes breadboard, wire, croc clips, pins and all components for experiments, as listed in introduction to Part 1.
**Batteries and tools not included.*

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MULTIMETER £14.45

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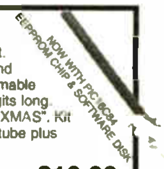
An innovative and exciting project. Wave the wand through the air and your message appears. Programmable to hold any message up to 16 digits long. Comes pre-loaded with "MERRY XMAS". Kit includes PCB, all components & tube plus instructions for message loading.



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Keep pets/pests away from newly sown areas, fruit, vegetable and flower beds, children's play areas, patios etc. This project produces intense pulses of ultrasound which deter visiting animals.

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- UP TO 4 METRES RANGE
- LOW CURRENT DRAIN

KIT 812. . . . .£15.00

SIMPLE PIC PROGRAMMER
KIT 857... £12.99

Includes PIC16F84 chip disk, lead, plug, p.c.b., all components and instructions

Extra 16F84 chips £3.84
Power Supply £3.99

MAGENTA BRAINIBOT I & II

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- Full kit with ALL hardware and electronics
- As featured in *EPE* Feb '03 – KIT 910
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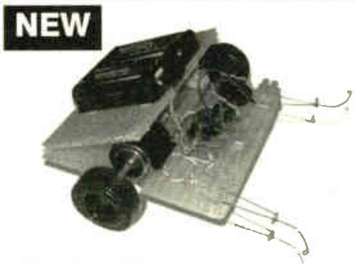
- Spins and reverses when 'cornered'
- Uses 8-pin PIC
- ALSO KIT 911 – As 910 *PLUS* programmable from PC serial port – leads and software CD provided



KIT 910 £16.99 **KIT 911 £24.99**

PIC 16F84 MAINS POWER 4-CHANNEL CONTROLLER & LIGHT CHASER

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- 12 KEYPAD CONTROL
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- WITH SOURCE CODE
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- EASILY PROGRAMMED

Kit 855 £39.95

PIC 16F84 LCD DISPLAY DRIVER

INCLUDES 1-PIC16F84 WITH DEMO PROGRAM SOFTWARE DISK, PCB, INSTRUCTIONS AND 16-CHARACTER 2-LINE

LCD DISPLAY

Kit 860 £19.99

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

Another super PIC project from Magenta. Supplied with PCB, industry standard 2-LINE × 16-character display, data, all components, and software to include in your own programs. Ideal development base for meters, terminals, calculators, counters, timers – Just waiting for your application!

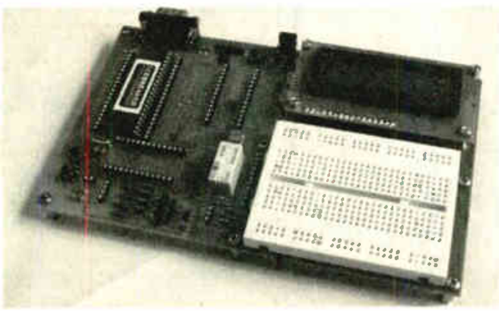
8-CHANNEL DATA LOGGER

NEW!

As featured in Aug./Sept. '99 *EPE*. Full kit with Magenta redesigned PCB – LCD fits directly on board. Use as Data Logger *or* as a test bed for many other 16F877 projects. Kit includes programmed chip, 8 EEPROMs. PCB, case and all components.

KIT 877 £49.95 inc. 8 × 256K EEPROMS

ICEBREAKER



PIC Real Time In-Circuit Emulator

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- Windows™ (95+) Software included
- Works with MPASM and MPLAB Microchip software
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Full emulation means that all I/O ports respond exactly and immediately, reading and driving external hardware.
Features include: Reset; Halt on external pulse; Set Breakpoint; Examine and Change registers EEPROM and program memory; Load program, Single Step with display of Status, W register, Program counter, and user selected 'Watch Window' registers.

KIT 900 . . . £34.99

POWER SUPPLY £3.99 STEPPING MOTOR 100 STEP £9.99

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MARCH - APRIL - MAY '98 EPE SERIES 16F84

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KIT 870 .... £27.95, Built & Tested £42.95

Optional: **Power Supply – £3.99, ZIF Socket – £9.99**
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THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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HOW DO THEY DO IT ?

How can they make a solar powered l.e.d. light with a light-sensitive switch, charging circuit, rechargeable batteries and a stylish plastic housing for just £3.99? This is what our local garage is selling as garden lights, and very good they are too. In fact, the staff of Wimborne Publishing must have nearly wiped out their entire stock. It would not surprise me if a plane does not land in someone's back garden soon!

If we cost up the components, the l.e.d., solar cell and two rechargeable AA batteries would be about £6.00, without a little circuit to turn it on at dusk etc. and the injection moulded housing. The same thing applies to basic digital clocks and calculators these days, and it makes one wonder if it is worth building anything yourself anymore.

Of course you only have to look at this month's and next month's contents to see the reason why our hobby continues to be popular – can you buy a MIDI Synchronome, or a Body Detector, or maybe an inexpensive Magnetometer (coming next month). There are plenty of projects like test gear, amplifiers, radios, alarms, timers, light flashers etc. that you can buy off the shelf, but where is the fun, satisfaction and "hobby" in that? As one reader put it, I cannot play golf as good as Tiger Woods but that does not mean I will not play and just watch him!

FIRST

We have also been able to introduce ideas that have later become available as commercial items – things like meters to measure the cost of electricity used by appliances, guitar tuners, l.e.d. torches, and possibly the Wart Zapper we have lined up for a future issue. Electronics continues to be a fascinating and ever changing subject, one with many facets.

We know that not every reader will be interested in building every project, but plenty of readers tell us of the knowledge they gain from reading about how the circuits work and seeing how each author solved the various problems. Or maybe they borrow a section of circuitry or a chunk of PIC software to use in their own pet designs.

The interaction between the magazine and the readers, and between readers, is great to see – our *Readout* page and the *Chat Zone* on the website are always lively forums. (Although we have only been able to fit in one page of Letters this month due to lack of space.) We are always interested in your views and ideas, so please keep them coming.

Mike Kenward

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see opposite), from all UK newsagents (distributed by COMAG) and from the following electronic component retailers: Omni Electronics and Yebo Electronics (S. Africa) *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just $10.99US (approx £7) per year available from **www.epemag.com**

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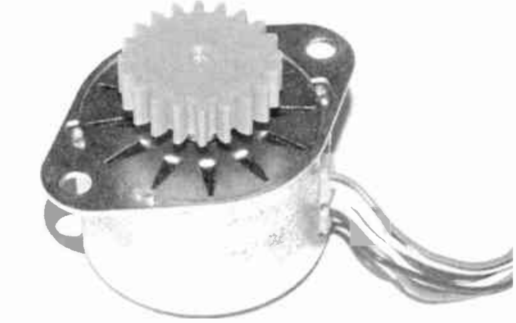
PIC QUICKSTEP



ANDY FLIND

A simple and versatile stepper motor driver and controller

FOR mechanical applications requiring precise control, stepper motors offer many advantages over simple d.c. types. They can start and stop virtually instantly and move in tiny, precise increments. Forward and reverse operation is simple. Accurate speed control is easy to achieve through step rate, and shaft position may be tracked simply by counting the steps.

There is a downside though, since electronic circuitry is required to generate the coil drive sequence needed for operating these motors. Special stepper driving i.c.s are available but these usually offer only one out of several possible drive methods, and they often draw too much supply current for battery applications.

Additional circuitry is usually required to generate step and direction inputs so it is often a better idea to use a custom programmed PIC microcontroller for complete step sequence control, and perhaps also the controlling system.

For the experimenter who has acquired a stepper motor, the priorities will usually be to check out its speed, torque and the effects of different types of drive sequence. It might also be desired to bolt it into a prototype design and rotate it back and forth in a controlled manner to check whether the project is likely to work. The PIC QuickStep allows rapid testing of this kind with many options that can be tried out to see their effects.

MOTOR CHOICE

There are various types of stepper motor. This article is concerned only with the four-phase unipolar type. This is the most common and may be bought new from suppliers or salvaged from old computer equipment such as printers and scanners. It will usually have either 48 or 200 steps per revolution and is likely to have either five or six connecting wires, four of which connect to four internal stator coils whilst the other(s) are "common" connections to the coils.

Sometimes the coils will be arranged as two pairs with a common lead each, sometimes all four will share a single common lead. Fig.1 shows the basic arrangement.

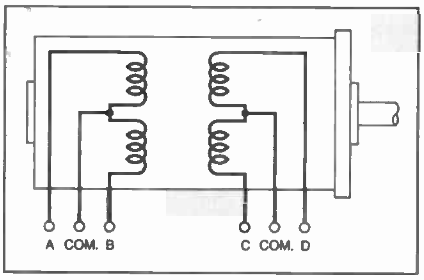


Fig.1. Connections for a 4-phase unipolar stepper motor.

The rotor of one of these motors is permanently magnetised so when its shaft is turned a "cogging" effect can be felt as its poles pass the poles of the stator. Fig.2 is a greatly simplified diagram showing the connections to a 4-phase unipolar stepper motor.

The rotor poles are facing stator coil *A*. If coil *B* is energised the rotor will turn one step to face it. If *C* is energised it will turn to face *C*, and then *D*, then *A* again. So by energising each coil in the sequence *A, B, C, D, A*... clockwise rotation is achieved. Powering the coils with the opposite sequence, *A, D, C, B, A* . . . would produce anti-clockwise operation.

WAVES AND STEPS

Powering one coil at a time is known as *wave* operation and has the advantage of low supply current and, if the supply is turned off, the motor is likely to stay where it is due to the attraction of the permanent magnet rotor to the last energised pole.

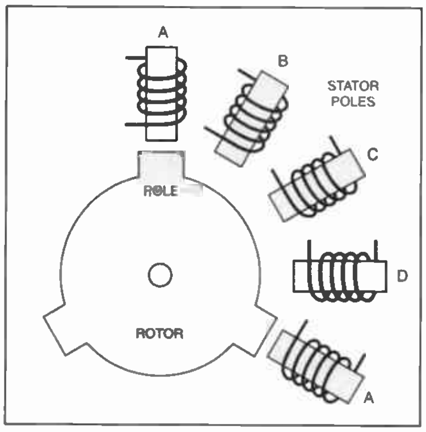
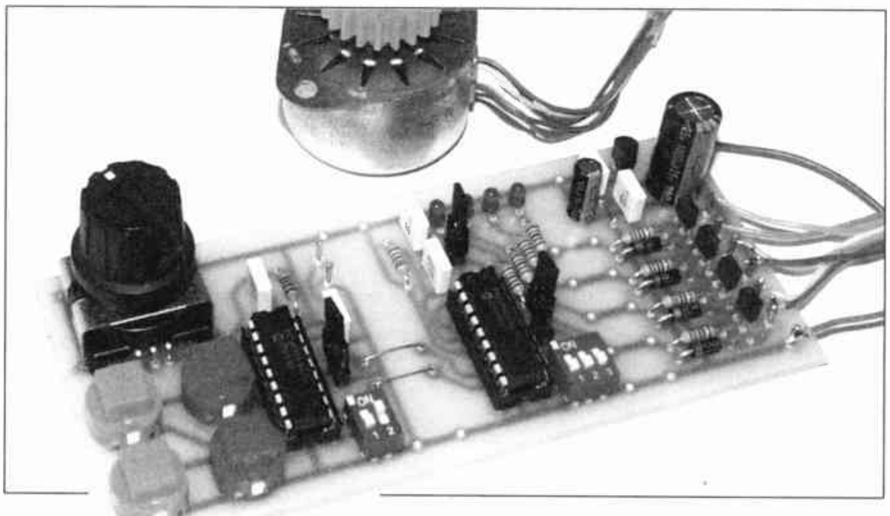


Fig.2. Stepper motor operation basics.

The drive method used by most stepper driver i.c.s is called *full step*. The coils are energised two at a time, *A+B, B+C, C+D, D+A, A+B* . . . This gives nearly twice the torque but also draws twice the supply current, and if the power is turned off the rotor may move slightly since it has been left halfway between two stator poles. For these reasons wave stepping may be preferable for some designs.

Finally, where greater precision or smoother rotation is required, half stepping may be employed. This is a hybrid



of full and wave stepping where the energising sequence takes the form of *A, A+B, B, B+C, C . . .*, the picture should be clear enough. For a given step rate the motor will rotate at half the speed given by the other two methods, but the increased precision and smoothness is instantly apparent.

It normally takes less than a couple of milliseconds for the motor to move. If the power stays on it will take considerable torque to move the motor from its static position, which can be useful. However, if the torque applied to the motor shaft is minimal it may be better to turn off the power between steps. This brings large power savings and may be the only practical solution for long-term battery operation. A "power-down" feature in QuickStep can be used to try this out.

CIRCUIT DIAGRAM

In the full circuit diagram of Fig.3 it can be seen that the QuickStep project is split into three sections. The first is the controller, based around IC1, a PIC16F628. Four pushbutton switches provide basic control, S5 for single step forward, S4 for single step reverse, S6 continuous stepping forward, and S3 continuous reverse. These four buttons are all "debounced" in software.

During continuous operation the speed may be controlled by variable resistor VR1 over a range slightly greater than ten to one, nominally from one step per second to 10 steps per second. The action of VR1 is non-linear, but adequate for testing.

Two switches, S1 and S2, multiply the speed range by ten or a hundred. S1 gives 10 to 100 steps per second and S2 gives 100 to 1000 steps per second. If both switches are "on", S2 takes precedence. The output from this part of the circuit consists of "forward step" commands from RA0 and "reverse step" commands from RB6.

Many dedicated stepper controller i.c.s do not use this method, instead they have "direction" and "step" inputs. To allow the QuickStep controller to be used with such i.c.s this method of operation is also available and may be selected by fitting link LK1. When this is done S5 controls direction through RA0, and S4 and S3 provide single and continuous steps respectively from RB6. In this mode "direction" switch S5 is not debounced, but S4 and S3 are, whilst S6 is not used.

During continuous stepping, RA1 provides output from test point TP1 for a frequency counter so that the precise step rate can be measured. There's little point in showing flowcharts for this project. Because of the many options available they are complex and space probably would not allow their inclusion. Basically both PICs check through the switches to locate the required action and then execute it.

The timer operation using VR1 may be of interest though; it works as follows. RA4 is made an output, taken low, and a few microseconds are allowed for C1 to discharge. It is then made an input again so C1 charges through VR1 and R1. As an input RA4 has a Schmitt trigger characteristic, ideal for this purpose. For timing, it is now only necessary to check occasionally to see if it has gone high.

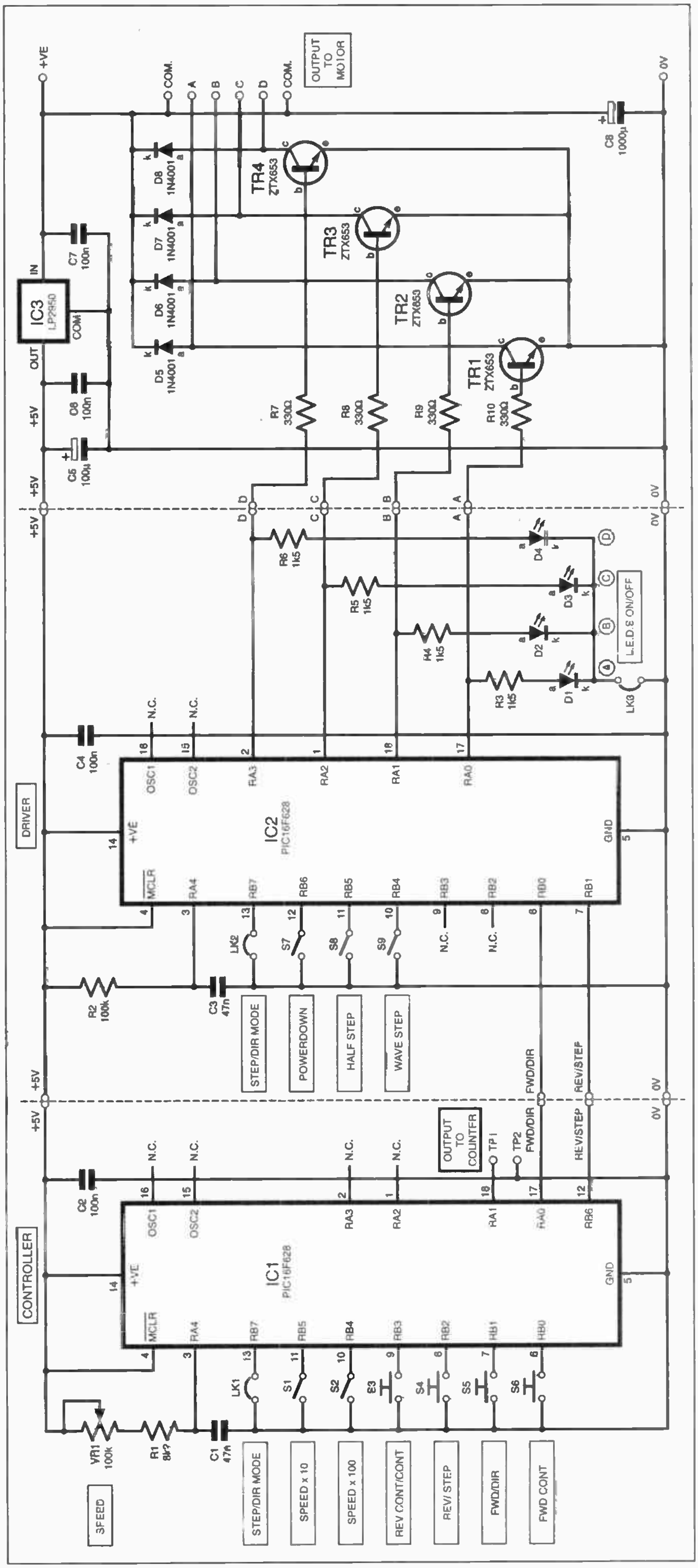
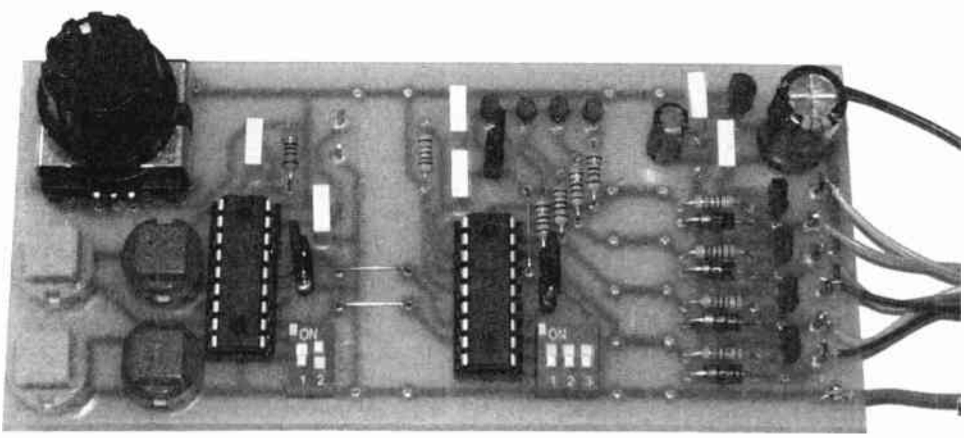


Fig.3. Complete circuit diagram for the PIC QuickStep stepper motor controller and driver.

PIC devotees will notice that there are no oscillator components in this circuit. The PIC16F628 has an internal 4MHz oscillator for use where timing is non-critical, thus saving the bother of including the usual oscillator components.

All the inputs and outputs of this circuit are "active low" since this allows use of the internal weak pull-ups of Port B, removing the need to use external resistors with the switches and buttons. If the circuit is used to test a commercial stepper driver i.c. it may need reversal of the outputs to "active high", as discussed later.



Component layout on the completed circuit board.

STEPPER DRIVER

The second part of the circuit, around IC2, another PIC16F628, is the stepper driver. It has two inputs, "step forward" and "step reverse" through RB1 and RB0 respectively. As with the controller section, fitting link LK2 changes these inputs to "direction" and "step" so that it can be used with a circuit designed for this type of input.

If switches S8 and S9 are both open the output will be full step, otherwise S8 selects half step and S9 wave step. If both are closed, half step takes priority.

The "powerdown" feature can be selected with S7; this causes all outputs to be turned off after about 5ms of inactivity. The timing for this is set by resistor R2 and capacitor C3 so it may be altered to some extent if desired.

Active outputs are indicated by low-current l.e.d.s D1 to D3, so at slow speeds the output sequence can be clearly seen. These diodes can be turned off by removing link LK3. Once again, the inputs are all "active low" to allow use of Port B's weak pull-ups option. It would have been possible to have the two links between IC1 and IC2 operate in "active high" mode, but this would have led to both inputs to IC2 being seen as "active" if open circuit, so this option was not taken.

Again, the flow chart is complex and would probably not be very helpful, so instead here are some guidelines on driving a stepper motor with PIC software. The method used by the author is to have a table containing the required step patterns, four of them for full and wave step, eight for half step, see Listing 1.

The register called STEPS is incremented or decremented for forward or reverse. The least significant two bits (or three bits for half step) of this register always contains the required step number, the values of its other bits do not matter.

When a call is made to the table, the value of STEPS is loaded into the working register W, ANDed with binary 00000011 or 00000110 (3 or 6) to get rid of the unwanted bits, then added to the program counter for a "return with literal in W" operation. A call to the table thus comes back with the required pattern in the W register, all ready to be copied into an output port, in this case Port A. This makes stepper driving a cinch. Alter the value of STEPS, call the table, output the value, job done.

Note that if this part of the circuit is constructed with just IC2, decoupling capacitor C4 and a wire link in place of LK2, it will perform the job of most dedicated stepper driver i.c.s by providing full-step operation from "direction" and "step" inputs. All the other components can be simply omitted for this.

OUTPUT DRIVER

The output stage consists of four ZTX653 transistors to power the motor coils. Despite their tiny E-line packages, these are 2A transistors, though the amount of bias provided by this circuit only safely allows for 1A or so per coil. This should be more than enough for most steppers, many of which take a couple of hundred milliamps or less. Diodes D5 to D8 protect against back-e.m.f. surges as the coils are turned off.

A 5V regulated supply is included in this section to provide power for the two PICs. Regulator IC3 is a low-dropout micropower type, suitable for battery operation. If the supply voltage falls below 5V it will follow it down with little further drop, so the circuit can either be used as it is with a 5V motor, or IC3 can be replaced with a link from input to output.

Additionally, this supply could feed other sections of control circuitry in the user's application. The main supply will be chosen to suit the motor, often 5V or 12V, though a maximum of 25V can be accommodated.

LISTING 1: Driving a Stepper Motor with a PIC Microcontroller

```
         ; TABLE FOR FULL STEPS
TABFULL  MOVF STEPS,W
         ANDLW B'00000011'
         ADDWF PCL,F
         RETLW B'00000011'
         RETLW B'00000110'
         RETLW B'00001100'
         RETLW B'00001001'

         ; STEP CLOCKWISE
CW STEP  INCF STEPS,F
         CALL TABFULL
         MOVWF PORTA
```

COMPONENTS

See SHOP TALK page

Resistors

R1	8k2
R2	100k
R3 to R6	1k5 (4 off)
R7 to R10	330Ω (4 off)

All resistors 0·6W 1%.

Potentiometer

VR1	100k rotary carbon, p.c.b. mounting, lin.

Capacitors

C1, C3	47n polyester layer, 5mm pitch (2 off)
C2, C4, C6, C7	100n polyester layer, 5mm pitch (4 off)
C5	100µ radial elect. 10V
C8	1000µ radial elect. 25V

Semiconductors

D1 to D4	3mm red l.e.d., low current (2mA), (4 off)
D5 to D8	1N4001 rectifier diode (4 off)
TR1 to TR4	ZTX653 *npn* transistor (4 off)
IC1, IC2	PIC16F628 pre-programmed (see text) (2 off)
IC3	LP2950CZ-5 micropower +5V regulator

Miscellaneous

S1, S2	2-way 4-pin d.i.l. switch (2 off)
S3, S6	push-to-make keyboard switch, p.c.b. mounting, red (2 off)
S4, S5	push-to-make keyboard switch, p.c.b. mounting, green (2 off)
S7 to S9	3-way 6-pin d.i.l. switch (3 off)
LK1 to LK3	2-way single row 2·54mm p.c.b. header plug plus jumper link (3 off)

Printed circuit board, available from the *EPE PCB Service*, code 448; 18-pin d.i.l. sockets (2 off); knob; terminal pins; connecting wire; solder, etc.

Approx. Cost Guidance Only **£21** *excl. servo, case & p.s.u.*

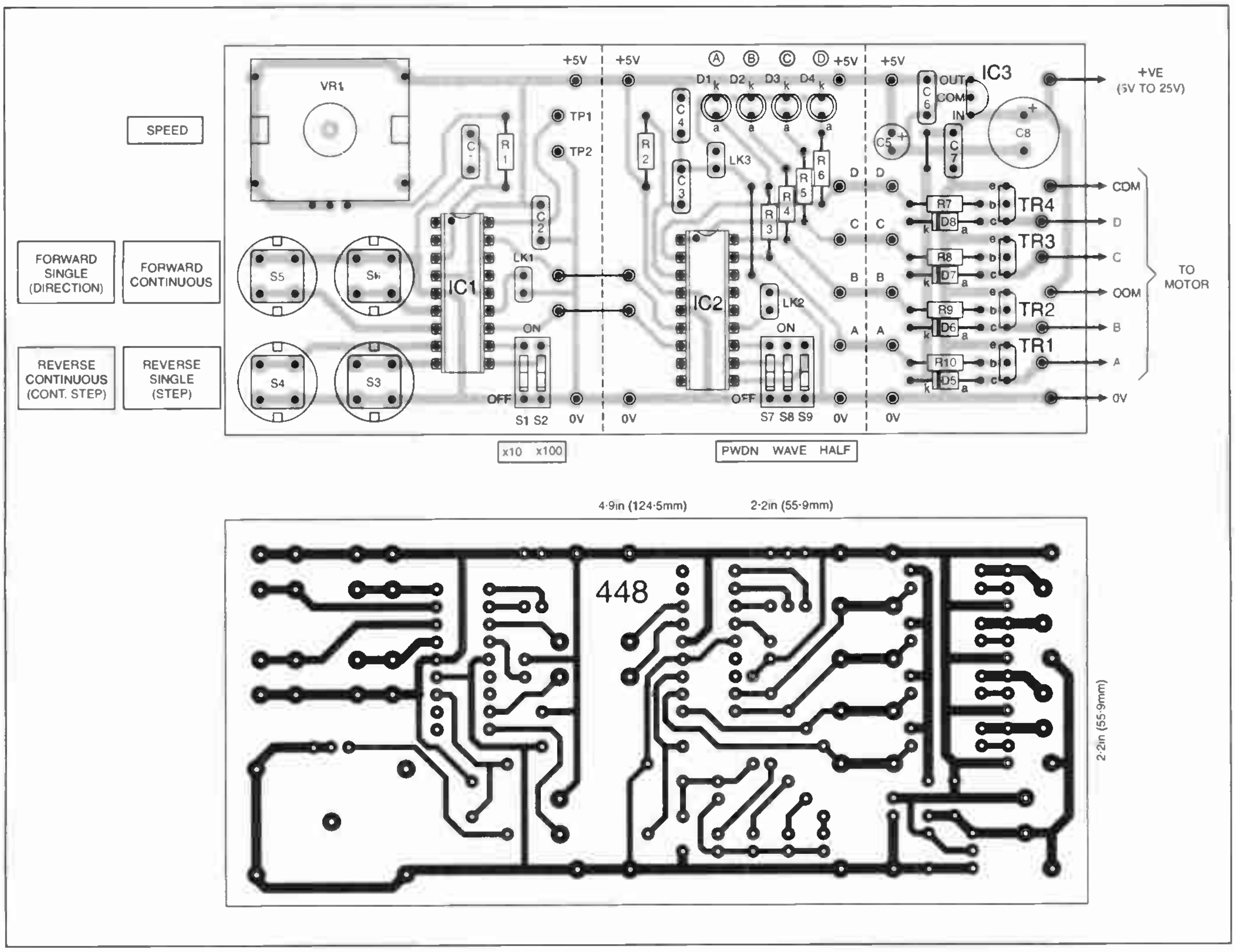


Fig.4. PIC QuickStep printed circuit board component layout and full-size copper foil master. Refer to Fig.1 for motor wiring.

CONSTRUCTION

The layout of components on the printed circuit board is shown in Fig.4. This board is available from the *EPE PCB Service*, code 448. It has been designed so that it can be literally cut into three sections if some of the functions are not required. On the left is the controller, which can drive a dedicated i.c. if needed. In the centre is the driver, and on the right the power output stage.

Positions for pins to give access to the inputs and outputs of each section are provided, but there is no need to fit these unless they are likely to be needed. The prototype has just the supply and output pins fitted, plus the two for frequency counter connection.

Dual-in-line (d.i.l.) sockets should be used for both PICs. All the other components are soldered directly to the board. Potentiometer VR1 is a type designed to fit to the component side of the board with a built-in mounting bracket, but where this is not available there is sufficient room to fit a standard pot to the board with its mounting bush and nut, and connect it with short leads.

All the components except IC1 and IC2 should be fitted. Throughly check the accuracy of your assembly and soldering before applying power.

OPERATIONAL CHECKS

The first check is to power up with a supply of 6V or more, and check that the 5V output from IC3 is present and correct. After this IC1 can be inserted. Link LK1 should be omitted and switches S1 and S2 should be off. The two outputs, the wire links to the right, should be high (+5V). If S5 is pressed, the upper output link should go low (0V). If S6 is pressed, the upper output link should alternate between high and low at a rate adjustable with VR1.

Switches S4 and S3 should have a similar effect on the lower output link. If this works, this part of the circuit should be fully functional, but feel free to try "direction and step" mode with link LK1 fitted, and to check out the counter output from TP1 if desired.

IC2 can be fitted next, with LK2 omitted and LK3 in place. Incidentally, LK1 and LK2 should always be fitted or removed as a pair so that the modes of IC1 and IC2 are the same, so LK1 should also be omitted at this point in testing.

If S9 (Wave) is on and S7 and S8 are off, repeatedly pressing S5 (Forward Single Step) should result in the l.e.d.s lighting sequentially, one at a time from left to right. S4 (Reverse Single Step) should have them lighting from right to left. Switching off S9 will show the full-step sequence, and switching on S8 will show the half steps. Switching on S7 (Powerdown) should show brief l.e.d. flashes as pushswitches S3 to S6 are pressed.

If LK1 and LK2 are now fitted, S4 should cause the stepping and S5 should set the direction.

Low voltage d.c. stepper motor.

MOTOR CONNECTIONS

The unit can now be tested with a motor! If this came with connection data there should be no problem connecting it up to this project. If it didn't, or it was salvaged from scrap equipment, the connections will have to be identified.

The "common" leads can be located with a meter. Where a resistance can be measured across any two leads, it will be found that it will be either the value for a coil lead to a common, or twice that value, i.e. two coils in series via a common. So, the common(s) will be the lead(s) having the lower resistance value compared to two or more of the others. Fig.1 shows how this comes about.

Having identified the common(s), connect them to the positive output of a

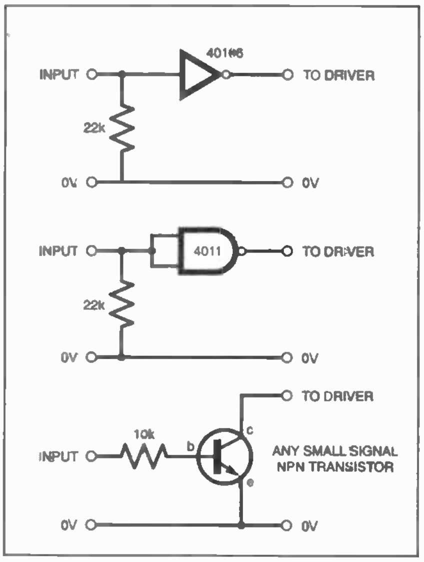


Fig.5. Interfacing other circuits to driver stage.

suitable power supply. Next, take one of the coil leads and label it "A", and touch the negative supply output to it. The motor will probably "jump" slightly. It may be necessary to attach something to the motor shaft so that the movement can be seen, as these motors step so rapidly that it can be difficult to see the movement by looking at the bare shaft.

Now find the coil lead that gives the smallest clockwise movement when touched with the negative supply. Label this lead "B". The motor can be taken back to the starting point before trying each lead by touching "A" again. Continue in like manner from "B" to find "C", then from "C" to find "D", and that's it. The four leads and the common(s) can now be connected to the board and tested with a suitable power supply.

There are few things that beat the satisfaction of seeing the precisely controllable response of one of these motors in operation for the first time, and trying out different step modes with it.

ACTIVE POLARITY

As mentioned earlier, if the controller or the driver are used with other circuits or devices it may be necessary to convert their "active low" signal lines to "active high". Any of the CMOS inverting gates could be used for this, or in the case of the driver, a pair of *npn* transistors could do the job. Fig.5 shows the method.

Note that depending on the controlling circuit, the 22kΩ pull-down resistors shown with the CMOS gates may not be needed. The transistor version has no collector resistor, since the PIC's Port B pull-ups will perform this function.

Two methods of connecting the controller to a dedicated driver i.c. are shown in Fig.6. Once again CMOS inverters could be used, or transistors, this time with pull-up collector resistors. To use just the controller or the driver sections of this project, it is not actually necessary to break the links between IC1 and IC2. If IC1 is removed from its socket, then the inputs to IC2 will be open circuit and free for other connections. Likewise, if IC2 is removed the outputs of IC1 will be unencumbered.

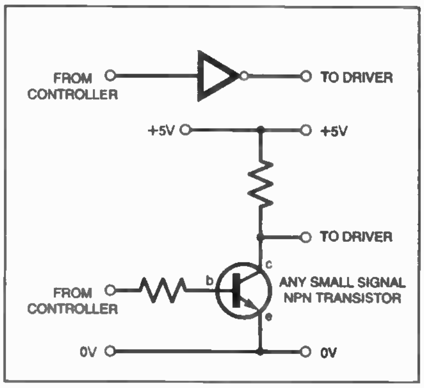


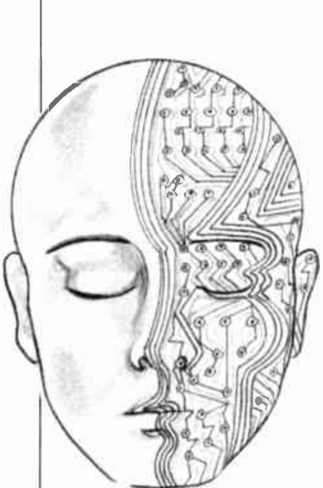
Fig.6. Interfacing controller to other types of driver.

Finally, for driving high power motors, a different output circuit could be designed using power MOSFETS as there is plenty of drive available from IC2's outputs for this. The only caveat is that they should be types which will be adequately turned on by the available 5V gate signals.

RESOURCES

The software for the PIC QuickStep 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** (path **PICs/QuickStep**).

Read this month's *Shoptalk* page for information on component buying for the PIC QuickStep, including pre-programmed PICs. □



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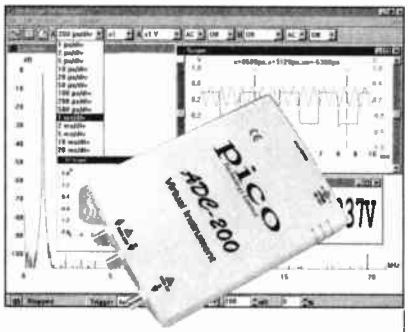

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White Noise Generator – Sound Check

HAVING a need to align the centre frequency and bandwidth of an 8MHz filter in a radio set, it was decided to find an alternative to using an expensive Spectrum Analyser. This is not a common item of test gear for your average experimenter and is not something the writer owns.

A cheaper alternative, although not as accurate, is to feed the output of a noise generator into the filter and adjust the filter for maximum output. A "white noise" generator is a useful piece of inexpensive test gear and it was decided to explore this further.

Investigating the existing literature suggests that a Zener diode was a good noise source. Some tests with a few "spares box" Zeners were disappointing, providing quite a low output even after amplification.

A very useful alternative to the Zener, using an "inverted" transistor, is shown in the White Noise Generator circuit diagram Fig.1. The noise source itself is the BC549 transistor followed by two 2N3904 transistors, used for amplification of the noise.

The interesting characteristic of this circuit is that TR1 is connected the wrong way round. Usually, an *npn* transistor's collector (c) is positive with respect to its emitter (e). It was found that by connecting it in this way results in a great rush of "white noise". I do not recommend this treatment for an *npn* transistor under normal conditions, but as an experiment it worked very well.

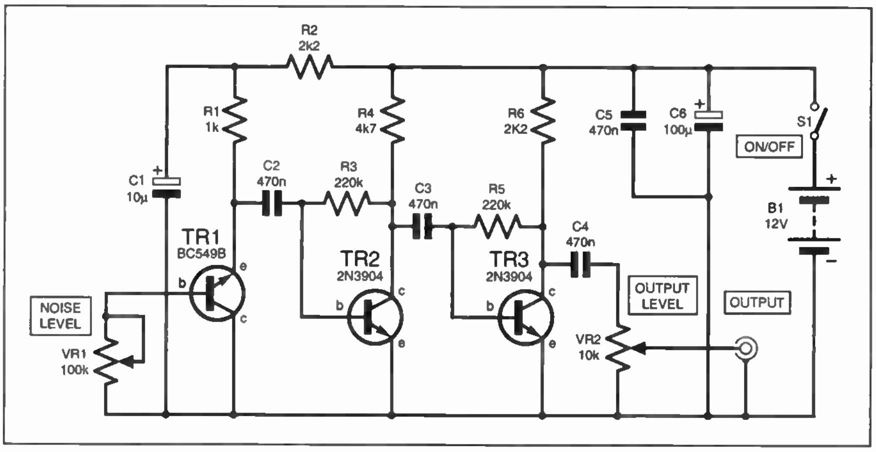

Fig.1. Circuit diagram for a White Noise Generator.

Potentiometer VR1 needs to be adjusted for maximum output, as measured at the collector of TR3, or simply take a length of wire from your receiver antenna socket and place it a few centimetres away from the generator's noise output. Tune the receiver to any frequency up to 30MHz and the noise should be apparent.

The output level can be adjusted by potentiometer VR2. This measured about 5V peak-to-peak output up to 30MHz, so I expect it could be used in the v.h.f. region.

Also, the high output could prove useful in driving passive r.f. bridges for measurement of circuit impedance or antenna characteristics.

Using a BC549 is not critical and other types could work as well or even better in this circuit. This is a matter for experiment. Potentiometer VR1 can be replaced with a fixed resistor once you are satisfied with the output.

Alan Lippett, Stafford

Pressure Pad – Step On It!

TRADITIONAL pressure mats (or pads) may be useful in a variety of applications, particularly for security. A smaller sized pressure pad may be especially useful in soft toys, to trigger a sound or an action.

However, pressure mats (or pads) of any kind tend to be pricy, even without the electronics. They also tend to be tailored to specific applications, and this may limit their uses. While one could resort to a simple pressure switch, such switches often pose problems with mounting.

The design in Fig.2 uses a sandwich made of conductive foam as the pressure pad. Conductive foam sheets are widely and inexpensively available, being used in particular for the safe storage of static sensitive devices. A small piece, say 2cm × 2cm, can be sandwiched between two similar sized pieces of copper-clad board, with the copper making contact with the conductive foam on each side. If the conductive foam is a little brittle to begin with, it may be softened up by squeezing it. The "sandwich" may be held together with sticky-back tape.

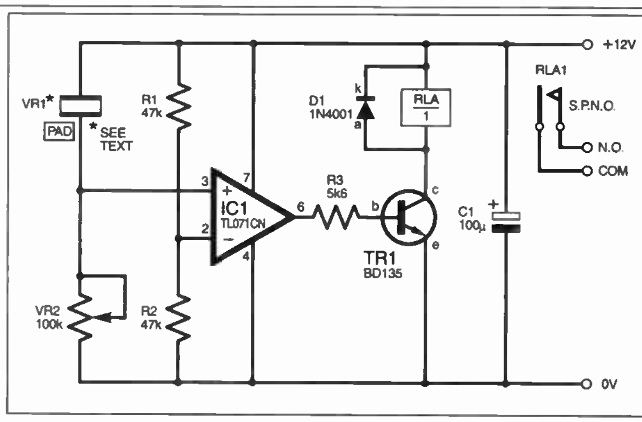

Fig.2. Versatile Pressure Pad circuit diagram.

Dual-mode Charger – Powerful Advantage

THERE are two main types of battery charger – constant voltage and constant current. Both have their advantages and disadvantages. For constant voltage, the battery cannot be overcharged but the charging rate is slow. Constant current mode can charge batteries more swiftly, but there is the danger of overcharging them.

The circuit in Fig.3 was designed to combine both modes, but without their disadvantages, for use with a 6V sealed lead-acid battery. The main players of the circuit are voltage regulator IC1, which is used for constant current mode, and precision adjustable shunt regulator IC2, which is used for constant voltage mode.

In constant current mode, resistor R4 sets the current at 370mA, according to the equation:

$$R4 = (1{\cdot}25/I) \times 1000$$

where I = the constant current required, in milliamps.

Diode D3 prevents the battery from discharging back into IC1 if the input supply is disconnected. Resistor R3 provides current to switch on transistor TR1 when the input supply is present.

Shunt regulator IC2, resistors R6, R7 and preset potentiometer VR1 form the network which determines whether or not the battery has reached its required voltage. When the voltage at IC2's reference input reaches 2·5V, IC2 switches on its internal transistor, connecting IC1's ADJ (adjust) pin to 0V. In this condition, IC2 holds IC1 in constant current supply mode. Capacitor C3 helps to stabilise the switching of IC2.

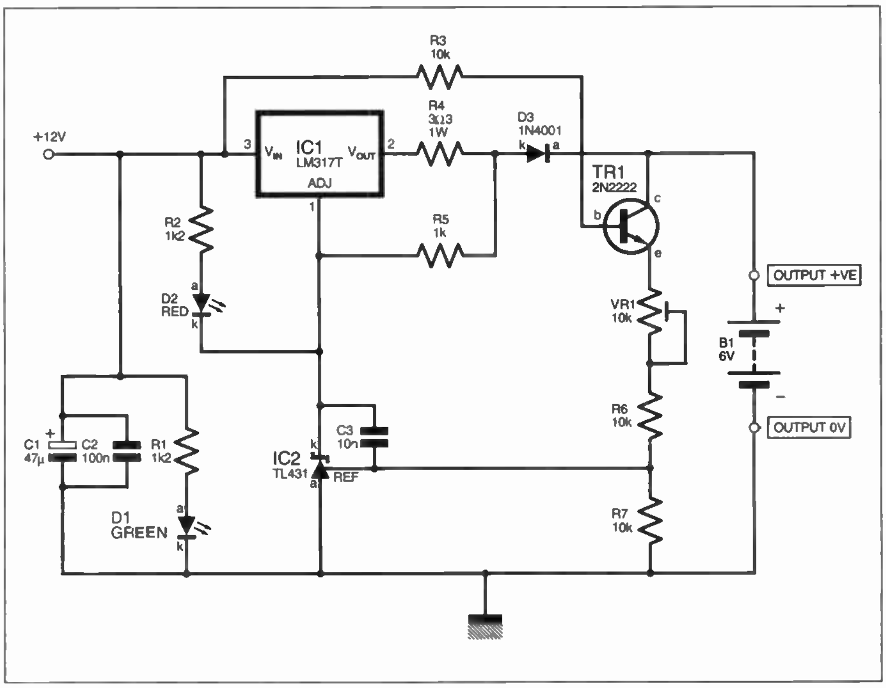

Fig.3. Circuit diagram for a Dual-mode Charger.

Capacitors C1 and C2 decouple the d.c. input supply voltage. Light emitting diode D1 is a power-on indicator, and l.e.d. D2 is turned on when constant voltage mode is activated. A heatsink may be needed with IC1.

In use, adjust preset VR1 so that the voltage at the output suits the peak voltage required by the sealed lead-acid battery, which is usually printed on its body. Once adjusted correctly, it should not need further adjustment.

The author used a 12V 600mA d.c. adapter for powering the circuit. The battery with which it is used has a peak voltage range of 6.9V to 7.12V.

Myo Min, Yangon, Myanmar

Simple Siren – Cacophony Unleashed!

THE circuit shown in Fig.4 provides a smooth, piercing, wailing siren with a minimum of components. Not only this, but three spare gates of hex inverter IC1 remain, which means that a true cacophony could be created by running two sirens off the same i.c.

Gate IC1a is configured as a slow oscillator which repeatedly charges and discharges capacitor C1. The charge on C1 is used to control the conductance of power MOSFET TR1, which in turn modifies the frequency of the audio oscillator formed around IC1b. IC1c serves as a buffer. The period of the siren is determined by C1 and resistor R1, and its frequency by C2 and R2.

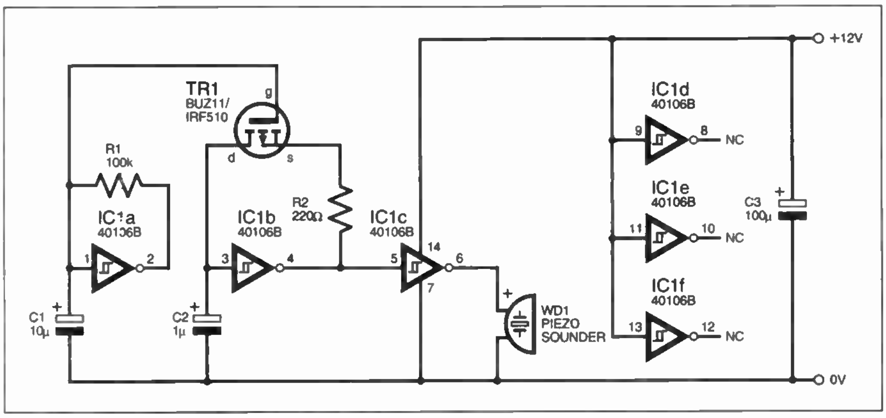

Fig.4. Circuit diagram for a Simple Timer.

Ideally, C2 and R2 will be selected to find the resonant frequency of the piezo sounder for maximum volume. If a piezo tweeter is used, the Simple Siren will produce an impressive volume. An inductive sounder (e.g. a speaker) may be used if a capacitor (e.g. 100μF) is wired in series with it.

Thomas Scarborough, Cape Town, South Africa

This is then wired to the simple circuit as shown in Fig.2, which is a common j.f.e.t. op.amp wired as a non-inverting comparator. Supply voltage may vary between wide margins (3·5V to 18V). Although a 12V relay is shown here (RLA), the output (pin 6) may be used to switch any logic circuit of corresponding supply voltage.

When minimal pressure is applied to the "sandwich", the resistance of the foam may represent around half a megohm. When pressure is applied, resistance drops dramatically. It will easily drop to 10kΩ, and with heavy pressure may drop below 1kΩ. Depending on the application, VR1 adjusts the circuit to respond to the appropriate amount of pressure.

Different sizes of pressure pad may be built, and in this case one only needs to ensure that potentiometer VR1 is suitably chosen and adjusted to the resistance of the pressure pad, with the voltage at pin 3 rising above that of pin 2 (half supply voltage) when pressure is applied.

More innovative uses are possible, e.g. switching off the light when getting into bed, or monitoring the amount of time someone spends in a seat.

Thomas Scarborough, Cape Town, South Africa

News . . .

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

HI-FI GETS HIGHER!

BARRY FOX

TAG McLaren Audio - the top end hi-fi spin-off from the F1 motor car racing company – looks like starting a new trend in home cinema. New AV amps from TAG add a "height" channel to make helicopters and aeroplanes "fly overhead". Owners of existing AV32R or AV192R amps can download new control software which adds the feature.

An extra speaker is fitted to the ceiling and connected to the wires normally used to drive a rear right surround speaker. The existing rear right speaker shares the feed to the rear left.

Any movie sound which moves from front to rear, or rear to front, is detected and fed to the ceiling speaker. So planes appear to be moving overhead.

An on/off switch stops F1 racing cars flying overhead as well!

THE CAT FROM OZ!

"ELECTRONICS – from Australia?! You have to be joking?" is the exclamatory opening line statement on the press release from Jaycar Electronics! It goes on to say: "No not all! The hobby electronics market in Australia has been historically very strong with large numbers of enthusiasts serviced by dynamic electronic magazines and vigorous commercial suppliers."

Jaycar Electronics is "the most dominant company in this Down Under market" and is now in a position to offer its great range of products to a wider audience, thanks to the internet, through which they have been doing business for over 10 years, using 128-bit secure-online ordering.

Their brand new 2004 catalogue is priced in UK pounds and is crammed with over 6000 "exciting products". You can get one free by logging on to **www.jaycarelectronics.co.uk/catalogue**. Jaycar tell us that they stock a huge range of exciting kits, a great range of robotics and electronics components, plus a large range of gadgets. They also stock security, surveillance, audio/video, lighting, computer and telecom parts etc.

For more information contact Jaycar Electronics, Dept EPE, 100 Silverwater Road, Silverwater, NSW 2128, Sydney, Australia. The Australian website address is **www.jarcar.com.au**.

RADIO PROPAGATION

IAN POOLE, whose *New Technology Updates* until recently graced our pages for many years, has had a new book published, *Radio Propagation – Principles and Practice*. The book gives clear introductions to various aspects of the title subject, covering the ways in which radio waves travel at frequencies beyond the Medium Wave broadcast band right up to the microwave region of the frequency spectrum. Readers are given a sound grounding in the subject to enable them to understand why radio signals are heard and how best to hear them.

The book is priced at £14.99, ISBN 1872309976, and is published by the Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3EJ. Tel: 0870 904 7373. Fax: 0870 904 7374. Email: sales@rsgb.org.uk. Ian Poole can be contacted via ian.poole@adriocommunications.co. Web: www.radio-electronics.com.

SCOPE TRAINING

FLUKE, the world leader in compact, professional electronic tools, is offering a free interactive oscilloscope training CD. Designed to operate on a standard PC, the guide provides illustrated lessons regarding standard analogue and digital scopes and their use.

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John Linsley Hood

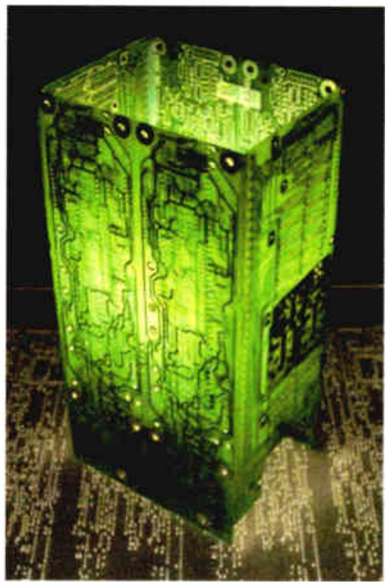
We regret to report the death of John Linsley Hood on 11 March 2004, aged 79.

Born on 9 February 1925, JLH became renowned for the quality of his audio designs. He published numerous technical feature articles in the leading electronics-related journals, from *Hi-Fi News* and *Short Wave Magazine* to *Wireless World* and *Electronics World*, and twice he also wrote for us.

He was the author of several well-respected books, including *Audio Electronics* and *The Art of Linear Electronics*. A list of his books and published articles is at **www.tcaas.btinternet.co.uk/jlharticles.htm**.

Our thanks to reader John North for advising us of JLH's death.

ELECTRICKERY



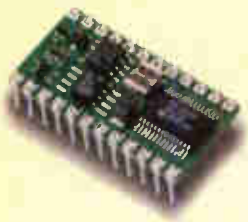
Now here's an intriguing story told in one press release received here at HQ – David Wright, an architect and founder of the design company Electrickery, has struck upon the innovative idea of using printed circuit boards in the construction of lights. He has discovered that passing light through translucent circuit boards can create amazing effects. He has just received a patent to cover this.

So what's new, you may be wondering – anyone who makes their own boards will know that when they hold their boards to the light to check that all the holes have been drilled that they are translucent in the non-track areas. What David has found, though, is that there is an infinite variety of colours and designs of circuit boards, and that many thousands of them are discarded each year by the electronics industry. He is now exploiting this resource to good effect.

What started as simple four-sided pendant lamps has turned into intricate multi-dimension installations and commissions. Electrickery have participated in a number of exhibitions and installed numerous private commissions.

David says that if anyone has a domestic or business space that could do with some exciting lighting, he can design "something ideal" for it. "We are always being inspired by our customers and their ideas to design and build totally new forms of lighting", he comments enthusiastically.

For more information contact David Wright at Electrickery.
Tel: 020 7610 9877.
Email: david.j.wright@freeuk.com.
Web: www.electrickery.uk.com.
Mention *EPE* when you contact him!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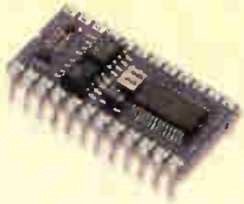
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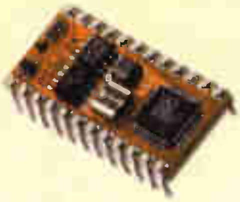
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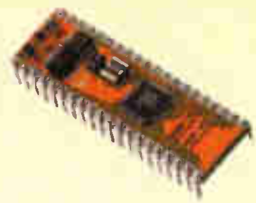
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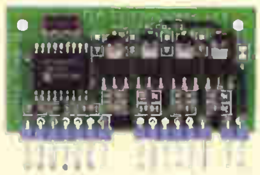
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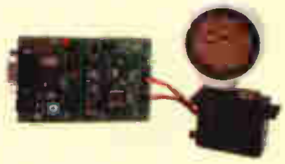
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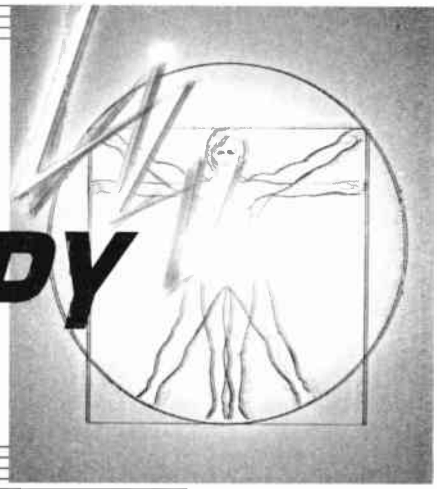
CLINICAL ELECTROTHERAPY



ED BYE

The application of clinical electrotherapy covers just about the full spectrum of electricity and magnetism, from direct currents through to light waves. Here we take a very brief look at developments through the ages and highlight some of its possible future progress.

This article starts by looking at some early developments in medical electricity and goes on to look at some current day clinical applications across the whole spectrum, including some areas of research and pioneering technology as well as other related topics.

HISTORY OF ELECTROTHERAPY

Man's interest in electrotherapy probably extends several thousand years before the birth of Christ. At that time only natural forms of magnetism and electricity existed. Many bracelets, necklaces and other items of jewellery made from loadstone have been found. Fishermen were certainly aware of the electrical discharge effect obtainable from certain types of fish; the electric torpedo fish is capable of delivering a very painful shock.

The first recorded clinical application of electric shock therapy is attributed to Roman physician Scribonus Largus in 46AD, using the electric power of a torpedo fish as a cure for headache and gout. Galen (131 – 201AD) also advocated the use of the electric torpedo fish for all types of disease and ailments. He is perhaps the first to try muscle stimulation by electricity from a fish in his cure for anal prolapse (the mind boggles).

The practice of using the electric discharge of this type of fish for clinical reasons continued until about the mid 1800s with ever increasing applications being found. The development of man-made electricity from electrostatic generators eventually took over from the natural source of electricity from fish. Also with the development of the Leyden jar (an early capacitor) it was found that stronger electrical shocks could be obtained.

Perhaps an unexpected contributor in this transformative time is the Rev. John Wesley (1702-1791), better known maybe as the founder of the Methodist Church movement. Part of his mission was to help the poor and sick people of London. In the UK at this time physician's bills were unaffordable by the poor, Wesley sought to bring cheap medical treatment to the poor and often found himself at odds with the medical profession. Not only did Wesley experiment with electricity and documented for what ailments and conditions he found it useful, he also took as much care over investigating various other medicinal and herbal treatments. He wrote several medical books in which he extolled the virtues of electricity as a cure.

By 1768 the Middlesex hospital in London was the first to have installed an electrical shock machine; many other hospitals followed this lead over the next decade. It seems almost every medical practitioner was using electricity and the diseases, illnesses, conditions etc curable or treatable by this means were unlimited. Pretty soon some very questionable cures were being offered by frauds and fakes, and over the years there have been many. One notable early quack practitioner was James Graham who in 1780 was offering a night's sleep for £50 in his electric "celestial bed" to promote fertility.

For over 100 years electricity was dispensed liberally for virtually everything presented to the doctor and of course there was also an ever increasing number of quack's. These factors contributed heavily to its decline in the early 1900s, electricity had fallen out of fashion and new ideas were not viewed with very high regard in main stream science. It was not until about the 1960s that electricity in medical circles began to make a comeback as being an effective form of pain relief, and its ability to activate muscles.

That provides a very brief history of electrotherapy; there are many gaps and considerably more developments than space here permits. For anyone interested in its fascinating past we would direct you to the website of Dr Gordon Gadsby **http://freespace.virgin.net/joseph.gadsby/**. You will find a lot of useful information on electrotherapy along with a very detailed account of its history, especially concerning Rev. John Wesley.

CLINICAL ELECTROTHERAPY TODAY

The term electrotherapy covers the application of just about the full spectrum of electricity and magnetism from direct currents, through electromagnetic radiation right up to light waves, stopping short of ionising radiation. Electric currents of all descriptions, along with electromagnetic waves, ultrasound, infra red and UV phototherapy as well as lasers, are all common place and in regular clinical use for eliciting thermal and non-thermal effects in the

BACKGROUND

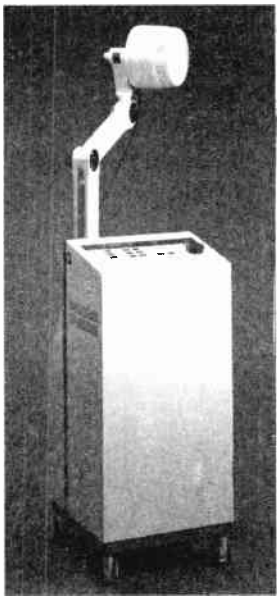
This work is inspired by the writings of Stan Hood in the December 2003 issue of *EPE*. Stan provided a very brief overview of many areas which are not widely accepted in main stream science and touched on a few areas that are. The previous article did not cover the impact of electrotherapy in clinical practice, nor the world-wide research of this technology in mainstream science. Therefore the aim of this article is to complement Stan's, to educate and provide interest in an exciting branch of electronics.

The author has worked professionally for a number of years as a medical electronics engineer and is currently employed as part of a team of doctors and scientists researching movement and movement disorders. He has also had more general experience in other aspects of electronics in medicine as well as holding an interest in this area outside of work.

body for an extremely wide variety of conditions and dysfunctions, including wound healing and, of course, pain relief.

Electrotherapy in clinical use can be regarded as another form of medicine, dispensed on prescription for a particular diagnosis or aliment. Just like medicines there is often a range of options available to the doctor. Not all will be effective for a particular case and patient. Electrotherapy is seen as another treatment option, which may not be the first or preferred choice. You are likely to see electrotherapy techniques in use in some hospitals more than others and in certain departments rather than others.

As an example; for pain management there are various options for treatment using electrical stimulation techniques and equipment. Heat inducing apparatus that employs shortwave or microwave radiation (diathermy apparatus) might be used in pain management. So might infrared sources, ultrasound or lasers be used for treating pain. Also there is a considerable variety of non-electrical treatment options available.



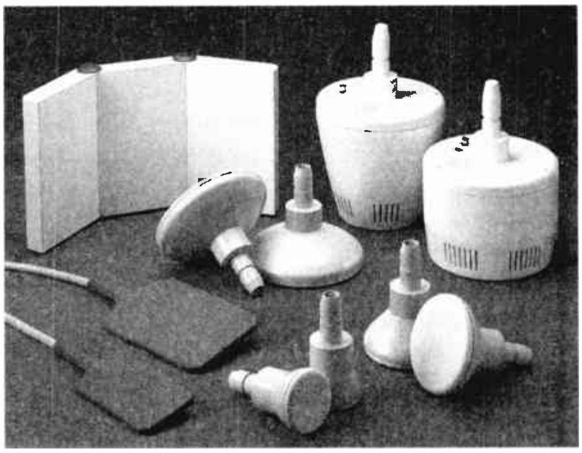


Fig.1 (left). A shortwave diathermy machine.

Fig.2 (above). A selection of accessory couplers (inductive and capacitive) for the diathermy machine. (Photos courtesy Mettler Electronics Corp.).

PHOTOTHERAPY

Phototherapy is a very effective treatment for the common disorder of neonatal hyperbilirubinaemia or newborn jaundice, a yellowish appearance of the skin and whites of the eyes. It is due to immaturity of the liver which causes an increased level of bilirubin in the blood. By exposing the baby to blue light (400 to 550nm) the bilirubin is broken down and excreted. Typically special fluorescent lights that emit in the blue part of the spectrum are placed above the baby (eyes are covered for protection) for a controlled period of time.

Phototherapy is also used regularly to treat a variety of skin conditions such as psoriasis and eczema. Ultra-violet light UVA (320 to 400nm) is delivered to the body in whole body cubicles or bed/canopy arrangement like those encountered in tanning salons for a set period of time. Depending on the condition being treated, often the exposure is made in conjunction with photochemicals applied topically to the skin or as ingested pharmaceuticals to improve the outcome.

There are dangers and risks associated with UV exposure; skin damage, skin aging, skin cancer and eye damage – so care must be taken to limit these effects. UV exposure also has some beneficial effects in thickening the skin and producing vitamin D.

Like all lamps their output diminishes with age, meaning longer exposure times and/or ineffective treatment. The intensity must be regularly monitored to ensure the correct dosage is delivered. This is especially important with new lamps because of the risk of an overdose, which could cause skin damage. UV phototherapy has also been used in wound healing although it is not yet a popular or recommended form of treatment in clinical practice in the UK.

Phototherapy using pulsating l.e.d.s with peak spectral output at 645nm has been used to treat migraine and PMS. A mask over the eyes blocks out all light. A pair of l.e.d.s are fitted to the mask, one on the left, the other on the right. A control box permits intensity and frequency to be adjusted in the range 10mcd to 45mcd and 0·5Hz to 50Hz respectively; a timer limits treatment time to a maximum of 15 minutes. The l.e.d.s flash alternately with a 50% duty cycle. Forty-four per cent of migraine sufferers that took part in the study (not a rigorous scientific study) claimed some benefit. Considerably more women with PMS claimed benefit. For further details see **http://www.lightmask.com/science.htm**.

Note: ***If anyone considers trying this for themselves, there are dangers at certain frequencies of triggering an epileptic attack, especially in those with epilepsy. More detailed information should be sought and you should of course discuss the matter with your doctor before starting any self-treatment plan.***

RADIO WAVES

Electromagnetic waves in the radio spectrum have a very long standing medical history and are in regular clinical use by physiotherapists, primarily to deliver heat deep to tissue within the body. Broadly speaking two bands are used, shortwave and microwave. The medical term for this type of treatment and apparatus is known as "diathermy".

Shortwave diathermy operates in the range 10MHz to 100MHz and the RF energy (around 27MHz in UK) is either inductively coupled to the body by means of a coil or capacitively coupled by way of insulated electrode plates. The RF output may be continuous or pulsed. Typically the average power for high dosage is about 80W with peak pulse power as much as 1kW. The heat produced can be very effective for treating joint stiffness, relieving muscle pain and spasm, as well as reducing swelling. Fig.1 and Fig.2 (courtesy Mettler Electronics Corp. **http://www.mettler electronics.com/**) shows an Auto*Therm 395 diathermy set with a selection of accessory couplers (inductive and capacitive). This particular model provides continuous or pulsed output up to 400W peak.

Microwave diathermy operates at much higher frequencies, up to 300GHz (UK has standardised on 2·45GHz). Because of the much shorter wavelengths, heat penetration into the body is less than that from shortwave equipment. Microwave energy is absorbed more by structures with a high water content (blood vessels, muscle, skin, internal organs but not fat). The energy is delivered to the body by means of "directors" (antennas).

ULTRASOUND

In therapeutic clinical terms ultrasound (US) covers the range of frequencies between 1MHz to 3MHz (diagnostic US extends to 20MHz or beyond). Sometimes low frequency ultrasound (~44kHz) is used. Principally, US is used for wound healing and has been in use for this purpose for a number of years. A UK survey in 1985 showed 20% of all NHS physiotherapy treatments involved US; this figure rose to 54% in private treatments (Haar G., Dyson M., Oakley E. M., *The use of ultrasound by physiotherapists in Britain, 1985, Ultrasound Med Biol.* 1987 Oct;13(10): 659-63).

Both thermal effects and non-thermal effects are utilised. An advantage of US thermal effects is that the depth of effective penetration in soft tissue can be controlled easily by altering the frequency (~4mm at 3MHz, ~11mm at 1MHz) see Fig.3 (courtesy of Mettler Electronics Corp).

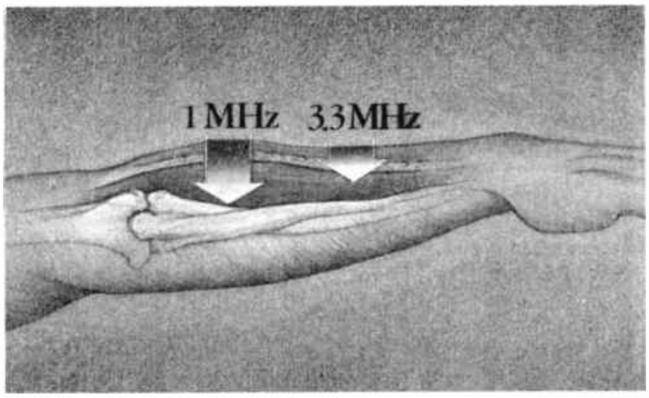


Fig.3. Ultrasound penetration at different frequencies. (Courtesy Mettler Electronics Corp.).

A sophisticated therapeutic ultrasound system 'Sonicator 730' is shown in Fig.4 (courtesy of Mettler Electronics Corp). It is microprocessor controlled and has interchangeable applicator heads. Membrane key pads and digital displays allow mode and timing selection and the device includes a feature to warn of poor patient contact. Like all US devices, the output transducer is formed from piezo-electric elements.

Fig.4. Therapeutic ultrasound set. (Courtesy Mettler Electronics Corp.)

SIMPLISTIC VIEW OF WOUND HEALING

There are three phases of tissue repair; inflammation, proliferation and remodelling. Inflammation is characterised by the formation of a clot; this serves as a temporary seal. Clotting also releases many active substances known as "wound factors" that are used in subsequent phases and also "cleaner" agents that break down and dispose of tissue debris, foreign matter and bacteria. The proliferation phase is where deposits of new tissue(s) are formed and new skin layer is created; the process can be monitored by observing the decrease in wound size. The last phase, remodelling, takes place over months or years. The wound has fully healed, but we are left with a scar.

EFFECTS OF ULTRASOUND ON WOUND HEALING

Ultrasound can modulate the chemical processes of the inflammatory phase in various ways that accelerate tissue repair. A single US treatment, if given early enough after injury (early inflammatory period), can be very effective. There is also evidence that wound contraction can be accelerated by the application of US during the proliferation phase. Commencing treatment at the early inflammatory phase and continuing treatment three times a week for two weeks has been shown to have a beneficial effect on scar formation.

An interesting recent development using ultrasound concerns delivering drugs into the body. Ultrasound has been shown to be able to "push" certain drugs though the skin into the body; this process is known as "phonophoresis". More research is needed to clarify parameters and limitations. For further detail on this application see **http://www.eng.utah.edu/~holzer/ultrasound.htm**.

Whilst on the subject of vibrating waves, there is the allegedly true story concerning Tesla's vibrating platform and his intrigued friend Mark Twain who overdosed on it and discovered its power as a laxative, apparently an effect known to many of the laboratory staff. **http://www.nuc.berkeley.edu/dept/Courses/E-24/E-24Projects/Krummel.pdf**. It is claimed that very low frequency sound and vibrations in the range 10·5Hz to 16Hz cause an urge to defecate, **http://www.rhfweb.com/hweb/shared2/Newrad.html**. Maybe someone would like to design a project based on this principle to relieve constipation. Annually in the UK some 10 million prescriptions are written for laxatives. If anyone is interested in other physiological effects of infrasound or infrasonics, then there is a range of material on the web, including "death rays" from giant whistles.

ELECTRICAL CURRENTS IN CLINICAL THERAPY

Electrotherapy has been used clinically for a few centuries for numerous and countless conditions, diseases etc. Current modern day regular practice and application can be broadly classified into muscular control, pain relief, and neuromodulation. Wound healing is a relatively new application of electric current and is not in widespread practice here in the UK.

Electric currents for pain relief have been covered in *EPE* in the past. The *Simple Dual Output TENS Unit* constructional project in the March '97 issue covered in depth the theory or principle(s) by which it is claimed to work, at least by what is currently understood in scientific circles. Therefore the subject will not be covered here.

Many electrical stimulators for whatever function are essentially the same – a repetitive rectangular pulse generator that switches a high-voltage stage on and off. The difference perhaps is the frequency of repetition, pulse width and amplitude which is usually a constant current or constant voltage output. Other refinements are frequently added such as "ramp-up" – "ramp-down" that slowly increases and decreases the amplitude to make the device's use more comfortable. Often a timer will also be incorporated to deliver the stimulation for a set period of time.

Electrical stimulators are often used for muscle strengthening in conjunction with some form of biofeedback, for example in toning up pelvic floor muscles for some forms of incontinence. They are also used for other muscle toning. The sports industry uses them for this purpose.

Anyone reading this who is overweight might be tempted to try such a device to aid slimming; they are commonly advertised as muscle toning devices. This to a large extent is a myth. Yes they can and do tone muscles but fat is a poor conductor of electricity, so to be effective in obese people the intensity would need to be so high that it would be a painful experience and people that have tried it discontinue with the program very rapidly.

In summarising the general state of electrical stimulators, it is fair to say that there is an immense variety of devices producing different output waveforms and patterns. There is also just as much variety, if not more, in the manner in which they are used. One may not be surprised therefore that for a particular form of electro-stimulation there are advocates and adversaries. Certainly further controlled and well documented studies are needed to separate the wheat from the chaff.

FUNCTIONAL ELECTRICAL STIMULATION

Functional electrical stimulation (FES) can play a significant role in patients with spinal cord injury (SCI) and may be the only way for some of exercising muscles artificially. Such exercise helps prevent muscle wastage and pressure sores and can even assist in whole-body exercise plans, for example aiding a paraplegic or quadriplegic to ride a trike, either in exercise mode or out and about. See **http://fesnet.eng.gla.ac.uk/CRE/overview5.html** and **http://www.mpi-magdeburg.mpg.de/people/negaard/HunSchNeg02.pdf** for further information.

A "Windcheater" tricycle is shown in Fig.5, courtesy of Tim Perkins UCLH. (T. A. Perkins, N. de N. Donaldson, R. Fitzwater, G. F. Phillips, D. E. Wood, *Leg Powered Paraplegic Cycling System Using Surface Functional Electrical Stimulation*, *Proceedings of the 7th Vienna International Workshop on Functional Electrical Stimulation*, Vienna, Sept 12-15, 2001, ISBN 3-900928-05-3, Pages 36-39, Fig.1). Research and development continues on the trike.

More often than not the electrical output of a stimulator is applied via electrodes to the surface of the skin (transcutaneous). This, as mentioned above, can cause some discomfort or even pain. There may well be other effects also. In clinical settings

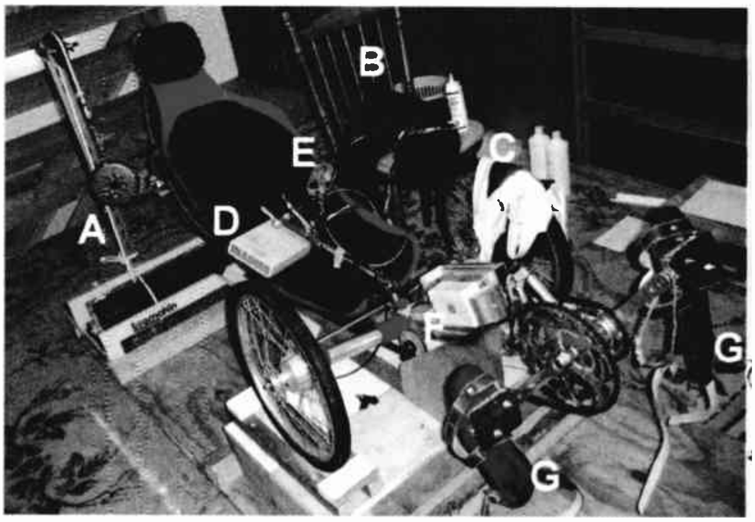


Fig.5. Windcheater functional electrical stimulation tricycle – A: Trainer. B: Electrode shorts. C: Tights to retain cables and electrodes. D: Stimulator. E: Throttle and switches. F: Shaft encoder. G: foot-plates. (Courtesy Tim Perkins, UCLH.)

sometimes the electrical signal is applied through the skin (percutaneous) by means of needle electrodes and also on occasions (heart pacemaker for example) a package and electrodes are surgically implanted to the body.

BIONS

An up and coming development is that which has been termed "BIONS". BIONS are microminiaturized electro-stimulators that are inserted by way of a large bore needle directly into a muscle. The device measures about 2mm diameter by 15mm long. Power and commands are sent to it by means of an external radio signal from a coil. See **http://www.vard.org/jour/02/39/3/sup/Loeb.htm**. These devices are currently undergoing clinical trials in aiding people recovering movement after a stroke, see **http://www.techtv.com/news/scitech/story/0,24195,3383097,00.html**. A second generation of BIONS is under development that will also transmit data via a radio telemetry link out of the body to some control equipment that can be used in a feedback control loop.

One issue that these devices may be able to address is that of giving fine control over a particular muscle. A muscle is made up of smaller muscle units; our normal nerve signals fire up only the units of a muscle needed for a particular task. With current day electro-stimulation technology we invariably fire up all the units simultaneously; it is difficult to get a fine graded response. By using much smaller and more localised stimulators, implanted directly at strategic points in a muscle, it might be possible to obtain a finer response.

NEUROMODULATION

Electrical stimulators are used effectively to modulate the impulses travelling along the nerve fibres to effect muscular control. A typical example is an aid for continence. An electrode is surgically wrapped around a nerve exiting the lower spinal column and an implanted electrical stimulator controls the current which travels along the nerve to the target muscle or muscle groups. Research is also in progress with less invasive methods of neuromodulation such as percutaneous and transcutaneous application in various regions such as the tibial nerve in the leg, which has been reported as having a beneficial effect in control of continence.

Neuro-implants are also successfully used for pain control. Like all treatments these devices are not without complications of surgery and side effects, many unwanted. A very desirable side-effect has been noted by some and commercial exploitation for an "orgasm generator" is being considered. See **http://www.wired.com/news/technology/0,1282,41682,00.html** for more detail.

DEEP BRAIN STIMULATION (DBS)

Several years ago surgeons were removing specific parts of the brain to treat some cases of Parkinson's Disease. They located the precise region to excise using an electrical stimulator and an electrode slowly inserted to deep within the brain. Once the tremor had stopped, they knew they had identified the target region and they removed it. Someone had the brilliant idea that perhaps excision of part of the brain wasn't necessary; it appeared that electrical stimulation would somehow counteract the symptoms of Parkinson's Disease. Further research took place and the result is what is called DBS.

In some ways DBS is to the brain what a "pacemaker" is to the heart. The pacemaker is an implanted device that controls the heart muscle's electrical activity by means of connected electrodes. Note that Charles Kite first used electricity to "jump start" the heart (defibrillation) in 1788, see **http://www.thebakken.org/artifacts/Kite-Charles.htm**, he received an inscribed medal for his electrical resuscitations, the translation reads *"Possibly a little spark may yet lie hid"*. Not of significant electrical content, but in part interesting reading is an overview of resuscitation. **http://www.aap.org/nrp/DOCS/historical_overview_nrp.doc** . It mentions a novel way of smoking, no longer practiced – medically (if it were a social requirement, then I'm sure the number of smokers would be reduced). This document also shows the colourful developmental path resuscitation has taken over history, with some quaint ideas and what is now widespread practice starting off very slowly or not widely accepted, in some respects similar to certain notions and practices in electrotherapy.

In DBS a similar sized and implanted package in the chest cavity is wired internally, by a process called tunnelling, to electrodes that have been implanted to deep within the brain. The DBS stimulator modulates neural activity in a certain part of the brain. As the brain comprises two hemispheres (left and right), often two sets of stimulators and electrodes are installed (bilateral stimulation). Fig.6 depicts a Kinetra® implantable pulse generator (IPG) that allows independent dual channel stimulation to both sides of the brain (except frequency).

Reproduced with kind permission of Medtronic Inc.

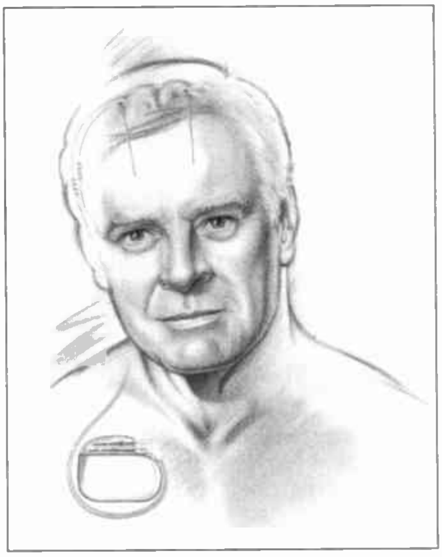


Fig.6. Dual-channel deep brain stimulation using the Kinetra implantable pulse generator (IPG). (Courtesy Medtronic Inc.)

In Fig.6 you will see implanted in the chest the dual-channel stimulator (pulse generator) package with wires under the skin leading up the neck to the top of the head and connected to two electrode sets that have been inserted deep within the brain.

The region frequently targeted is called the Sub-Thalamic Nucleus (STN) and has been found very effective in treatment of some cases of Parkinson's Disease as well as other tremor based disorders including dystonia. There are other areas of the brain that have also been found to be effective targets. Not all patients are eligible on medical grounds for this form of therapy, but it is very effective and an utterly amazing transformation takes place when stimulation is switched on. To see some video footage visit the Medtronic website **http://www.medtronic.com/activa/physician/video_downloads.html**.

Technically the pulse generator delivers a pulse about 100μs wide and 3V amplitude at a frequency of just over 100Hz. These parameters can be altered and the pulse generator can be turned on and off via a radio telemetry link. The implant is battery powered with a life expectancy of five years.

If anyone wants to read more about this topic, there is plenty of material available on the internet, for example **http://www.southshoreneurologic.com/clinical/move-dis/dbs/dbs-overview.html**.

There are also other conditions that are being researched that appear to respond to this form of electrical stimulation.

GALVANIC STIMULATION

Galvanic, d.c. or pulsed d.c. stimulation is used for several therapeutic purposes and may be high or low voltage. Areas of application include pain relief, drug delivery and wound healing.

Many drugs have an electric (ionic) charge. If placed on electrodes connected to the body and a current passed between the electrodes, then the substance can be transported through the skin into the body; the process is called iontophoresis. Crudely speaking it is rather like the process of electroplating where certain metals in an electrolyte can be deposited on other conductive objects by the passage of an electric current. See **http://physicaltherapy.about.com/gi/dynamic/offsite.htm?site=http%3A%2F%2Fwww.life-tech.com%2Fpm%2Fwhatis.html**.

It is also possible to extract small quantities of substances out of the body, a process called strangely enough "reverse iontophoresis". This extraction process is used commercially for glucose monitoring of diabetics in a product called the "Glucowatch", a wristwatch-sized device that uses electrical current to drive out a small sample of the extra cellular fluid (ECF). This fluid is present in our bodies surrounding the cells, it is the fluid found in blisters. From the ECF the level of glucose in the body can be determined by the machine and the results displayed. Although not therapy, it is an application of electric currents in medicine and one that makes a painful finger pricking exercise non-invasive. See **http://care.diabetesjournals.org/cgi/content/full/24/5/881** for more detail on the Glucowatch.

WOUND HEALING

Wound healing using electric currents is an area that appears to be gaining popularity. The latest edition of *Clayton's*

Electrotherapy (now called *Electrotherapy; Evidence-based practice*, edited by Sheila Kitchen, published 2002, ISBN 0 443 07216 7) includes a good deal on wound healing by electrical currents. If you want to learn more about therapeutic clinical applications across the broad spectrum of electricity from d.c. to light waves this book deals with theory and effects of a number of modalities in current clinical practice and is aimed primarily at student physiotherapists but covers very well the electrical basis. It is quite technical and deep.

Some people have been involved with research into electromagnetic radiations for bone healing and found a degree of success in improving healing times of certain fractures. In terms of galvanic currents there appear to be many options, low voltage, high voltage, simple waveform, complex waveform, all claiming to offer improvements in soft and hard (bone) tissue wound healing. Perhaps, based on Dr Beker's work, setting up an electric field enhances healing times by promoting increased blood flow and for other reasons. It is interesting to note that electricity in the form of charged gold leaf was first used to treat wounds (prevention of smallpox scars) over 300 years ago.

GALVANIC VESTIBULAR STIMULATION (GVS)

The passage of a small direct current between electrodes placed just behind the ears can influence the vestibular apparatus, the principle organ that gives us a sense of balance and is often disrupted in motion sickness, and can cause the body to sway or lean to one side. The direction can be changed by reversing the current.

At the moment interest seems to be focused on establishing the effect and control on posture and balance. There might at a later date be some therapeutic benefit to this research.

CRANIAL ELECTRICAL STIMULATION (CES)

Time varying d.c. or a.c. at low amperage (microcurrents) is applied via electrodes typically clipped to the ear lobes or fixed just behind the ears to provide, it is claimed, relaxation and relief from depression, anxiety, stress and insomnia. There are some claims that also mental alertness and performance can be improved using this technique.

The basic idea is that currents in the microamp range with frequencies of certain brainwaves can be used to promote production of specific neurotransmitters (chemicals) in the brain. Depending on the frequency, and maybe waveform, specific effects may be induced. For further detail on the whole subject of "microcurrents" see **http://alpha-stim.com/Information/Products/Educational/CES_Intro/Old_CES_Intro/old_ces_intro. html**.

MAGNETIC STIMULATION

In the ever increasing quest for less invasive and non-invasive clinical methods and procedures, the body's magnetic properties can and have been exploited to provide a "non-contact" means of stimulation. The tissues of the body are not particularly magnetic and therefore a vast amount of energy is required to elicit an effect. Current commercial equipment can generate in a brief period of time enough energy to lift a person weighing 50kg, one metre. Essentially this type of apparatus charges a bank of capacitors to a high voltage and then rapidly discharges them into a coil which generates an electromagnetic pulse.

Because of practical limitations on re-charging, the achievable repetition rate is very slow using a single magnetic stimulator. Where faster repetition rates are needed, then several stimulators are coupled to the same coil and fired in succession. As the power generated is very high, care must be taken to avoid overheating.

A typical selection of magnetic stimulators and coils is shown in Fig.7. This photograph, reproduced with thanks to Peter Assleman, Institute of Neurology, is a small example of apparatus used in one of the research labs. Several different types of magnetic stimulator can be seen on the rack and two typical coils rest on the pillow. At the back you can see a selection of coils. Note the thickness of the cable to the coils, required to reduce heating effects of the very high currents. The coils are temperature monitored and if overheating occurs, the equipment automatically shuts down to prevent injury and damage.

By placing the coil over a neuromuscular junction, the interface between muscle and excitory nerve, a muscle twitch can be elicited in response to a magnetic pulse from the coil. The coil can also be situated over the spinal column and muscles can be influenced by magnetic stimulation of the nerve roots. It can also be sited over one hemisphere of the brain in the motor cortex region and indirect non-invasive stimulation of muscles can be made by stimulating the brain (trans-cranial magnetic stimulation or TMS). Note if the coil is placed over the visual cortex at the back of the head then flashes of light (phosphenes) can be seen in response to the stimulation.

The large coils used means the beam is not particularly focal and quite a large area gets excited by the stimulation pulse. Also some care and adjustment is needed to ensure the desired structure is stimulated. Apart from muscle control, magnetic stimulation has also been used to treat other disorders such as depression. It provides the researcher a means to non-invasively stimulate the brain, which is good for volunteers knowing that they don't need to have their head cut open, whilst helping to advance medical science. For anyone wishing to find out more a good starting point is **http://www.biomag.hus.fi/tms/**.

TEMPORAL LOBE EPILEPSY (TLE)

From the extensive research of Dr Michael Persinger on TLE and religious and ecstatic experiences it has been observed that weak electromagnetic stimulation of the front part of the brain can cause spiritual responses in some people. Persinger uses a special helmet in which several coils are placed and these are excited in specific sequence in an attempt to elicit a response and has found a variety of responses can be obtained from physical type arousal of emotions through to states of religious ecstasy and also the feelings of hauntings. He has also found that similar responses can be obtained in some from long exposure to electronic equipment such as computers.

The UK BBC TV *Horizon* science series carried a program on his work in 2003 **http://www.bbc.co.uk/science/horizon/2003/godonbrainqa.shtml**. More detail on the topic can be found at **http://www.angelfire.com/tx5/randysresume/termpaper.html**.

ELECTRODIAGNOSIS

In the main the preceding information only addresses therapeutic applications of electricity. There is also a great deal of interest in main stream science on diagnostic techniques using the body's electricity and related properties.

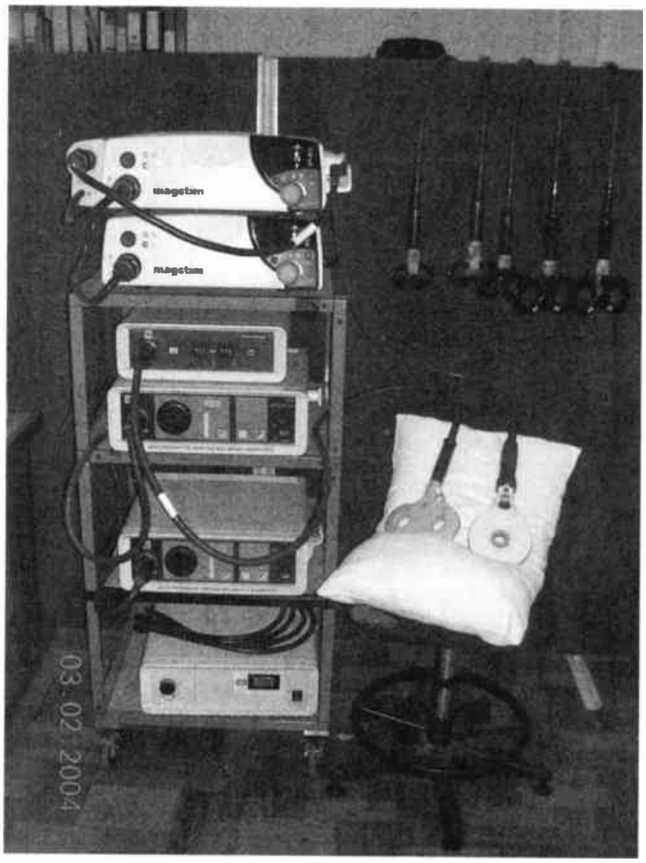


Fig.7. A rack of typical magnetic stimulators and coils. The coils are temperature monitored and if overheating occurs, the equipment automatically shuts down. (Photo courtesy of Peter Assleman, Institute of Neurology.)

For numerous decades measurement of electrical activity of the heart (electrocardiogram e.c.g.), that of the brain (electroencephalogram e.e.g.) and the electrical activity associated with muscle movement (electromyogram e.m.g.) have formed regular and routine clinical diagnostic tools for certain disorders. Several of the stimulations described above are used in diagnosis to attempt to evoke a response from the body that can be electronically measured.

BIO-IMPEDANCE ANALYSIS AND ELECTRICAL IMPEDANCE TOMOGRAPHY

Disease and illness is known to alter the electrical impedance of tissue and other biological substances and there is investigative work trying to establish the usefulness of this technique for diagnostic purposes. A novel application of this is the electronic bra to detect breast cancer **http://www.bra-n-bras.com/8592-electronic-bra.html**. Impedance analysis is also the principle used in the devices available in the high street shops as electronic body fat analysers, fatty and non-fatty tissue have different impedances at different frequencies.

An extension of bio-impedance techniques is electro-impedance tomography or EIT for short. This is essentially an impedance imaging system that uses electrical currents delivered between multiple electrodes. A computer running a reconstruction algorithm creates a visual image, see **http://www.geocities.com/CapeCanaveral/9710/html/eit.html** as just one sample of some of the work undertaken, there are many more.

KIRLIAN PHOTOGRAPHY

The work of Kirlian is a curiosity which is said to produce photographs of the human aura or life force. There is certainly an effect. The Kirlian effect stems from corona discharge, much the same as the infamous "St. Elmo's fire" witnessed by mariners since the dawn of time. A high voltage charge say during or just after a thunderstorm on an object like a ship's mast under the right conditions gives rise to an eerie white/bluish glow. A good short synopsis and history can be found at **http://lkm.fri.uni-lj.si/xaigor/eng/kirlian.htm**.

In Kirlian photography, the high voltage is electronically generated by an amplified oscillator that drives a very high voltage transformer, typically a car ignition coil, TV line output transformer (LOPT) or a transformer for a neon sign is used.

Kirlian coupled the high voltage to what is effectively a capacitive circuit that included the object to be studied and a photographic plate in series. When energised the high voltage breaks down (ionises) the surrounding air and maybe the dielectric. The result is a weak glow that can be detected by the photographic paper. There is some debate if detection is a result of light by the photosensitive paper or by direct electro-chemical action to the photographic emulsion(s) on the paper. Corona discharge is predominantly in the ultraviolet (UV) region for which our eyes and photographic papers are not particularly sensitive. Such "contact" means of producing "Kirlian photographs", especially using colour film, are prone to process errors and distortions, artefacts that over the years have fuelled the debate on the claims made over this effect relating to "human energy fields". For further information see **http://www.geocities.com/lemagicien_2000/kfpage/kf.html**.

Non-contact methods that use cameras to photograph this phenomenon have been developed; these eliminate many of the artefacts of the "in-contact" method. Usually some transparent electrode arrangement is used. Fashioned from two glass or clear acrylic sheets a slim-line sealed tank is formed, rather like a double-glazed window. The gap is filled with conductive liquid (water) and an inserted wire electrode that connects to the outside world. The high voltage generator connects to this external terminal and to the object of interest which then touches one side of the transparent plate. The camera is used to take a picture from the other side of the plate.

Kirlian photography appears to be regaining a much wider appeal under the more general title of gas discharge visualisation (GDV) or electrophotography. CCDs have been used to produce videos of this phenomenon. See **http://www.gdvusa.org/index.html** for more information.

GALVANIC SKIN RESISTANCE (GSR)

The "psycho-galvanometer", is a device popularised by Carl Gustav Jung, back in 1906, for use in psychoanalysis. Today we would say this device measures the galvanic skin resistance (GSR). It formed a significant role in the development of the polygraph or lie detector. Basically the principle by which this works can be described as a psychological state giving rise to a physiological response – in this case a change in resistance of the skin. With what amounts to little more than an ohmmeter (usually a bridge circuit is used and "peak" detectors and other refinements are added) changes in skin resistance can be detected. Much more information is available on the web, especially concerning the interpretation.

Back in the 70s Christian Scientologists used this principle and a similar meter for "spiritual divination" and a healing process they called "clearing". Much the same techniques are still used today but by a much wider audience, and without religion being involved for dealing with psychological issues and in promoting spiritual growth by either a practitioner or as some form of self-help/development program. For further information see **http://www.trans4mind.com/psychotechnics/gsr.html**.

THE AURAMETER

Side-tracking away from GSR for the moment. Professor Valerie Hunt of UCLA noticed during studies of electrical muscle activity there was a high frequency noise. For more than 20 years she has studied this phenomenon and has developed a system for detecting these signals. See **http://www.spiritofmaat.com/archive/nov1/vh.htm** for more information. Dr Hunt believes these signals relate to a non-physical energy field surrounding the body and has related these signals to the colours of the human aurora as seen by "sensitives". Essentially she performs a spectrum analysis of the high frequency noise signal; the results show non-random peaks which over the years she has classified.

SPECTRUM ANALYSIS OF GSR SIGNAL

Similar effects by spectrum analysis have been observed in the GSR response, see **http://www.trans4mind.com/psychotechnics/energyfield.html.** So, anyone up for the challenge of designing a safe project to experiment with this? Not so long ago in *EPE* (Feb 2002) there was a PIC based spectrum analyser and it is not too difficult to design a bridge circuit to acquire the GSR signal. There have in the past been published designs in some electronics magazines, maybe it's time for a new design.

Although man's interest in electrotherapy has been around for millennia, very little of how it works and what works when is understood. We know certain things work some of the time for some people. We should also realise that our bodies are essentially electrochemical and therefore expect electricity to influence it. A very large industry has grown up focusing on chemical (pharmaceutical) effects and remedies, nowadays there are still many "tweaks" to medicines to improve their potencies or reduce side-effects and even new chemical options appear. Why should there not be a similar multitude of electrical treatments?

On the highly controversial issue of harmful effects of electromagnetic radiation, it is possible that there could be some ill-effects. Many medicines taken in the right amount for the right condition are highly effective. If they are overdosed on there could be serious and even fatal consequences, some have an accumulative effect. Maybe the same is true of EM radiation. We are just scratching the surface on the very wide range of electrotherapy topics, those with a strong scientific background and those with a less general acceptance by the scientific community.

Perhaps from dubious beginnings and false assumptions we are beginning to see that such things work, at least in modified form, and understand more what makes it work and its limitations. In some respects what was once, and maybe still is, considered fringe or pseudo-science is beginning to take a place in main stream science and become respected. Much more research is required to establish what techniques will be more useful as therapeutic and diagnostic tools. □

AUTHOR'S SUMMARY

I began this journey by exploring some of the early history of electrotherapy, looking at the clinical uses of natural electricity and how it has developed over the centuries. There has over its history been many strange and sometimes "quack" ideas and devices produced. I have endeavoured to stay away from the fringe of science and focus on aspects that are well accepted in mainstream science and also have tried to show that the level, interest and application is very well accepted within the main core of medical science with many branches in regular clinical practice as a treatment option. I have ended up looking at a few current areas of scientific exploration and some considered to be on the fringe in diagnostic applications.

CRAFTY COOLING

TERRY de VAUX-BALBIRNIE

Make a drink can cooler and learn about Peltier and Seebeck effects at the same time!

MANY recent inventions depend on principles that were discovered years ago. Modern applications of well-established ideas may come about because a new need arises. At the same time, modern materials and techniques that allow devices to operate more efficiently or to be made more cheaply create commercial opportunities.

THAT'S COOL!

To give an example, many readers will have seen the small portable refrigerators that are now widely available. These may be advertised as "wine chillers" or being "large enough to hold four drink cans". There may be some confusion because they are often said to be suitable for either *cooling* or *heating* the contents!

These little fridges rely on the *Peltier Effect*. If you look through advertisements in *EPE*, or in the pages of electronic suppliers' catalogues, you will find Peltier modules for sale and one, or more, of these forms the basis of such a fridge. You may have seen similar devices used in sophisticated microprocessor coolers, in night vision equipment or for cooling laser diodes. They are also found in certain medical and scientific instruments.

WATCHMAKER'S FINDING

Far from being new, the Peltier Effect was discovered long ago – in 1834 – by the French watchmaker, Jean Charles Athanase Peltier (1785 – 1845). The background to his discovery is that some years previously, Thomas Johann Seebeck (1770 – 1832) had demonstrated a phenomenon which we now know as the *Seebeck Effect*.

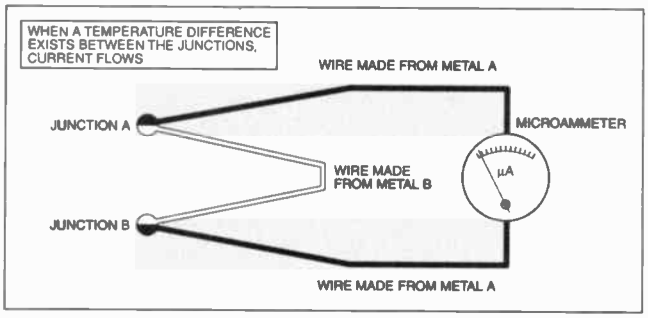
Seebeck had connected together three pieces of wire made from two different metals to provide a pair of junctions (see Fig.1a). He heated one junction and found that a small current flowed when a circuit was completed (he showed this by a compass needle moving but the diagram shows a microammeter).

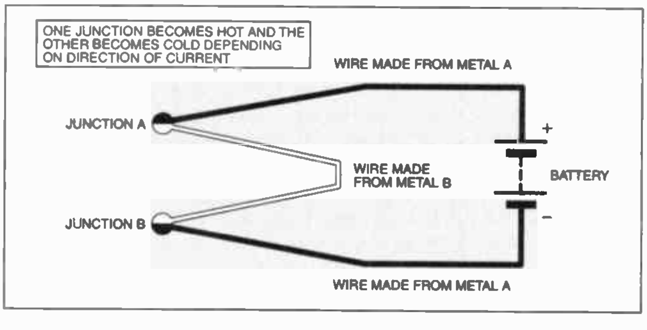
Peltier tried the converse effect. He found that when current was passed through a similar arrangement of wires, the temperature of one junction fell while that of the other rose (see Fig.1b). Which one heated up and which one cooled down depended on the direction of current flow.

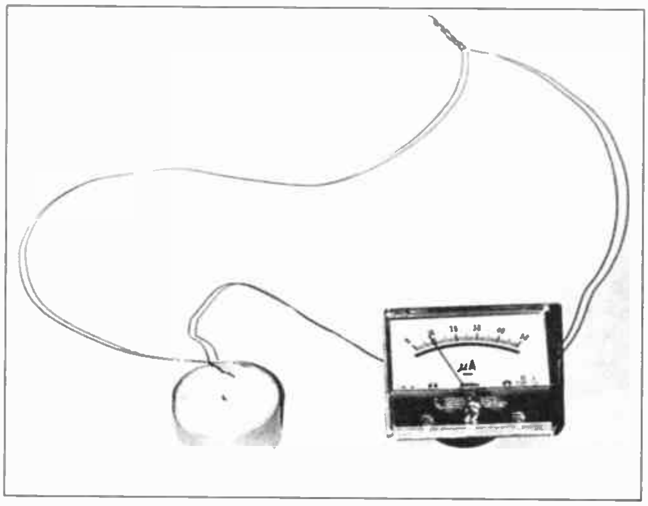
Before looking at the Peltier Effect in more detail, it would help to look more closely at Seebeck's discovery.

The Seebeck Effect is easily demonstrated by twisting a piece of bare iron wire (say, thin garden wire) with two pieces of constantan wire in the manner shown in Fig.1a and the photo below. Constantan wire (an alloy of copper and nickel) may be obtained from electronics suppliers and is used as a type of resistance wire. A microammeter may be used to measure the current. Alternatively, you could use a digital voltmeter because it is a *difference in voltage* between the free ends of the wires that causes the current to flow. When one junction is heated, current flows or a voltage is indicated. Even warming the junction between the fingers or placing it in warm water will be sufficient if the meter is sufficiently sensitive.

This could not be explained during Seebeck's lifetime because the electron had yet to be discovered (in 1897 by the initial experiments of J. J. Thomson). We now







Demonstrating the Seebeck Effect with a candle, wire and meter. See also Fig.1a above left.

Fig.1b (left). The Peltier Effect, one junction becomes hot, the other cold.

know that the Seebeck Effect is a consequence of the different electron densities in the materials used. Dissimilar (unlike) metals have differing numbers of free electrons in a given volume and these wander around randomly inside the structure. The higher the temperature, the faster they move.

PARTY PROPULSION

If wires made from different conducting materials are connected together, there will be a tendency for electrons to move from the region of high to that of low density (see Fig.2). This is because they spread out. This situation is similar to a party where there are already too many people in a room (a region of high people-density). They tend to wander into another place which is less crowded.

However, when electrons (which are negatively-charged particles) do this they tend to be drawn back by the region they came from and be repelled by the one they travel to. This is because the place from where negative charge has been removed will be left more positive and the one it travels to, more negative. The forces will rapidly balance and the process stops – just like the party, the place to where people go becomes just as bad as the room they left and overall movement stops.

There will, however, still be an equal to-and-fro trickle of people just as with the electrons. Fig.3 represents the situation shown in Fig.1a, but now in terms of electron density. Here, the left-hand side of Junction A becomes negative (to where some electrons have travelled) while the right-hand side becomes positive (where they have left). There is therefore a voltage across it, known as the *thermoelectric EMF* (electromotive force).

The same happens at Junction B, but here the left-hand side will be positive and the right-hand side negative. The voltages produced at the two junctions are equal and opposite so they cancel to give zero overall effect at the free ends of the wires.

ENERGETIC ELECTRONS

If one junction is heated, the electrons move faster and more easily cross the junction. This increases the voltage across it. There is now a voltage difference between the junctions and hence at the ends of the wires. This is the EMF that drives current through the microammeter or is indicated by the voltmeter in the experiment above.

The arrangement of wires shown in Fig.1a is called a thermocouple. This device is often used in industry for measuring a temperature so that it may be displayed on a remote meter. Sometimes it is good enough for one junction to remain at ambient temperature. This will be the case when the temperature of the "hot" junction is very high, so variations in the "cold" junction's temperature are insignificant. However, for accurate work, the "cold" junction will be maintained at a fixed temperature (by placing it in a thermostatically-controlled water bath, for example).

THERMOELECTRIC TABLE

A chart known as the Thermoelectric Table lists the chemical elements in thermoelectric EMF order. The further apart are the materials comprising the junctions, the greater will be the EMF. Table 1 shows some of the more common elements, in high to low EMF order.

Some alloys (mixtures of metals) or an alloy in combination with a single metal show more marked thermoelectric properties than elements alone. Constantan (an

Table 1. Thermoelectric Table

Silicon	Gold
Bismuth	Silver
Nickel	Aluminium
Cobalt	Zinc
Platinum	Tungsten
Copper	Cadmium
Manganese	Iron
Lead	Antimony
Tin	Germanium
Chromium	

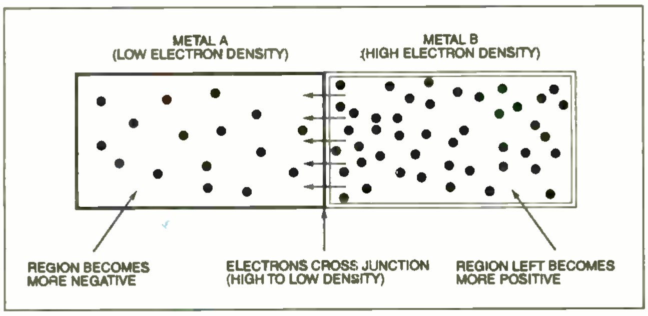
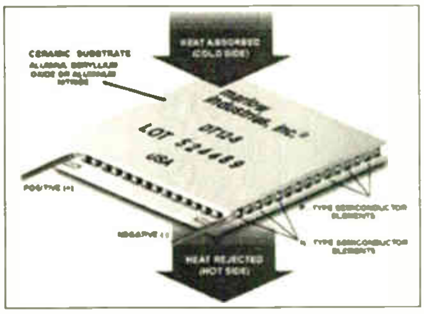


Fig.2 (left). The movement of electrons from a high density region to a low density one.

(Right) Structure of a practical TEC (thermoelectric cooler). Courtesy Marlow Industries Inc.



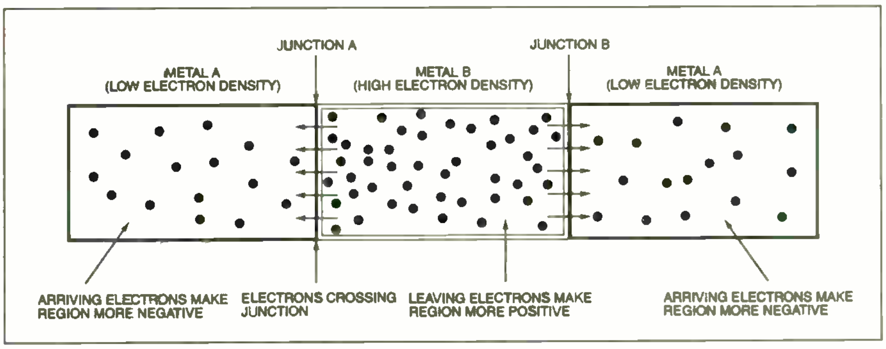


Fig.3. The effects of "arriving" and "leaving" electrons on region density.

You Will Need . . .

Peltier Module – 36W 14V (nominal) 40mm square
Aluminium beaker – 250ml 67mm internal diameter
Heatsink (finned) – 1°C/W or better
Fan(s) – 12V cooling fan (see text)
Heatsink thermal transfer compound; plastic case; 5A connecting lead; 5A screw terminal block; strain-relief grommet; bubble-wrap (see text); nuts and bolts etc.

Experimental Drinks Cooler using a Peltier Effect module.

alloy of copper and nickel) in conjunction with iron gives a particularly high thermoelectric voltage, so wires made from these materials are often used to make practical thermocouples.

Antimony and bismuth have a very marked effect and have been widely used for scientific purposes. However, the highest thermoelectric voltages of all are obtained using semiconductor materials, whereby junctions are established between pieces of the *p*-type and *n*-type doped material.

PRACTICAL MODULES

Commercial Peltier modules are often called "thermoelectric coolers" (TECs). A typical unit has 127 junctions formed between *p*-type and *n*-type bismuth telluride (a semiconductor material which has been found to be particularly effective). The precise degree of doping is controlled at manufacture to maximise its thermoelectric properties. The junctions are soldered together in series and grouped so that the "cold" ones appear at one face and the "hot" ones at the other. Which surface becomes hot and which ends up cold will depend on the direction of the current.

Although the junctions as connected electrically in series, they may be regarded as being connected thermally in parallel (to multiply the effect of one junction). The device is fitted with faceplates made of a ceramic material (an electrical insulator but a good thermal conductor). Short circuits are therefore avoided between the junctions and any external metalwork, while allowing the free flow of heat.

A TEC is just a type of heat pump. Its purpose is to transfer heat (thermal energy) from one face to the other. A conventional refrigerator is also a heat pump but uses the latent heat of evaporation (liquid to gas where heat is absorbed) and condensation (gas to liquid where heat is liberated) as the working medium. It becomes cold inside of the fridge cabinet but the fins outside become hot.

A TEC can develop a temperature difference of several tens of degrees Celsius. In fact, the cold face may fall well below 0°C if heat is removed efficiently from the hot one and the ambient temperature is not too high. Peltier devices are limited in their physical dimensions (at the moment to some 50mm square). The reason is thermal expansion. In operation, the cold side of the device will contract while the hot one will expand. This can be tolerated by the design up to a point. However, beyond a certain size internal stresses would destroy it. For greater power transfer, multiple units are therefore used.

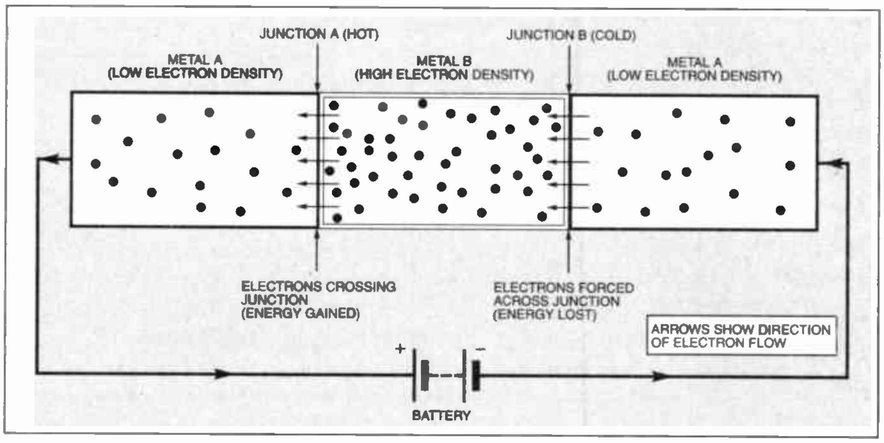


*Fig.4. Peltier Effect. Movement of electrons from low density to high produces a **cold** junction, movement from high to low produces a hot junction.*

CHILL OUT

Returning to the Peltier Effect and referring to Fig.4, the negative battery terminal will force electrons across Junction B in the direction right to left – that is, from a region of low density to one of high density. To do this against the natural repulsive force, they must do work and give up energy – they slow down and the junction becomes cold.

At Junction A, the electrons move from a region of high density to low density and acquire energy – they speed up and the junction becomes hot. The electrons then return to the positive terminal of the battery and start another trip.

Think of a roller coaster. When the car rises against the force of gravity, it gives up kinetic energy and slows down. On a downward slope, it increases its kinetic energy and speeds up.

Before reaching for your pieces of wire to try out the Peltier Effect, remember that current flowing through the resistance of any wire causes a rise in temperature (*Joule Heating*). This will dwarf the Peltier Effect if common materials are used. This is especially so because Joule Heating is proportional to the square of the current (doubling it multiplies the heating effect by four) whereas Peltier phenomena are proportional to the current alone.

Note that Joule Heating occurs whichever direction the current flows – it never causes a fall in temperature as does the Peltier Effect. Another important difference is that the Peltier Effect only takes place at junctions, whereas Joule Heating occurs throughout the entire circuit. If you were to use bismuth and antimony for the materials, the Peltier effect would be large enough to observe using simple equipment. However, this is not very practical and it is much easier and better to use a commercial device.

EFFICIENCY

With a conventional machine, such as an electric motor, there is a definite notion of "power in" (electricity) being converted into "power out" in the form of work done. The ratio of power in to power out expressed as a percentage then gives a measure of the efficiency – that is, how well the machine performs. With a Peltier device, its "goodness" is measured by comparing the electrical power entering with the power transferred between its faces.

A typical TEC might be described as 36 watts. This means that, working "flat out", it can transfer 36 watts or 36 joules of thermal energy per second. Suppose its maximum current and voltage ratings are 4·4A and 13·5V respectively. Since amps multiplied by volts gives watts, the power drawn from the supply will be almost 60 watts. The "goodness" of the device is therefore 36/60 or 60 percent. 40 percent of the ingoing electrical energy is converted into heat by Joule Heating.

Due to its arrangement of many thermoelectric junctions, a Peltier module may also be used to generate a useful amount of electricity (using the Seebeck Effect) if its faces are subjected to a temperature difference. Such a system could be used to turn waste heat into electricity. In fact, a similar low-tech method has been in use for many years to make inexpensive generators. These use a large number of thermocouple junctions connected together in series and heated by an oil lamp or fire. They have been used in remote areas to charge batteries or to operate a small radio.

In deep space exploration, sunlight is insufficient to provide an adequate amount of electricity using solar panels. To overcome this problem, heat developed naturally by the radioactive isotope plutonium-238 is utilised. Into this is buried an arrangement of thermoelectric junctions. The electricity produced is sufficient to power the transmitting equipment that sends data back to the base station.

CONSIDERATIONS

Peltier modules are fairly expensive and easily damaged through misuse. However, if used correctly they are robust and reliable. Sure ways of ruining one are failing to remove heat effectively from the hot surface or passing a current greater than the rated value through it (both of which cause it to overheat). It will also be destroyed by putting it under mechanical stress.

The removal of heat is extremely important, so never connect a Peltier module as it stands to a supply to see if it works! You must use a substantial heatsink (possibly assisted by a fan) placed in good thermal contact with its hot side. The temperature here should rise as little as possible above that of the surroundings, but up to 15°C is acceptable.

BATTERY SUPPLY

A practical Peltier device needs a high current, low voltage supply. If this is derived from the mains, a substantial transformer and rectifier would be needed. Also, a high-value smoothing capacitor would be required because these devices work best with smooth d.c. – their ability to pump heat falls with any ripple present (although, in practice, up to 10% would be tolerated).

A cost-effective power supply which avoids these components would be a car battery (but check that the TEC is rated at 14V minimum). Remember, a well-charged "12V" car battery can develop considerably more than the nominal voltage and this must be allowed for.

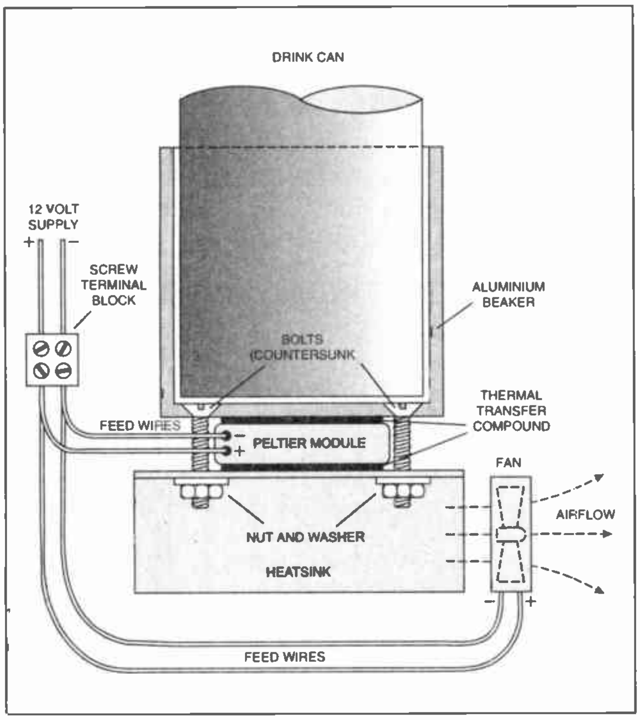
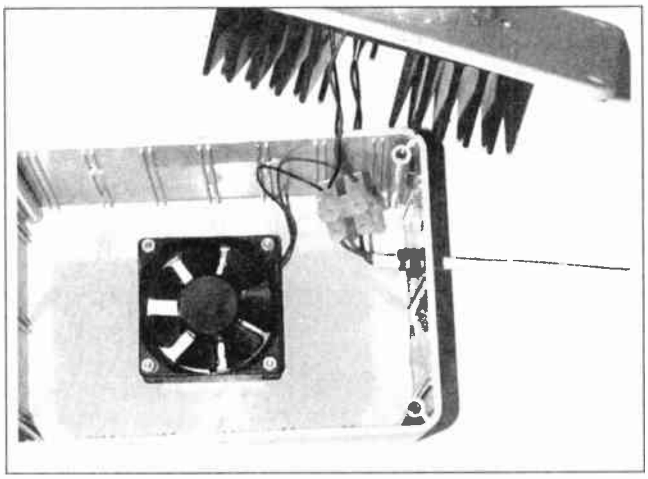


Fig.5. Experimental Drinks Cooler construction details.



Cooling fan mounted in the base of the case and the finned heatsink on the rear of the lid.

If a Peltier module were to be connected to a supply developing a higher voltage than the rated value, a larger current than it was designed to carry would flow. Its pumping ability would be exceeded by Joule Heating and the device would heat up the system that it was supposed to cool. After that, it would probably be destroyed.

When a nominal 14V module is connected to a 12V supply, the current will be less than the rated value. Calculation shows that only about 26W will be available from a nominal 36W TEC and this will result in longer cooling times.

COOL IT YOURSELF!

We now show you a drink can cooling design you can construct for yourself, using a 12V car battery as a power source. It will be found handy for cooling a drink while in the car. A 40mm square 14V 36W (nominal) TEC was used in the prototype unit and was found to be adequate.

It is impossible to say with any accuracy how quickly it will cool the drink. This depends on the required final temperature, the ambient temperature, the efficiency of insulation and thermal contact, how well heat is removed from the heatsink and the supply voltage. To give an idea, the prototype provides adequate cooling in less than one hour.

However, unless you are desperate for a drink, the cooling time does not usually matter and the unit may just be left operating for as long as required. It is important for the cold side of the TEC to make efficient thermal contact with the can to be cooled. The better the coupling, the quicker the cooling will be. The specified 250ml aluminium beaker has an internal diameter of 67mm and provides a good fit for many drinks cans. It was found that some supermarket "own brand" cola cans gave a tighter, and therefore better, fit than some "famous make" ones.

By attaching the bottom surface of the beaker to the cold side of the Peltier device, a drink can placed in the beaker is cooled effectively. At the end of construction, insulation ("bubble-wrap") will be placed around the beaker so that cooling is confined as much as possible to the can and the drink inside it, rather than reducing the temperature of the surrounding air!

MOISTURE SEALED

It is best to choose a TEC which has been factory sealed against the entry of moisture. This is because the cold surface will make the temperature of the surrounding air fall below the dew point and condensation will form. Without sealing, water will enter the module and eventually damage it. An unsealed module would need to be protected by applying some flexible, waterproof material around the periphery.

Arranging for the TEC to be vertical would help because it would allow any condensation to drip off. However, for ease of construction, the device was placed horizontally in the prototype unit. It is vital to choose a heatsink that will remove heat from the hot surface of the TEC as well as possible. This should be rated at 1°C/watt (or better) and a small 12V fan, or fans, should be used to assist the removal of hot air. A suitable fan would be a 12V unit designed for cooling a microprocessor.

Referring to Fig.5, drill holes in the heatsink and beaker to allow the Peltier device to be sandwiched between them. These parts must make very good thermal contact with the TEC's faces and thermal transfer paste should be applied to the surfaces to assist the flow of heat. If the bottom of the beaker is not absolutely flat around the area of contact, it should be rubbed on a sheet of abrasive paper, which is itself placed on a flat surface, until it is. Similarly with the heatsink.

Countersink the fixing bolts so that the heads are flush with the inside surface of the beaker. **Important:** ***when tightening the bolts, use only sufficient force to hold the module securely without slipping. Any more will destroy it.***

TESTING

Make up a connecting lead of 5A rating (or use a ready-made lead) having a cigar lighter plug on one end. This should be no longer than necessary to avoid an excessive voltage drop. Taking care over the polarity, connect the other ends of the wires to the TEC and the fan using a two-section piece of 5A screw terminal block. The TEC will probably have its polarity marked (say, a red wire used to indicate the positive). If the fan is of the microprocessor type, only the red and black wires are used – the red one being connected to supply positive.

If there is a yellow wire, it should be cut off short and ignored – this would normally be connected to the computer motherboard to monitor the fan's performance. It will not be necessary to actually use the fan during short tests. Just leave it free but out of the way for the moment. Connect the supply and check that the "cold" side of the TEC (and hence the beaker) becomes cold. If it becomes hot, reverse the current. Also check operation of the fan. Allow the unit to operate for a minute or two but do not allow the heatsink to become hot.

BOXING UP

The finished assembly is housed in a plastic box (see photograph). This has a hole cut in the top a little larger than the can. The heatsink, and therefore the whole assembly, is bolted to the underside of the lid. Make a large hole in the base of the box and mount the fan over it on the inside (see photograph) making sure that, in operation, air will be extracted from the box rather than the opposite.

Drill a few holes in the sides of the box to allow air to enter and flow between the heatsink fins. Drill a hole in the side of the box for the connecting wire to pass through. Fit a rubber grommet and use a tight cable tie on the wire inside the box to provide strain relief (or use a strain relief bush). Leave a little slack in the wire inside the case.

Plastic blocks should be attached to the base of the box to hold it 10mm minimum above the surface on which it stands. This must allow the free flow of air out of the box. Always make sure that, in operation, this hole is not obstructed and the fan is not fouled. Wrap several layers of insulation, "bubble wrap" for example, around the beaker and place a drink can in position.

Make certain the fan is not obstructed by stray wires and route them as necessary so that this can never happen. Allow the unit to operate for increasing times up to one hour, checking that the box remains quite cool and the heatsink does not become excessively hot. When satisfied, attach the lid.

Happy cooling! □

TECHNO-TALK ANDY EMMERSON

Limited Life Cycle

Electronic products that destroy themselves sound like a mixed blessing and Andy Emmerson confirms this.

CONSUMER electronics that self-destruct are nothing new. Twenty years ago certain brands of colour TV were notorious for catching fire, whilst the switch-mode power supplies in another mass-market manufacturer's satellite receivers and home fax machines invariably suffered an early demise.

Of course these effects were unintentional, unless you consider lousy design and penny pinching (sorry – value engineering!) a deliberate policy. But today's novelty is products intentionally designed to self-destruct after a period of use.

The stated and obvious reason for these is to assist recycling and thus protect the environment, although a secondary objective is limiting what manufacturers and rights holders would consider misuse. We'll touch on waste recycling in a moment but let's look first at self-destructing DVDs.

IMPECCABLE VIEWING

This time last year an American company, Flexplay Technologies Inc., announced what it called "a breakthrough in the DVD manufacturing process" and "a major technological achievement for the industry". The industry breathed a sigh of relief, although savvy consumers were not so ecstatic, since Flexplay DVDs self-destruct after 48 hours. Branded "EZ-D", these discs start to deteriorate as soon as they are removed from their packaging.

Consumers can enjoy their movie as many times as they wish during this time frame. After 48 hours of impeccable play, the DVDs are no longer readable by the DVD player and can then be recycled (or more likely thrown away as general rubbish). The makers say a Flexplay-enabled DVD works in all players, DVD drives and gaming systems designed to accept a standard DVD. GE Plastics, a division of (American) General Electric, developed a new patented Lexan resin co-polymer essential to the flexible play design.

EZ-D's goal is to expand the overall home entertainment market by appealing to consumers who find the current rental process tedious. With EZ-D they no longer have to return their choice to the shop, nor need they worry about late fees or scratched discs. The Buena Vista Home Entertainment Division of the Walt Disney Company certainly likes the idea and started test-marketing this technology last summer.

Hollywood studios are enthusiastic too and are planning to use self-destructing DVD for the "screeners" (viewing copies) they send out for judges of the Oscar awards. Voters for France's César awards, the French equivalent of the Oscars, have already received DVDs that become unplayable after two days. In both cases the idea is to defeat bootleggers who bribe voters and then sell pirate copies of the brand-new movies. Whether the move will succeed is debatable, since 48 hours is plenty long enough to copy a DVD.

SPOILSPORT SONY

One of Sony's subsidiaries has devised a spoiler for downloadable movie files, making these self-destruct after a given time. There's big money to be made offering video entertainment over the Internet but in the process the door is opened to illegal copying as well. The movie provider Sonet has incorporated into its service a digital rights management (DRM) technology from software maker Japan Wave that makes copying impossible.

Instead of saving a video to a single file and location, Japan Wave's technology splits the data into numerous directories on a hard disk. People need to download special software to play back the various pieces as a continuous movie. A second layer of protection embedded in the file then ensures that it self-destructs after a given time.

How successful this technique will be is debatable. There are plenty of computer programs that capture the video and audio bitstreams before they are saved or processed, and if you can see material, you must be able to capture the bitstreams.

SMART MATERIALS

If you think saving the planet is more important than saving movies for watching a second time, then you'll be interested in moves to make recycling simpler. The pressure to limit waste when electronic products come to the end of their life cycle is exercising the minds of activists and technologists alike. It's also spawning some mighty ingenious new ideas involving "smart materials" and one of these is plastic screws that self-extract when heated.

Active Fasteners Ltd, a spin-off company of Brunel University, has spent three and a half years perfecting a product that self-disassembles for recycling. The plastic screws use special "shape memory polymers" that lose their mechanical strength when heated and can be used as releasable fasteners. The development project involved manufacturers such as Nokia, Motorola and Sony, all of whom have a keen interest in minimising their exposure to the new pan-European recycling regulations that come into force in 2006.

Known as the Waste Electrical and Electronic Equipment Directive (WEEE), the rules apply to a huge spectrum of products and aim to minimise the impacts of electrical and electronic equipment on the environment during their life times and when they become waste. Critically, the new regulations make producers responsible for financing most of these recycling activities, with private householders being allowed to return products covered by WEEE without charge.

Manufacturers will need to ensure that their products – and their components – comply in order to stay on the Single Market. If they do not, they will need to redesign products.

BIG BANG THEORY

Some kinds of electronics self-destruct with explosive force. Researchers at the University of California in San Diego (UCSD) have developed silicon chips that explode. Two years ago professor Michael Sailor, head of the project, stated: "We're making a silicon nanocrystal which has such a high surface area that it burns very quickly. The faster the burn, the bigger the bang."

The explosive effects were discovered accidentally when a researcher working on porous silicon wafers substituted potassium nitrate with gadolinium nitrate. The effect has two potential applications, for performing rapid chemical analysis of elements in the field and as a propulsion source for micro-electrical mechanical systems (nanobots).

Some electronics hobbyists are already familiar with the explosive capabilities of electronic components. I myself have created a miniature Mount Vesuvius after accidentally applying 24V d.c. to a memory chip (impressive . . . and expensive). And electrolytic capacitors are not called "smoothing bombs" for nothing. Big ones can cover an entire ceiling with their mess when provoked.

EXPLOSIVE CHARGES

Most spectacular of all are the detonators hidden in some Allied and German WW2 military surplus radio equipment. At least one collector has seen his garden shed go up with a bang (spontaneous detonation) and another, to his horror, had an innocent-looking "component" identified as a charge. Frequently these detonators look extremely similar in shape and size to electrolytic capacitors, as a photo feature in the German historical wireless society's magazine, *Funkgeschichte*, showed. It also quoted a newspaper report of 1949 in which a domestic radio technician testing war-surplus radio components for re-use lost his sight when one of these "capacitors" blew up in his face.

Next month I'd better bring more cheerful news!

BODY DETECTOR MkII

THOMAS SCARBOROUGH

Create your own invisible defence shield

EVERY living human body is surrounded by an electric field, which may potentially be detected at a few metres' distance. Even if this can only be detected at a distance of a few centimetres (as opposed to millimetres), the applications are legion.

Consider now that the phenomenon of *capacitance* is entirely dependent on the existence of electric fields. If, therefore, a human body should approach the positive plate of a capacitor, the body's electric field will cause the value of the capacitor to rise.

In the Body Detector circuit described here, this is detected by means of an *RC* (resistance-capacitance) oscillator. As the value of *C* rises, so the frequency of the oscillator drops. All that remains is to detect this drop in frequency to obtain some very interesting results.

APPLICATIONS

Some of the possible applications for the Body Detector MkII are outlined in the "Modes" panel, together with operation diagrams (Fig.1a to Fig.1g).

While in theory its operation is dependent on the electric field which surrounds the human body, in effect it would seem that an invisible field surrounds the sensor – somewhat like the "invisible" defence shields seen in the *Star Wars* movies. It would appear, therefore, that as a human hand (for instance) enters this invisble field, an alarm is triggered.

DESIGN PRINCIPLES

Modern proximity sensors will seldom detect a human body at more than a few millimetres' distance (for example, the touch switch on a bedside lamp, or the button of a lift). Besides the fact that some applications don't *need* a greater range, this is because it is difficult to achieve greater sensitivity with any reliablity.

In order to achieve a greater range, two challenges in particular need to be overcome:

The first is environmental variations which affect the stability of the circuit, as well as variations within the circuit itself (such as warming).

The body's electric field may be described as extremely weak, and the body's capacitance at a small distance from a sensor is typically measured in fractions of a picofarad. Therefore the circuit needs to be exceedingly sensitive.

This, however, greatly increases its sensitivity to variations in voltage, temperature, humidity, and so on, and means that special measures need to be taken to protect it from such variations, or to eliminate them.

The second important challenge is to find a means of reliably picking up small shifts in frequency as a body approaches, and (if possible) to incorporate these in the circuit in a user-friendly way.

The author's original *Body Detector* (*EPE* March 2001) used five "building blocks" in its detection section, while the new Body Detector MkII circuit (Fig.3) uses only two. The new version also requires no special optimisation for the sensor, as did the original design, and may be easily adjusted to almost any sensor of one's choosing.

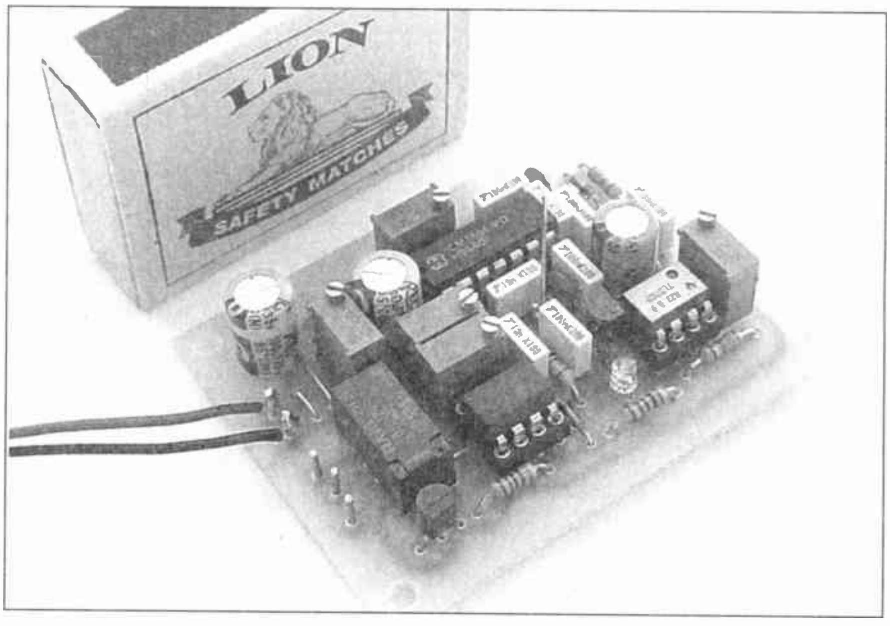
In brief, the new design is based on an astable oscillator (IC1a) and a non-retriggerable monostable (IC1b) operating in tandem – see Fig.3. Notice that these use somewhat similar component values, as well as similar physical components, so that any environmental influences on IC1a are duplicated in IC1b. Most importantly, nearly all of the components surrounding IC1 have the same temperature coefficients.

Also, notice that both the astable oscillator and the non-retriggerable monostable are housed in the same package (IC1), which means that any warming or cooling of the device affects both sub-circuits more or less equally. Thus environmental variations are largely cancelled out.

SENSITIVITY

It is hard to quanitify the circuit's sensitivity and stability, since this depends on a number of factors, particularly the range it is adjusted to, and the surface area of the sensor.

During tests, at 100mm range, using a 300mm × 300mm sheet of tin foil as the sensor, the prototype showed just over 1·5% shift in sensitivity per 1°C temperature variation. This means that in most situations the circuit is "solid" at 100mm range, which is more than adequate for protecting a bicycle, or valuables on a shelf.



However, at 250mm range, and using the same sensor, temperature becomes a significant problem (it triggers the circuit) if temperature *increases* by more than about 10°C. The maximum range of the circuit will lie around *600mm.*

CHERRY PICKING

The output of IC1a (at pin 5) is fed to the trigger input of IC1b. Therefore astable IC1a triggers monostable IC1b. However, it is the way in which IC1b is triggered that is important.

Suppose that monostable timer IC1b goes "high" for a duration fractionally longer than the period of astable IC1a (with IC1b being triggered by the trailing edges of pulses from IC1a). Therefore IC1b will miss the next trailing edge from IC1a, and will only be triggered by the following trailing edge. The result is a square wave as seen at the top of Fig.2a.

If then a body comes near, the frequency of IC1a will drop, therefore monostable timer IC1b will go "high" for a duration fractionally *shorter* than the period of astable IC1a. Therefore, IC1b is almost instantly triggered again as it "runs smack into" the next trailing edge from the oscillator. The result is the sharp negative-going pulses seen at the top of Fig.2b.

It need hardly be said that these two very different waveforms will have a significantly different effect on a standard charge pump. Therefore a minute variation in frequency at IC1a pin 5 results in a very significant difference at IC1b output pin 9. In effect, a great amplification takes place. A variation amounting to a fraction of a picofarad at C1 results in a voltage swing of about 1V at IC2 input pin 2.

To explain this by means of analogy, imagine that a worker at a conveyor belt needs to place cherries on passing cakes. The worker is barely able to do this fast enough, yet manages to give each cake a cherry.

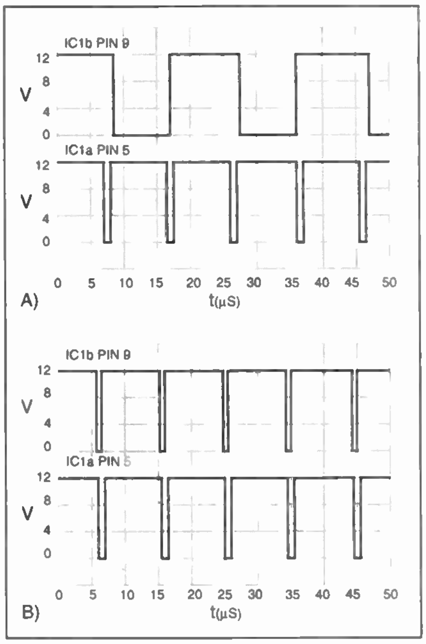


Fig.2 (right). Body Detector trigger waveforms: a) before and b) when triggering.

MODES OF OPERATION

If the positive plate of the timing capacitor *C* is attached to a metal sensor, this makes it more receptive to the body's electric field. This sensor may have several "modes of operation", as illustrated by Fig.1:

• As a simple metal sensor plate, Fig.1a, for example the button of a lift. This may be as small as desired – even the size of a pinhead. Or the sensor plate may be replaced with another metal object – e.g. a set of burglar bars as shown in Fig1b. This may weigh as much as tens of kilos.

Up to a point, a larger sensor increases the Detector's sensitivity, until the mass of the sensor begins to "swamp" the electric field of the human body approaching it.

Note that the Body Detector may be used either with or without an earth wire (or a "proxy" earth through a d.c. power supply), and this will make a significant difference to its performance (see article).

With an earth wire, the author's prototype had no difficulty protecting his large and heavy single-cylinder motorbike. When clipped to the exhaust pipe at the rear, a finger touching a spoke on the front wheel triggered the circuit.

Without an earth wire, sensitivity is much reduced. Even so, without an earth, the prototype was easily capable of protecting a bicycle. It was stretched to the limit, however, with a 6-metre aluminium ladder.

The author also tested the Detector on a cat, which triggered the circuit every time it climbed through a set of burglar bars.

• Place a conductive object on top of a sensor plate (e.g. a drink tin) as shown in Fig.1c. This object then becomes an *extension* of the sensor. This could be useful to protect a valuable or dangerous object.

• More interesting still, place some insulating material between a sensor plate and the conductive object. A book is shown in Fig.1d, since paper serves as a good insulator. (Plastic, rubber, glass, ceramics, wood, and even air serve as good insulators.) If the circuit is suitably adjusted, the object on top of the insulator will serve as an extension of the sensor, even though it is not physically connected to it.

Now consider that the book is replaced with a tablecloth, or even a tabletop, and a silver dinner service is placed on top. The dinner service is now protected by the Detector, without the need for any wired connections, and without any "electronics" being evident.

This could be useful, among other things, for protecting items on shop shelves, or at a hospital bedside. It could detect feet passing over a carpet – even a hand placed over an invisible "panic plate" hidden in concrete.

• Conversely, if a metal object which is in contact with a human body approaches the sensor plate, Fig.1e, the circuit will detect this object as though it were the body itself. As far as the Detector is concerned, such an object becomes indistinguishable from the human body.

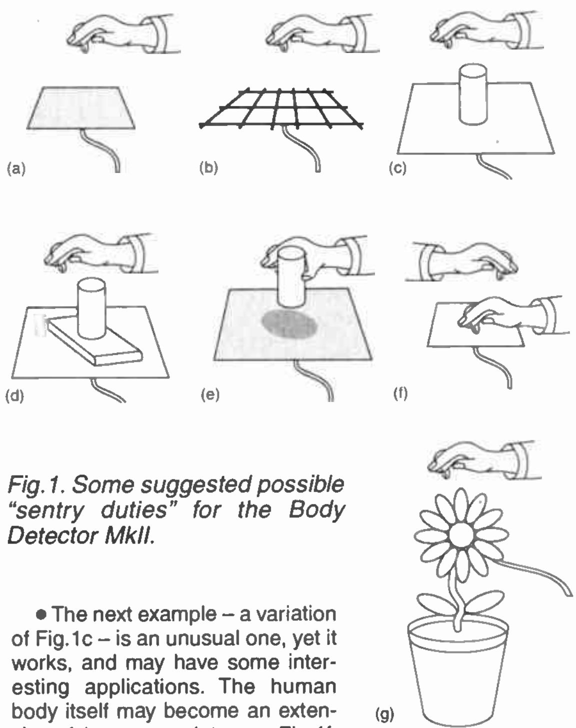


Fig.1. Some suggested possible "sentry duties" for the Body Detector MkII.

• The next example – a variation of Fig.1c – is an unusual one, yet it works, and may have some interesting applications. The human body itself may become an extension of the sensor plate, see Fig.1f. In this case, a second human body which approaches the first will trigger the circuit.

If, as an example, a metal sensor were strapped to the ankle of an infant, the circuit would detect a person touching the infant – even with the tip of a finger. This works better when a larger person is touching a smaller person. We might call it an "Anti-Kidnap Alarm".

The circuit is also able, to a point, to detect how *large* a body is, and whether two or more bodies are in physical contact with each other when they touch the sensor. In fact if the Body Detector were capable of a little more accuracy, it would indicate someone's weight by shaking their hand!

• Since plants are conductive, as well as having a high degree of electrical isolation from the ground, these may also serve as the sensor, Fig.1g, with the contact to the circuit being made, for example, through a pin stuck into the stem. This could serve to protect valuable flora, or ripening fruit.

In one experiment, the author detected bare feet walking on grass. Since this was buffalo grass, the grass "sensor" covered an area of about 1m x 1m.

Consider then that the conveyor belt slightly speeds up. The worker is unable to keep up any more, and is too late for every second cake. A slight increase in the speed of the conveyor belt thus results in a 50% change to the appearance of the cakes.

Needless to say, this same filter arrangement may be used in various applications where a frequency remains within known parameters (that is, comfortably within $2f$, where $1/f$ is the frequency threshold to be detected). This will work at frequencies from tens of hertz to a few hundred kilohertz, assuming that the component values in the charge pump are suitably adjusted.

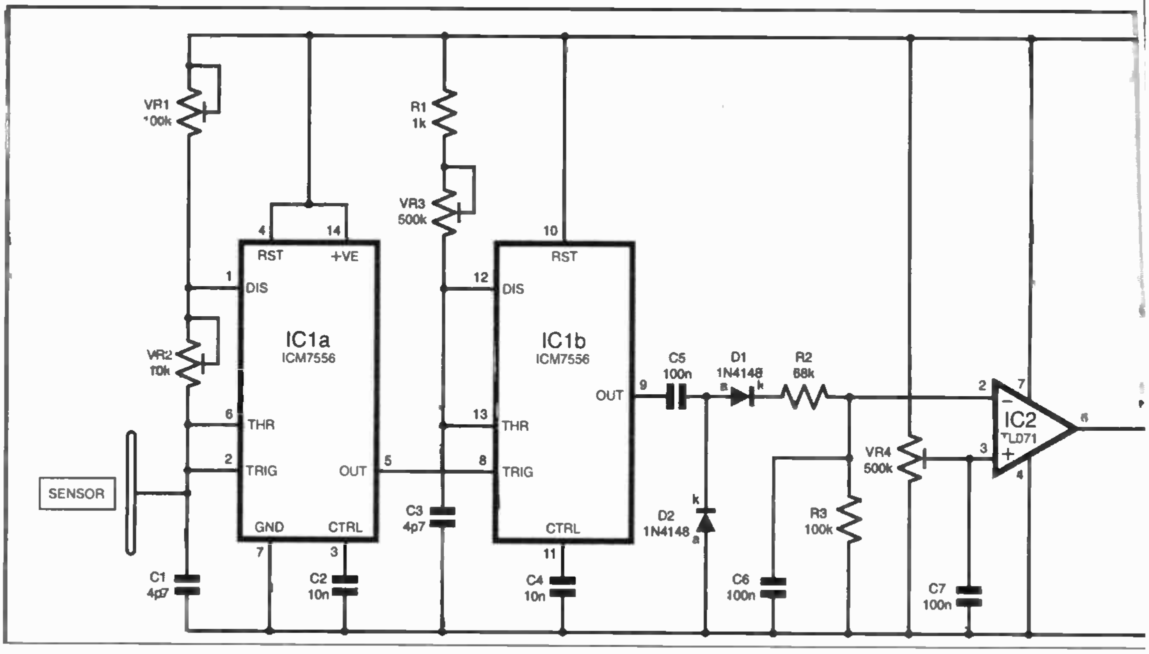


Fig.3. Complete circuit diagram for the Body Detector MkII.

CIRCUIT DETAIL

The full circuit diagram for the Body Detector MkII is shown in Fig.3. The functions of IC1a and IC1b have just been described. A dual CMOS 7556 timer is used for IC1, and this should not be replaced with a standard 556 timer i.c. – it will not work!

The frequency of oscillator IC1a is calculated by the formula:

$$f = 1{\cdot}46/((VR1+VR2) \times C1)\text{Hz}$$

while the period time of monostable IC1b is calculated by the formula:

$$t = 0{\cdot}69 \times (VR3+R1) \times C3 \text{ seconds.}$$

IC1a oscillates at around 100kHz, although its frequency is dependent to a large degree on the mass of the sensor.

A very small value timing capacitor (C1) is employed for IC1a, in particular so that the oscillator will readily respond to the body's electric field. Capacitor C3, as used with IC1b, is the same value as C1. If possible, both C1 and C3 should have a zero temperature coefficient or NPO. Control voltage decoupling (C2 and C4) has been included on both IC1a and IC1b for added stability, along with supply decoupling capacitors C12 and C13.

All the timing components of IC1a and IC1b have identical temperature coefficients. This is why variable resistors (trimmer potentiometers) are used throughout – with the one exception of R1. Resistor R1 amounts to just one kilohm (1k), and will only have a small effect on the stability of the circuit. Perfectionists might, however, wish to replace this with a link wire (or with another variable resistor). In this case, VR1 should never be reduced below about 1k, otherwise IC1 is sure to self-destruct!

The output of the non-retriggerable monostable timer (IC1b) is fed to a standard diode charge pump. Charging is both limited and controlled by resistors R2 and R3, so that the charge on capacitor C6 will vary between about 5·5V and 6·5V as a body comes near the sensor.

The values of resistors R2, R3, and C6 are chosen to be large enough to damp mains transients and electromagnetic pulses (e.g. a nearby fluorescent light switching on or off) for greater reliability. This may be appreciated by tapping the sensor very rapidly. If it is tapped rapidly enough (thus mimicking a transient), the Body Detector will fail to trigger. The value of capacitor C6 may be increased if there is any problem in this department.

A simple inverting comparator is formed around IC2 and associated components. The "threshold voltage" is set by preset VR4, so that the output, at IC2 pin 1, swings "high" or "low" as the inverting input crosses the threshold. It will swing "low" as a body approaches the sensor – assuming that VR4 is suitably adjusted.

BLANKING OUT

Resistor R4, together with field-effect transistor TR1, R5, C8, and D3, represent a "blanking" circuit, which for a brief moment (about 200ms) blanks the action of relay RLA after it has been activated. This ensures that the relay's back-e.m.f. does not destabilise the very finely balanced circuit.

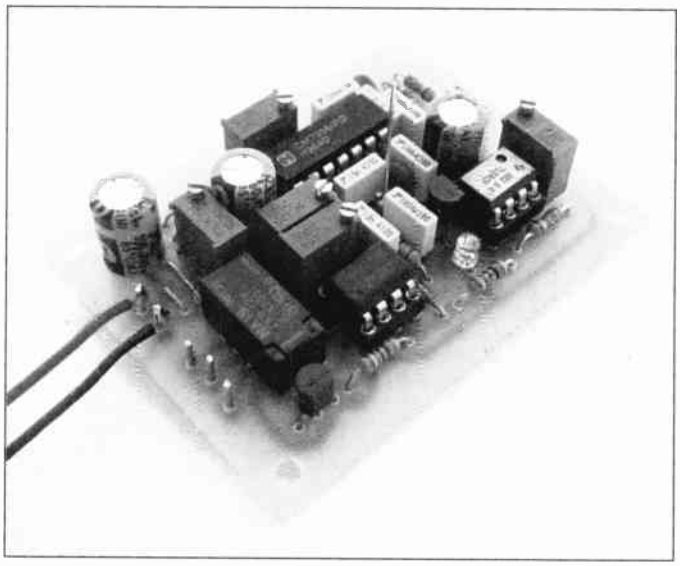
The effect of these components may be appreciated by holding one's hand to the sensor continually. As IC3's timing period comes to an end, and l.e.d. D4 extinguishes, a fraction of a second's delay is noticed before it illuminates again.

A simple monostable timer, IC3, triggers the relay for a period determined by preset VR5 and resistor R8. Its period time is calculated by the formula: $t = 0{\cdot}69 \times (VR5 + R6) \times C9$ seconds, so that it may be adjusted between about 70ms and 35 seconds with the component values shown. If different timing periods are required, the value of capacitor C9 may be increased for longer time periods, and vice versa. The output of monostable timer IC3 (pin 3) provides current for transistor TR2, which in turn switches relay RLA.

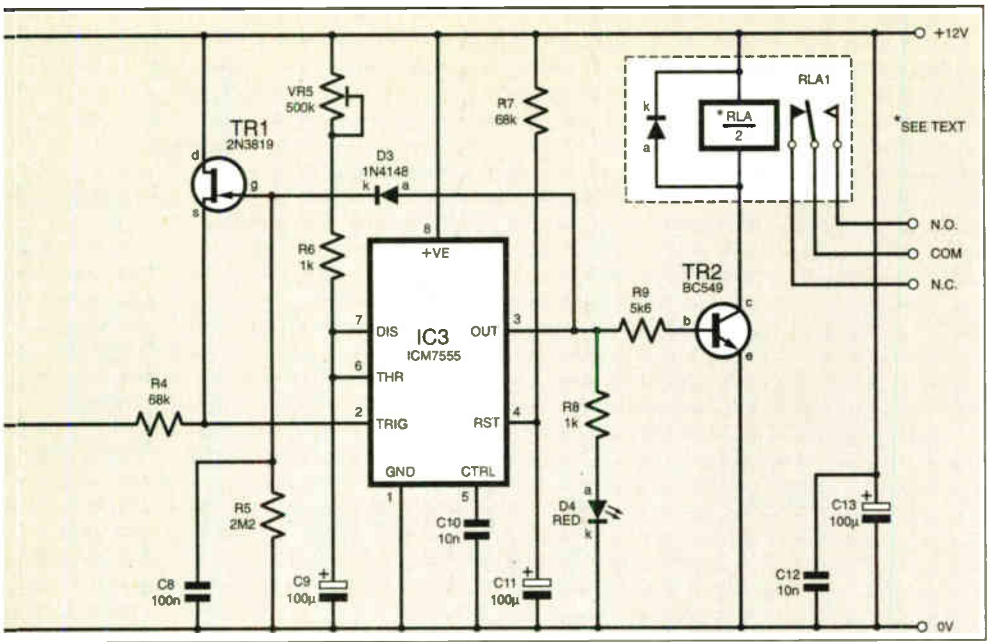
The arrangement at IC3 reset pin 4 delays the circuit's "coming alive" at switch-on by about seven seconds, so that one has time to stand back from the circuit after switching on. Failing this, body capacitance could trigger the circuit at switch-on.

Although, in circuit diagram Fig.3, there is no direct provision for a delay before the circuit is triggered (e.g. when returning to a bicycle which is protected by the Body Detector), this could be arranged by wiring a large value capacitor (say 47µF) in parallel with C6, then reducing preset VR4 as far as possible (this means turning it *clockwise*!) without disabling IC2's output (see further notes under "Setting Up").

Relay RLA is a miniature Telecom type with integral diode to reduce back-e.m.f. It has two sets of changeover contacts, which are rated 60W (2A/30V d.c.) maximum.



Completed Detector circuit board showing the d.i.l. relay and the three contact pins on the edge of the p.c.b.



POWER SOURCE

No reverse polarity protection is included in the Body Detector circuit, so that it may be run off both 12V and 9V (up to about three days and nights off a small 9V alkaline PP3 battery). Note, therefore, that special care needs to be taken that the power is connected the correct way round.

The circuit is unusually stable, therefore no voltage regulation is included. However, a clean, regulated supply is sure to improve performance.

The circuit is virtually immune to static, and to e.m.f.-induced eddy currents in the body. The Body Detector MkII is designed to detect the electric field surrounding the human body, and has a high degree of immunity to a.c. fields, as well as being able (unlike some proximity detectors) to function well out of range of such fields.

CONSTRUCTION

The Body Detector MkII is built up on a small printed circuit board (p.c.b.) measuring about 65mm × 50mm. Details of the topside component layout, together with the full-size underside copper foil master, are shown in Fig.4 (note that these differ slightly from the photographs). This board is available from the *EPE PCB Service*, code 449.

All the components should fit into place without too much difficulty. However, a fine-tipped soldering iron would help, since this is a compact circuit board.

Before soldering and commencing construction work, adjust preset VR1 to about 50k, VR2 to 5k, VR3 to 10k, VR4 to 250k, and VR5 to 10k.

Turning to the circuit board, solder the eleven link wires and six solder pins, and the three dual-in-line (d.i.l.) sockets in position. Since the printed circuit board is so densely populated, the author abandoned the usual soldering sequence, and built up the board by filling the holes from one side to the other, including the presets.

Take special note of the orientation of electrolytic capacitors C9, C11 and C13. All other orientations are clear from the layout diagram Fig.4. The electrolytic capacitors must also be suitably rated, namely 16V or higher.

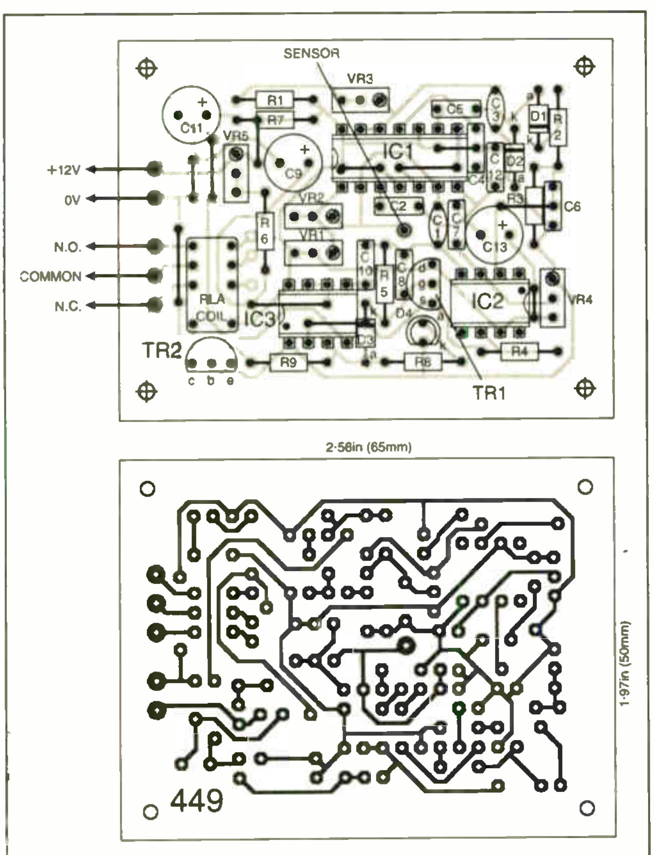


Fig.4. Printed circuit board topside component layout, wiring and full-size underside copper master for the Body Detector MkII. Note, some of the link wires pass under some components.

COMPONENTS

See SHOP TALK page

Resistors

R1, R6, R8	1k (3 off)
R2, R4, R7	68k (3 off)
R3	100k
R5	2M2
R9	5k6

All 0·25W 5% carbon film

Potentiometers

VR1	100k 25-turn cermet preset, top adjust
VR2	10k 25-turn cermet preset, top adjust
VR3 to VR5	500k 25-turn cermet preset, top adjust (3 off)

Capacitors

C1, C3	4p7 ceramic (2 off)
C2, C4, C10	10n polyester (3 off)
C5 to C8 C12	100n polyester (5 off)
C9, C11, C13	100µ radial elect. 16V (3 off)

Semiconductors

D1 to D3	1N4148 signal diode (3 off)
D4	3mm ultrabright l.e.d. red
TR1	2N3819 field-effect transistor (f.e.t.)
TR2	BC549 *npn* small signal transistor
IC1	7556 CMOS dual timer
IC2	TL071CN j.f.e.t. op.amp
IC3	7555 CMOS timer

Miscellaneous

RLA	12V d.c. coil, Telecom TX series, relay with 2A 30V d.c. d.p.c.o. contacts

Printed circuit board available from the *EPE PCB Service*, code 449; plastic case, size and type to choice; 8-pin d.i.l. socket (2 off); 16-pin d.i.l. socket; plastic self-adhesive p.c.b. stand-off pillars (4 off); battery clip, with leads, or power socket (see text); link wire; solder pins; solder etc.

Approx. Cost Guidance Only **£17** *excl. case & batt.*

Any lead which is taken from the board to a sensor should be *soldered* to the solder pin at the centre of the p.c.b., and the "free" end *bolted* to the sensor to ensure good electrical contact.

Finally, insert the i.c.s in the d.i.l. sockets, noting their correct orientation. Observe anti-static precautions with IC1 and IC3, which are CMOS devices, albeit relatively tough ones. The most important precaution is to touch your body to ground immediately before handling these devices. Take care also with f.e.t. TR1, since this is also a more sensitive device.

RELAY

One set of relay contacts is routed to three solder pins on the edge of the p.c.b., and these may be used to wire up an external load. Another three holes are provided on the p.c.b. in case the spare set of relay terminals is required.

Since the relay is rated 60W (2A/30V d.c.) maximum, a powerful siren may be wired to the contacts. The Body Detector may also be wired to the input of a standard alarm system.

Finally, check that there are no solder bridges on the board, and connect the power (9V or 12V, but preferably 12V), again being very careful not to confuse these wires!

A mains to 12V power supply would usually provide a "proxy" earth for the circuit – or a separate earth wire may be taken from 0V on the p.c.b. to ground, which may be a metal stake driven into the ground, or the household metal plumbing in particular.

SETTING UP

Setting up may require a little patience, but should not be difficult. Do not further adjust preset VR1 or VR2, which only serve the purpose of matching temperature coefficients.

The best way to adjust the circuit is to use an oscilloscope. First touch the probe to IC1 pin 8 and glance at the period on the screen, which will eventually more or less match the period time of IC1b. This waveform should show short negative-going pulses as seen at the bottom of Fig.2.

Then touch the probe to IC1 pin 9, and start turning up preset VR3 (clockwise). The positive-going pulses will gradually widen, until they turn into very narrow negative-going pulses (see the top of Fig.2b). Then suddenly a more or less balanced square wave will bounce onto the screen (see the top of Fig.2a). Touch the sensor, and the narrow negative-going pulses will reappear.

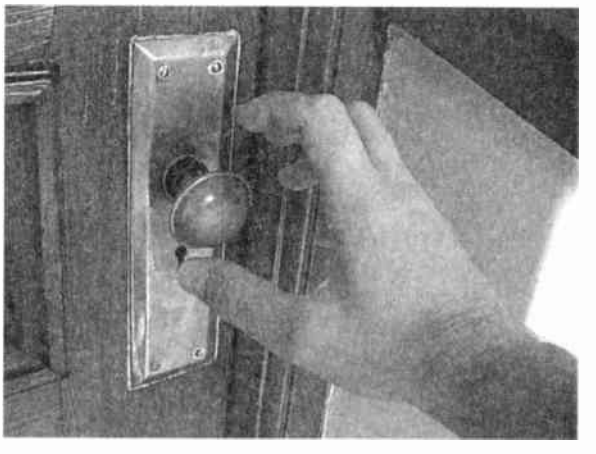
Now adjust preset VR4 so that l.e.d. D4 illuminates and the relay clicks when the narrow negative-going pulses appear. Note that if VR4 is turned up too high (too far *anticlockwise*), the circuit will be needlessly susceptible to transients.

Adjustment with a multimeter is equally straightforward. Monitor the voltage at the positive plate of capacitor C6, and slowly turn up VR3. The voltage should gradually rise to above 6V, then suddenly plunge to somewhere over 5V. This "plunge" amounts to about 1V or a little more.

Measure the voltage at IC2 pin 3, and adjust it (via VR4) to about 0·3V higher than the voltage measured after the "plunge" referred to above. When the sensor is now touched, l.e.d. D4 should illuminate.

If a different sized sensor is used, or if a sensor is moved about, preset VR3 will likely require readjustment. If there is a significant difference in the mass of sensors used, VR4 might need readjusting also.

If the Body Detector is attached to a new sensor, and the set-up above has already been completed, VR3 may be turned right back (anticlockwise), then turned up (clockwise) until l.e.d. D4 illuminates, continuing until D4 just goes out again. The rest is fine-tuning.



Bear in mind that the circuit might be affected by your own body capacitance during adjustment, so that you might need to stand back between adjustments to check how it is going. Ideally, you would use a screwdriver with an insulated shaft. Also bear in mind that the circuit might need to settle after initial adjustment. Come back to it ten minutes later to re-check the adjustment.

SUMMARY

All in all, it is sensible to adjust the Body Detector so that it is sensitive enough to safely trigger, yet not so sensitive that it comes too close to its trigger threshold, which may lead to false triggering, particularly with temperature variations. A distance of 100mm (4in.) represents a dependable range for a lightweight sensor such as a sheet of tin foil or a small set of burglar bars.

Finally, adjust preset VR5 (turning this clockwise) to set the monostable timer and relay to the desired time period.

You can now go to the "Modes of Operation" panel listed earlier (see Fig.1), to test any of the options which are of interest to you, as well as testing the outer limits of the circuit. □

READOUT

Email: john.becker@wimborne.co.uk

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

All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

ONLINE P.C.B. SIZING

Dear EPE,

In response to Harry Wellborne's letter (Mar '04) outlining the sizing problem of p.c.b. track layouts from the *EPE Online* editions, I would like to share my three-step method which produces fairly good quality images.

Step 1: Open up the *EPE Online* (Adobe Acrobat) document on the desired page and reduce the size of the bookmark section to as small as possible. Then use the Zoom In function (CTRL++) on the View menu to increase the copper foil master to the maximum size that still just fits on the screen (use the horizontal and vertical sliders to position it properly). Now put the image on the clipboard by pressing and holding the Alt key, while pressing the PrintScrn key.

Step 2: Open up Microsoft Paint and paste the image into it from the clipboard. Use the Select tool in Paint to select the complete copper foil master with its border only. Once done, copy it to the clipboard. Now open up a new Paint window, and paste the image into it. It happens occasionally, especially with larger images, that unwanted "noise" ends up between the tracks. Simply zoom in by selecting Large or Custom Size, then use the Eraser tool to delete the unwanted "noise".

Ensure that the image is saved as a 24-bit bitmap, as the higher the quality, the better the end product will be.

Step 3: The final step is to scale the image to the exact size. I use Adobe Photoshop 4.0, but most image editing software packages have a resize function. Open the saved file, select Image Size on the Image menu, and specify either the print size width or height as printed on the copper foil master. Ensure that the Constrain Proportions option is selected.

Anton Fouche, via email

Thanks Anton, that seems to be advice that will be useful to quite a few readers.

TEACH-IN CAPS

Dear EPE,

I have been reading Max Horsey's *Teach-in 2004* Part 4 about the coffee machine controller. Why does the circuit in Fig.4.10 have two capacitors in parallel, C1 1000μF and C2 100nF, across the power supply? Also, does a capacitor have to be in the physical position that the circuit diagram indicates, i.e. close to the battery, to smooth out power supply voltage fluctuations, or could it be soldered anywhere across the power supply rails?

Len Doel, via email

Max Horsey replies:

A large capacitor is required to smooth out fluctuations in the power supply. Fluctuations occur particularly when an output device switches on e.g. a large bulb, solenoid or motor. Large value capacitors have to be electrolytic (non-electrolytic large-value capacitors are not readily available). The physical position of a large capacitor is not normally critical.

A small value capacitor (e.g. 100nF) is also required as large electrolytic capacitors are not able to remove brief voltage "spikes". These come from many sources including electro-magnetic induction. The small capacitor should ideally be physically close to any sensitive component, e.g. logic i.c., radio receiver module, regulator i.c., etc. Several such capacitors may be required in large circuits.

Max Horsey, via email

RADIO CONSTRUCTOR

Dear EPE,

I've just read Roger Parker reminiscing (Apr '04) about *Radio Constructor*. I too enjoyed the same column of "In your Workshop". I'm reminded of a very interesting article in this mag sometime during the mid to late '50s. It concerned a record player amplifier which required no external power supply. It employed an electron multiplier valve. This valve had a number of anodes and the principle of operation was that an electron arriving at A1 would dislodge two electrons which would migrate to A2 and each dislodge two more electrons and so on, the number of electrons increasing as they progressed up the anode chain.

In the amp a radioactive source took the place of the heater/cathode, the radiation then passed through a grid to which was applied the output of a crystal or similar high output pick-up. Amplification then took place as described above. The output from this device was then suitably coupled to a loudspeaker. I can't for the life of me remember which year in the '50s that this article appeared but I do remember quite clearly the month . . . it was April!

By the way, did you know that before the condenser, capacitance was measured in *jars*? As described in the *Admiralty Handbook*. Keep up the good quality of *EPE*, all the best to you all.

Peter Mitchell, via email

Before my time Peter! It was not till the late '50s I first got an interest in electronics (having blown up my father's hi-fi by making an ill-considered link between it and another bit of gear – I forget what).

But, yes, an April edition was I'm sure well-suited to the design you mention! Even today, though, the occasional reader on our ChatZone *(access via* **www.epemag.wimborne.co.uk***) asserts his total conviction that perpetual motion does exist and requires no energy input!*

No, I didn't know the other term, but I assume it has to do with Leyden jars, which if I recall correctly were the method through which electricity was first stored, and invented in Leyden (now Leiden, Holland).

MISSING THE POINT

Dear EPE,

I read the *Jazzy Necklace* letter (April '04) with dismay. I realise that you always publish a fair and balanced selection from your mailbag, good or bad, but feel that this particular letter was indicative of missing the point of having such a magazine as *EPE*.

I have taken your magazine from 1964 (when it was *Practical Electronics*) and have thoroughly enjoyed looking at all of the projects, obviously some more than others. Whilst I may not necessarily build them due to me designing and building my own in the process of my work, I always enjoy "reading" the diagrams and especially the explanations so as to see how the author has solved a particular problem. Indeed the classic to me was the one John Becker did, which was an altimeter using a 6502 microcontroller, because it also included a good background on the subject of air pressure.

I noted the first batch of Rev Thomas Scarborough's *Ingenuity Unlimited* some time back and would like to say how impressed I have been with his practical and simple approach to solving a problem – I would like to "take my hat off" to him and applaud his creativity. He displays a depth of talent. Unfortunately, the writer of the said April letter appears to have totally missed the point about Rev Scarborough's *Necklace* project. I do not, in any way intend to be critical of the writer's view or cause offence. However, it should be that projects do not always have to be practical, long lasting, earth shattering . . . they can also be there to stimulate thought on certain principles.

Long may Rev Scarborough continue to be inventive and please do not let such a negative criticism dissuade him. I look forward to his next one.

Dr Stephen Alsop, via email

It is rare to get negative views on what we publish, Stephen, but I'm just as content to publish criticism if it arises as I am praise (although, frankly, publicising too much praise gets tedious!)

Like you, I took PE *since 1964 (although I was in another career at the time, but electronics eventually got the better of that!). I have long maintained that* EPE *is not just about building as published, but about illustrating techniques of problem solving and discovering how others find solutions.*

And yes, we very much appreciate Thomas's ingenuity, and its simplicity of implementation.

PRAISING MILFORD

Dear EPE,

I recently acquired a 3-Axis Machine, which was in need of some repair. I contacted the manufacturers, Milford Instruments (a regular advertiser in *EPE*), to quote for the item needed to repair this machine. Not only did they reply straight away, they also agreed to supply F.O.C. the item needed.

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D. J. Lacey, via email

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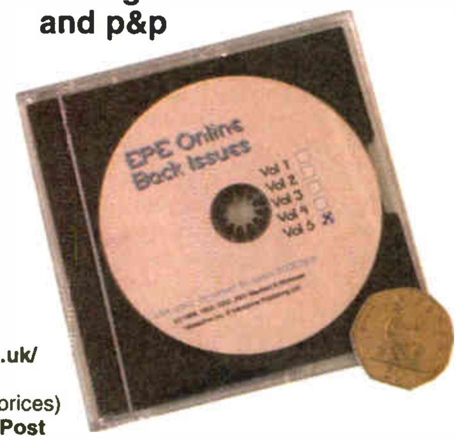

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651.578	150W Continuous	24V	~~£36.39~~	£29.72
651.582	300W Continuous	12V	~~£50.64~~	£41.93
651.585	300W Continuous	24V	~~£50.64~~	£41.93
651.583	600W Continuous	12V	~~£101.59~~	£83.76
651.593	600W Continuous	24V	~~£101.59~~	£83.76
651.587	1000W Continuous	12V	~~£177.18~~	£147.52
651.597	1000W Continuous	24V	~~£177.18~~	£147.52
651.602	1500W Continuous	12V	~~£314.52~~	£261.18
651.605	1500W Continuous	24V	~~£314.52~~	£261.18
651.589	2500W Continuous	12V	~~£490.54~~	£416.27
651.599	2500W Continuous	24V	~~£490.54~~	£416.27

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INTERFACE

Robert Penfold

SOME MORE PRACTICAL IDEAS FOR CASE MODDING YOUR PC

IN the previous *Interface* article some ideas for improved PC case modding were put forward. Things continue along the same lines this month before returning to weightier matters next time.

A big advantage for case modding electronics enthusiasts is that you can "do your own thing", rather than being limited to what is available from the computer stores and fairs. You can also produce what might be termed "value added" versions of commercial units.

The circuits featured here were inspired by a young computer enthusiast who was not totally impressed with one or two EL (electroluminescent) panels he had purchased. A gadget of this type consists of a small inverter unit plus the panel itself. The panels have various designs, such as the classic "alien" type shown in Fig.1. Long EL strips are also available.

In use the EL material lights up, and various colours are used. For example, blue and green are the colours used for the "alien" design. The voltage needed to drive an EL display is higher than the maximum (12V) that can be provided by a PC. A simple inverter is therefore used to provide the necessary voltage step-up, and a suitable unit is normally supplied with the display.

Alien Flasher

This is fine as far as it goes, but the display would clearly be more dynamic and interesting if it did a bit more than light up continuously. The obvious improvement is to have it flash on or off or vary in intensity.

The amount of current drawn by one of these devices is surprisingly low, and is typically about 10mA to 15mA. In common with l.e.d.s, EL displays are quite efficient and produce very little heat. Also, in common with l.e.d.s, the actual light output is not that huge. Even with a large EL panel or long strip, and with losses through the inverter taken into account, the power consumption is only a fraction of a watt.

The low power consumption makes it easy to pulse one of these devices. Something as basic as the 555 oscillator circuit of Fig.2 will do the job perfectly well. A standard 555 timer was used in the prototype circuit, and represents the safest option. The output stages of some low-power 555 timers have inferior ratings and could produce unacceptable voltage drops in this application.

Timer device IC1 is used in the standard 555 oscillator configuration, which has timing capacitor C1 repeatedly charging via resistors R4 and R5, but discharging through R5 alone. The output at pin 3 is high while C1 is charging and low while it is discharging. The inverter is switched on while the output of IC1 is low.

Tinkering

Using the specified values for the timing components this means that it is briefly switched on every second or so. This gives quite a good effect with most EL displays, but different effects can be obtained by tinkering with the values of the timing components.

The "on" time can be increased by using a higher value for resistor R5, and it is proportional to R4's value. If approximately equal on and off times are required, make the value of R5 high in relation to that of R4. For example, using a value of 4M7 for R5 and 47k for R4 gives "on" and "off" times that are both a little over one second. The "on" and "off" times are both proportional to the value of C1, and can easily be extended or shortened by making its value higher and lower respectively.

Resistors R1 to R3 and transistor TR1 are optional, and enable the display to be switched off via any standard digital output. A flashing display is more interesting than a continuous type, but it is potentially more of an irritation as well.

Accordingly, it is a good idea to have some means of switching it off. Transistor TR1 is switched off when there is a logic 0 level at the Control Input of the circuit, and the unit is then able to function normally. A logic 1 input level switches on TR1, which then holds capacitor C1 in a discharged state. This in turn keeps the output at IC1 pin 3 high and the display switched off.

Making Connections

Power for an EL display is usually obtained from the PC's +12V supply via a simple adaptor. If there is a spare drive power lead, the socket on this lead is connected to the plug on the display unit's adaptor.

Power can still be obtained if there is no spare power lead, and it is just a matter of connecting the display unit's adaptor in-line with the power lead to a CD-ROM or hard disc drive. Two leads run from the adaptor to the inverter, and the one that connects to the yellow lead on the adaptor carries the 12V supply. The other lead connects to one of the black leads on the adaptor and is the 0V or ground connection.

These two leads must be cut so that the flasher circuit can be connected between the adaptor and the inverter. Make sure that the supply is connected to the flasher circuit with the correct polarity and that the inverter is also connected to the output of the flasher unit with the right polarity.

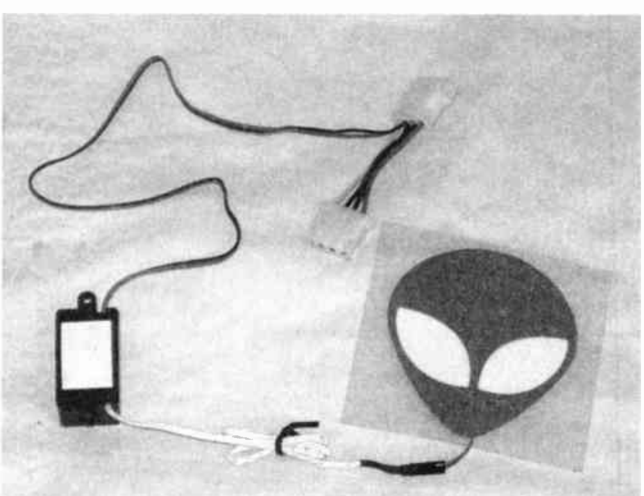


Fig.1. A typical EL (electroluminescent) panel with matching inverter and power adaptor.

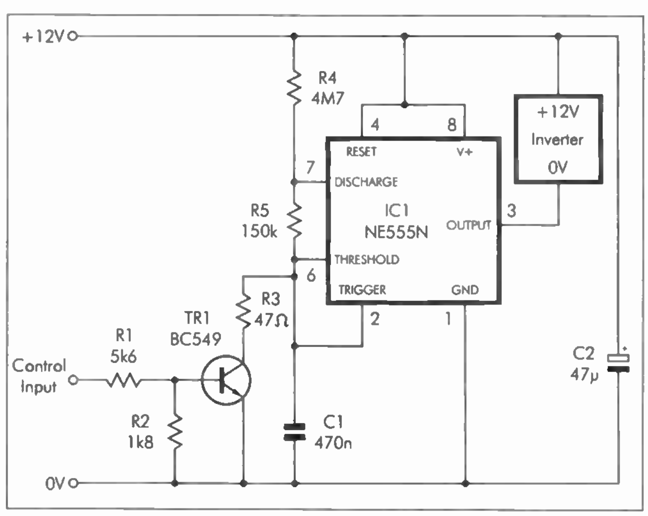


Fig.2. Basic flasher circuit diagram using a standard 555 timer i.c. A high level on the control input switches off the EL display.

Of course, cutting the power leads will certainly invalidate the guarantee, but EL display units are very cheap so you are not risking much. However, it would be prudent to check that the inverter and display are functioning correctly before cutting the wires.

Fading

The flasher circuit diagram of Fig.3 provides a slightly more sophisticated effect that has the display faded in and out rather than switching abruptly on and off. Op.amp IC1 is used in a standard oscillator configuration that provides a triangular output signal at pin 1 and a squarewave signal at pin 7. In this case it is the triangular signal that is required, and it is amplified slightly by the inverting mode amplifier based on IC2. A slightly clipped triangular output signal is provided by IC2, and this is used to drive the inverter via a common emitter buffer stage (TR2). Note, TR2 is a *pnp* device.

The display is switched on for a second or two, switched off for a second or two, and so on. However, the slow transitions at the output of IC2 (pin 6) give the required gradual change from one state to the other. There is a potential problem with this method, which is that the display might not vary in intensity as the supply voltage is varied. The inverter could have a stabilised output voltage, or it could simply cut off when the supply voltage is reduced slightly.

Tests on a few EL displays always provided good results, and the inverters seem to be extremely basic. Changes in the input potential were matched by proportionate changes in the output voltage. Nevertheless, it would be a good idea to try the unit with a variable voltage power supply before building this circuit. The display should work well with this circuit if varying its supply voltage from about 5V to 12V gives a smooth increase in its brightness.

Going Digital

Resistors R6, R7 and transistor TR1 are optional, and enable the display to be controlled via a standard digital output. Applying a logic 0 input level leaves TR1 switched off and the circuit then functions normally. A logic 1 input level switches on TR1 and pulls the inverting input (pin 2) of IC2 down to little more than 0V. The non-inverting input (pin 3) is biased to half the supply voltage, and will therefore be at the higher potential. Consequently, the output of IC2 goes high and cuts off the supply to the inverter.

Note that the CA3140E used for IC2 has a PMOS input stage and that the usual anti-static handling precautions are therefore required when dealing with this device. The "on" and "off" times are proportional to the value of capacitor C3, and can therefore be altered by changing the value of this component. A fairly high value has to be used in order to obtain a good fade-up and fade-down effect, so it is advisable not to use a value much lower than the one specified in Fig.3.

Audio Controlled

The circuit diagram shown in Fig.4 responds to the audio input level. The stronger the input signal, the brighter the display. Left and right hand channel input signals are provided by the audio output of the sound card. A line or headphone output will do.

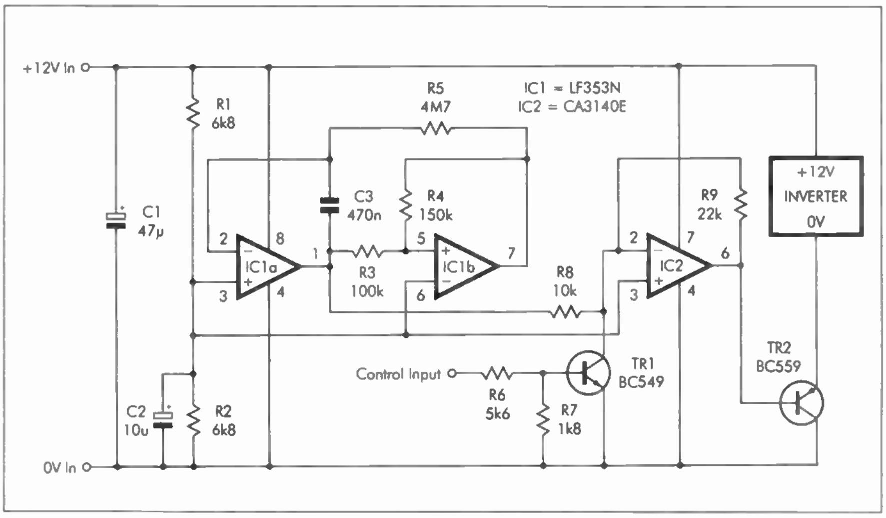


Fig.3. Circuit diagram to provide a gentle fade-up and fade-down display effect.

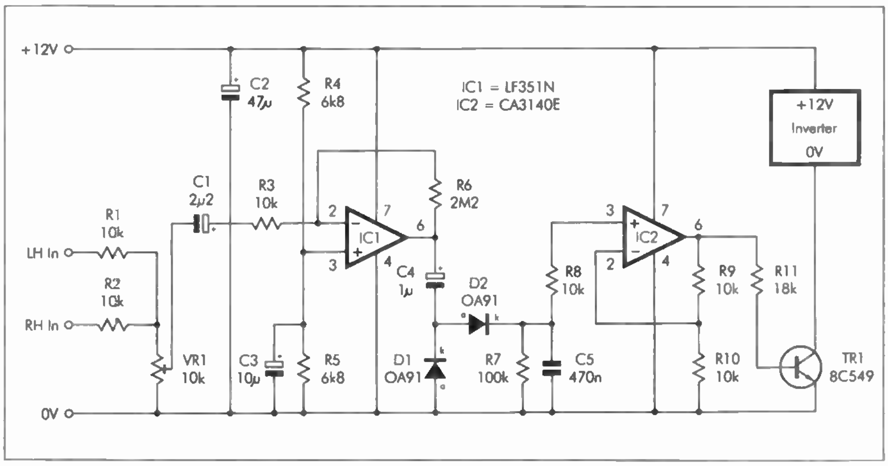


Fig.4. Circuit diagram for a sound-controlled display. The stronger the audio input signal, the brighter the display.

Preset potentiometer VR1 enables the sensitivity of the circuit to be adjusted, and in practice it is given the setting that provides the best effect. IC1 is an inverting mode amplifier that provides a voltage gain of 220 times, which should give more than adequate sensitivity using any soundcard.

Diodes D1 and D2 rectify the output from IC1 to produce a positive d.c. signal that is roughly proportional to the amplitude of the input signal. D1 and D2 can be any general-purpose *germanium* diodes.

The values of smoothing components R7 and C5 provide the circuit with a fast attack but a much slower decay time. This enables the circuit to respond to brief high level signals. Op.amp IC2 operates as a low gain d.c. amplifier which drives output transistor TR1. This operates as a simple common emitter output stage.

Try adding a capacitor of about 470pF in parallel with resistor R6 if you would rather have the circuit respond primarily to low frequency signals. Remember to observe the standard anti-static handling precautions when dealing with the CA3140E used for IC2.

MIDI SYNCHRONOME

DAVID CLARK

Need help to improve your musical time-keeping when recording with MIDI instruments? This project could help!

THIS article describes a novel metronome that will automatically synchronise to the clock messages output by most MIDI (Musical Instrument Digital Interface) instruments and computer sequencers. Furthermore, this design not only provides the usual time-keeping click but also simulates the swinging arm of a mechanical metronome with nine light-emitting diodes (l.e.d.s).

ON THE BEAT

Many modern music recording sessions, and live performances that involve a combination of live performance integrated with pre-recorded backing music and/or pre-programmed lighting and effects, involve the musicians synchronising their playing to a click-track. This click-track usually takes the form of a series of short percussive sounds transmitted to the performer's ear-piece, and it allows time-keeping to be much more accurate than would otherwise be likely.

For the home studio user recording with a computer-based sequencer, a click-track is usually available, and takes the form of a MIDI output that is normally converted to a percussive sound by a sound card or MIDI module. The options for the home studio musician who does not have or even want a computer-based system are more limited.

One channel of a multi-track recorder can be dedicated for use as a click-track, which would, of course, have to be recorded manually before recording proper was started. This, however, is an inconvenient and inflexible solution – one track is lost, and for a home user, tracks are at a premium, often being limited to four in an analogue system. The beats per minute (b.p.m.) rate cannot be altered either once the click-track has been recorded.

Owners of digital multi-tracker recorders often fare little better. Some do have a Metronome Output option, but many do not. And none of these options offer the visible time markers that a mechanical metronome offers, namely the sight of the arm swinging from side-to-side.

This project overcomes these limitations; it connects to the MIDI output of a multi-track recorder or sequencer that offers MIDI clock timing information, and the recorder or sequencer controls the swinging arm l.e.d. display and triggers an audible click at appropriate points. Straight or triple-time feel can be selected, and the device automatically calculates the b.p.m. rate and adds off-beat clicks between beats as appropriate.

This not only gives the straight or triple-time feel, but also fills in the gaps at low b.p.m. rates, making it easier to keep on the beat. The device also detects song pointer messages so that the metronome stays in synchronisation with the recorder or sequencer even when the controlling device is stopped, started or restarted within a song. There is also a reset button so that when used with a device that only outputs clock messages the swinging arm and beat click can be set to begin on the beat.

BASIC IDEAS

A very important aspect of the metronome is, of course, the audible click given for each beat. This allows the musician to concentrate on reading music, or perhaps on some aspect of playing the instrument itself. However, the subtle aspects of the swinging arm of the metronome should not be overlooked. The speed of the swing of the moving arm, perhaps only caught out of the corner of the eye, and maybe only registered subconsciously, nevertheless gives the musician a sense of the rate of (musical) time passing.

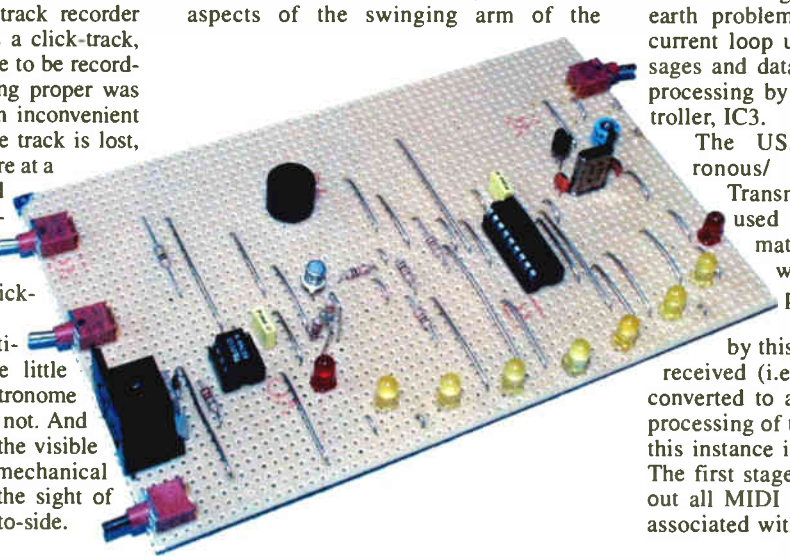
Its position unconsciously prepares the musician for the actual occurrence of the beat. This is something that is missing from the type of electronic metronome that provides only a beep and/or a single l.e.d. that flashes with the beat.

This MIDI Synchronome provides not only the click and a simulation of the swinging arm of the mechanical metronome, but also off-beat clicks at a lower volume, something that a mechanical metronome does not supply. This gives better timing guidance, particularly for blues and jazz-influenced styles where a shuffle or swing feel is all-important.

GETTING THE MESSAGE

The complete circuit diagram for the MIDI Synchronome is shown in Fig.1.

The input section is a standard MIDI input based on a 5-pin DIN socket and an optoisolator, IC2, in this case a type 6N139. This provides electrical isolation, thus reducing the chance of multiple-earth problems, and converts the 5mA current loop used to convey MIDI messages and data into 5V logic signals for processing by the PIC16F627 microcontroller, IC3.



The USART (Universal Synchronous/ Asynchronous Receiver/ Transmitter) module of the PIC is used to extract the MIDI information from the logic signals, which are input on Port B pin RB1.

The interrupt generated by this module when valid data is received (i.e. when the single bits are converted to an 8-bit word) triggers the processing of this data, processing that in this instance is all done by the software. The first stage of this process is to filter out all MIDI messages other than those associated with time keeping.

KEEPING THE BEAT

The range of tempo for music is, of course, large – classical music uses a range of terms to describe tempos of between 40 and 208 b.p.m., see Musical Terms panel.

Some modern electronic music has a tempo outside even this range, and digital multi-track recorders and computer sequencers typically offer a range of 20 b.p.m. to 300 b.p.m. for outputting timing information. At 300 b.p.m. a musician is more likely to miss a beat than play too early, but at a low b.p.m. rate, with anything up to three seconds between each beat, hitting the beat accurately is more difficult.

Musical Terms Relating To Tempo

Largho	40 – 60 b.p.m.
Larghetto	60 – 66 b.p.m.
Adagio	66 – 76 b.p.m.
Andante	76 – 108 b.p.m.
Moderato	108 – 120 b.p.m.
Allegro	120 – 168 b.p.m.
Presto	168 – 200 b.p.m.
Prestissimo	200 – 208 b.p.m.

The MIDI Synchronome solution to this, as has already been mentioned, is to add in off-beat clicks. Depending on the b.p.m. rate, one or three off-beats are added in for a straight-time feel, and two for a triplet or shuffle feel. No extra beats are added in for high b.p.m. rates. The break points at which these changes take place are shown in Table 1.

The TMR1 (Timer 1) module of the PIC is used to establish the b.p.m. rate, and this is done by measuring the time that has elapsed since the last clock message that the USART received. A simple switch-check sub-routine determines whether Straight or Triplet feel has been selected on switch S2. The sequences for the lighting of the l.e.d.s and sounding the click are held in look-up tables, and the appropriate table is chosen according to b.p.m. rate and feel chosen.

Table 1: B.P.M. rates and Additional Off-Beats

'Feel'	*B.P.M.*	*Off-beat clicks added*
Straight	less than 85	3 x 1/16 notes
Straight	85 to 119	1 x 1/8 note
Straight	120	no notes added
Triplet	less than 85	2 x triplet 1/8 notes
Triplet	85 upwards	no notes added

PASS THE PORT

It was decided that nine was the minimum number of l.e.d.s that should be used to simulate realistically a swinging metronome arm, especially at low b.p.m. rates. This is an awkward number in the digital world where it is convenient if everything is divisible by two, or even better, eight. However, nine was the most practical number to use for this application.

The ports of PIC microcontrollers are perfectly suited to driving low-current l.e.d.s, and the ideal situation would have been to have the PIC drive eight l.e.d.s sequentially via its Port B. Unfortunately, as well as the project needing nine l.e.d.s, lines RB1 and RB2 of Port B have also to

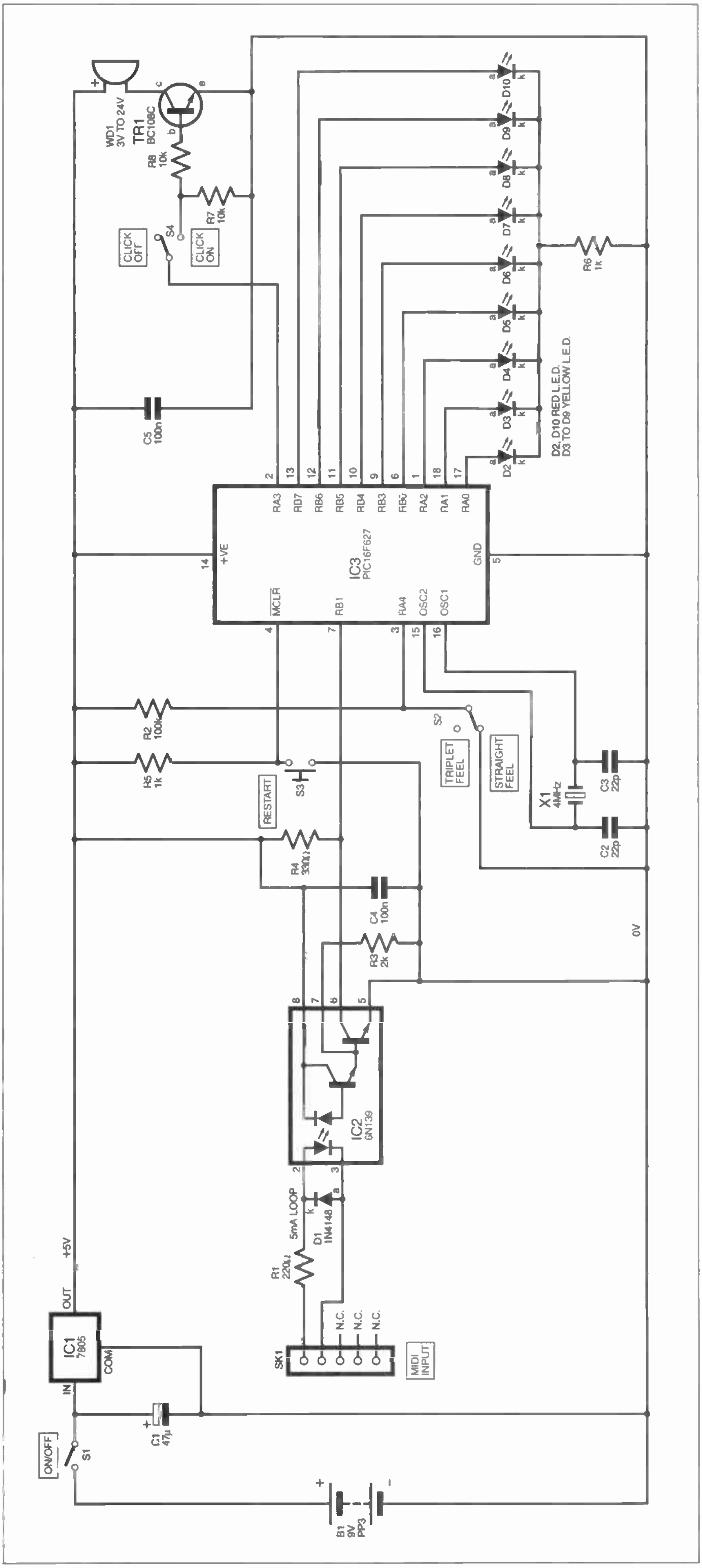


Fig.1. Complete circuit diagram for the MIDI Synchronome.

be configured as inputs in order to use the USART. These therefore are by-passed as l.e.d. drivers.

This could be overcome by using further software procedures to alter the configuration of Port B between reading MIDI data in, but this increases processing overhead, which is at a premium in real-time applications and raises the chance of a clock message being missed while other processing is occurring.

Six lines of Port B and three lines of Port A are therefore use to drive the l.e.d.s. A further two lines of Port A are used, one as an input to read the state of the Straight/Triplet Feel switch S2, and one as an output to drive the sounder that makes the MIDI Synchronome tick.

CLICK SOUNDER

The sounder chosen (WD1) generates its own frequency and so it is not necessary to use software to cause the PIC to create an output waveform; a change of level simply switches the sounder on and off. This again saves processing overhead. (The loudness is determined by how long the sounder is held on.)

The specified sounder needs 30mA to drive it. Unfortunately, the maximum output that any PIC16F627 output pin can sink or source is 25mA. The Port A driver output is therefore connected to the sounder via a general-purpose driver transistor, TR1. Fitting the sounder directly to the stripboard on which this circuit is assembled makes the click sound louder, as well as being a neater option since the metronome is not housed in an enclosure.

HARDWARE

The rest of the hardware for the circuit is straightforward. Voltage regulator IC1 provides the 5V needed to power the circuit from a 9V battery, and the timing of the PIC is determined by the usual quartz crystal arrangement (X1 plus C2 and C3) for accuracy, operating at 4MHz. The Restart switch, S3, although connected to the PIC's $\overline{\text{MCLR}}$ pin to provide a standard reset function, actually has a special function that will be described later.

To provide a further visual marker, the l.e.d.s at both extremes of the swinging arm arc are red (D2 and D10). Finally, since only one l.e.d. is lit at any one moment, a single common-cathode resistor, R6, is used to limit the current through the l.e.d.s.

SONG POSITION

Although timing the interval at which the clock messages are received enables the b.p.m. rate to be determined, it gives no information as to when the actual beat occurs. To overcome this, many MIDI instruments and sequencers also transmit a song position pointer message – see Song Position panel.

The MIDI Synchronome will detect this message and use it to calculate where the beat is. The appropriate entry in the look-up tables is then selected so that the appropriate l.e.d. lights and the click sounds at the correct time.

Some MIDI instruments, such as digital multi-track recorders and computer sequencers, allow a song recording to be stopped and re-started at any point. These usually send a fresh song position pointer message at the time of stopping and re-starting. These systems present no problem for the MIDI Synchronome. Some types of equipment, however, do not transmit a song position pointer because in most cases this is inappropriate, for example when playing a synthesiser.

Clock messages might be needed to synchronise the tempo of a delay unit perhaps, but there is no meaningful start or stop point. In these cases, it might be necessary to re-start the MIDI Synchronome at an arbitrary point, and to this end it has been given a Restart button (S3). This resets the PIC via its $\overline{\text{MCLR}}$ reset pin.

However, the software has been written so that on receiving the first clock message in the absence of a song position pointer message, the MIDI Synchronome starts on the beat with a click and with the swinging arm at its extreme position.

CONSTRUCTION

The MIDI Synchronome is assembled on stripboard. The component layout and track cutting details are shown in Fig.2.

Begin assembly by enlarging slightly the stripboard holes needed to accommodate the p.c.b.-mounting DIN connector, SK1. Next make the track cuts, 52 in total. Ensure that the tracks are cut cleanly, removing any debris or burrs that might cause a short-circuit across the cut or between tracks. There is a relatively large number of track cuts, so ensuring each is of good quality at this stage could ease any fault-finding that might be necessary later.

The components should then be fitted in the usual order of increasing height for ease of soldering, apart from the transistor and the i.c.s, beginning with the wire links, 33 in all. Carefully observe the orientation of any polarity-conscious components.

Special note should be made of fitting the l.e.d.s. In order to maintain the sense of a swinging arm display, l.e.d. D6 needs to be offset slightly. This can be achieved by soldering one lead of the l.e.d. in position so that its base is a millimetre or two above the surface of the stripboard. The body of the l.e.d. can then be pushed towards the top of the stripboard, which will bend both of the l.e.d. leads. When the l.e.d. is suitably positioned, its second lead can be soldered in place.

For a consistent appearance, all the l.e.d.s could be positioned at the same height above the stripboard, but in practice

COMPONENTS

See SHOP TALK page

Resistors

R1	220Ω	
R2	100k	
R3	2k	
R4	330Ω	
R5, R6	1k (2 off)	
R7, R8	10k (2 off)	

All 0·25W 5% carbon film or better.

Capacitors

C1	47μ radial elect. 16V
C2, C3	22p ceramic disc, 2·5mm pitch (2 off)
C4, C5	100n polyester 63V, 5mm pitch (2 off)

Semiconductors

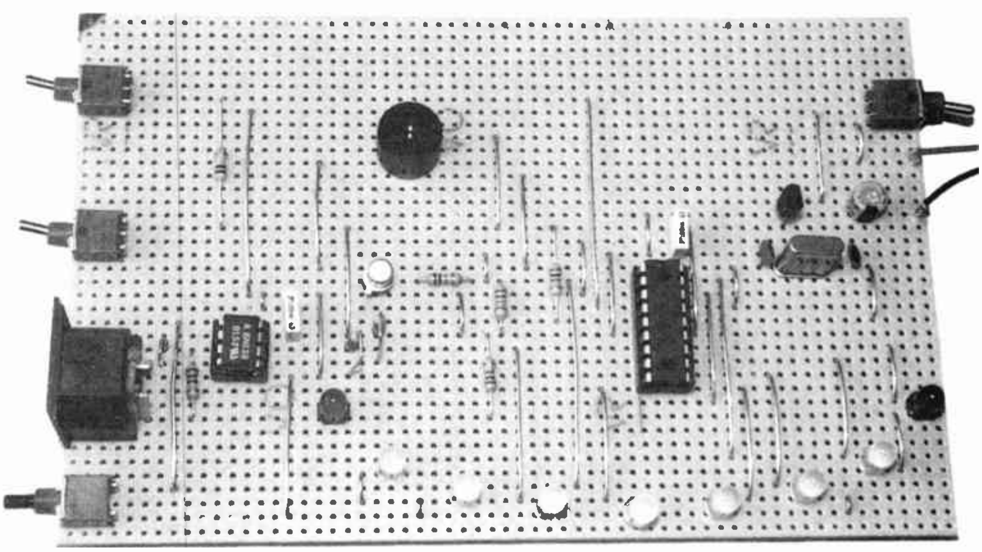
D1	1N4148 signal diode
D2, D10	5mm red l.e.d., low current, (2 off)
D3 to D9	5mm yellow l.e.d., low current, (7 off)
TR1	BC108C *npn* transistor
IC1	78L05 +5V 100mA voltage regulator
IC2	6N139 optoisolator
IC3	PIC16F627 microcontroller, preprogrammed (see text)

Miscellaneous

WD1	piezo sounder, 30mA
SK1	5-pin 180 degree DIN socket, p.c.b. mounting
S1, S2, S4	min. s.p.s.t. toggle switch, p.c.b. mounting (3 off)
S3	min. s.p.s.t. momentary toggle switch, p.c.b. mounting
X1	4MHz crystal

Stripboard, 39 strips x 62 holes; 8-pin d.i.l. socket; 18-pin d.i.l. socket; PP3 battery clip; tinned copper wire, 22s.w.g. or similar, for link wires; solder, etc.

Approx. Cost Guidance Only **£15** *excl. case*



this does not affect the illusion of the swinging arm.

After all the passive components and the l.e.d.s have been fitted. transistor TR1 can be soldered in place. Voltage regulator IC1 should be soldered into position last. The pre-programmed PIC and optoisolator should only be inserted into their sockets when construction is complete, noting that they face downwards.

Care needs to be taken when fitting the sounder. This entails some cautious bending of the sounder terminals before fitting in place as their spacing does not exactly match the stripboard hole pitch. Note that this device has polarised connections – the positive terminal should be marked on its case.

SOFTWARE

The heart of the software lies in the tables that define the outputs to Port A and Port B and hence the lighting of the l.e.d.s and the sounding of the click. The main

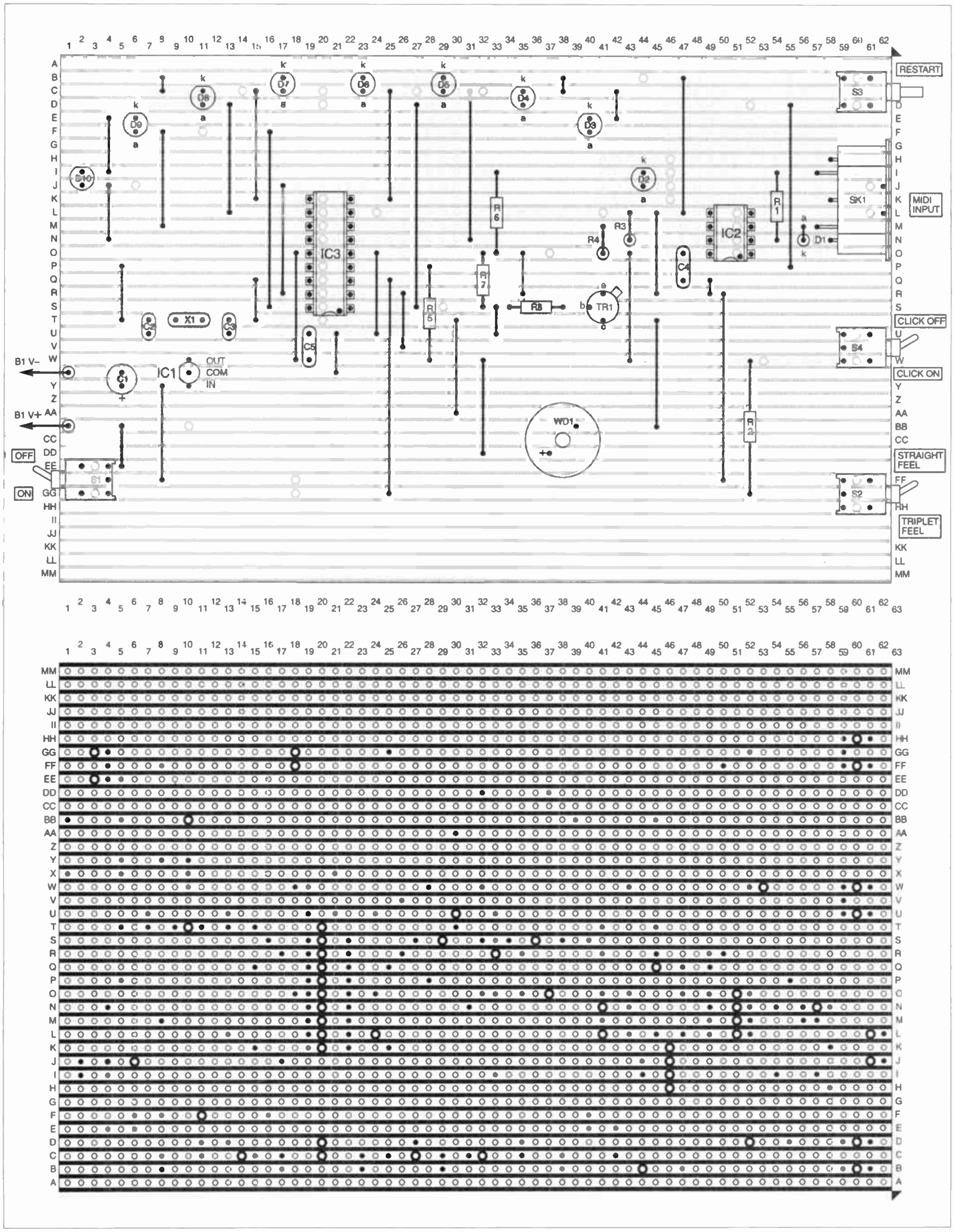


Fig.2. MIDI Synchronome stripboard component layout and details of breaks required in the underside copper tracks.

section of the program consists of a two-line loop that resets the USART and waits for the next interrupt, which occurs when a MIDI message is received.

All the processing of the messages received is done in the interrupt service routine (ISR), and this must be completed in the minimum time allowed before another MIDI message could conceivably be received. This is around a third of a millisecond (0·33ms), though as most MIDI messages need three bytes there is usually longer.

However, the software does not have the luxury of using this extra time, since, if a clock message were to be missed, the proper (musical) timing would be lost. Nevertheless, 0·33ms allows a lot of processing to be done at a clock rate of 4MHz, and there is plenty of time for the relatively simple requirements of this application.

The ISR firstly checks to see if the current message is needed for determining song position. If so, this procedure is followed. Otherwise, having ignored any messages not relevant to the Synchronome, the ISR calculates the b.p.m. rate from the time elapsed since the last clock message was received and checks whether the Feel switch (S2) is set to Straight or Triplet.

From this information the appropriate entries in the look-up tables for Ports A and B are selected and output to the ports at appropriate intervals, giving an electronic impression of a mechanical metronome.

Determining the Song Position

A MIDI system that transmits MIDI clock timing information sends out 24 messages for every quarter note. The look-up tables used by the MIDI Synchronome each contain 48 entries to correspond to the clock messages that drive the l.e.d. display through a complete cycle, i.e. from one extreme to the other and then back to its original state.

Although the MIDI Synchronome uses only eight l.e.d.s per quarter note beat (the ninth is the beginning of the next series of eight) 24 entries are needed for each beat, or half-cycle. This is to accommodate the triplet feel, since the click falls between lit l.e.d.s in this situation. The MIDI clock message is the basic timing information. For a b.p.m. rate of 85, one clock message will be sent every 29·4ms. For a b.p.m. rate of 120, one clock message will be sent every 20·8ms. Thus a simple timer will determine b.p.m. rate, as shown earlier in Musical Terms panel.

Further information is needed to determine where the main beats fall. This information can be provided from the Song Position Pointer (SPP). The SPP is a count of the number of MIDI Beats that have occurred since the beginning of a song, and a MIDI Beat is defined as six MIDI clocks. The data sent with an SPP consists of the least significant byte of the SPP count followed by the most significant byte.

To determine where in the 48-step cycle the MIDI Synchronome needs to be, the Interrupt Service Routine (ISR) first takes the three least significant bits of the SPP least significant byte. The most significant byte is ignored. This value cycles from zero to seven (i.e. eight counts, equivalent to two quarter-note beats) and then restarts from zero. Each increment of this value corresponds to six clock messages, so multiplying this value by six will give the table offset number corresponding to that point in the cycle.

By designing the table values to be on the beat at the first and twenty-fifth entries (offsets of zero and 24) the MIDI Synchronome will always be synchronised to the SPP.

THE BEAT GOES ON

Using the MIDI Synchronome could not be more straightforward. Connect it to the MIDI output of the controlling instrument, switch it on, select Straight or Triplet feel as required and leave the rest to the master device. The click sounder can be switched off if the unit is to be used while recording with a microphone, rather than by using a direct electrical input to the recording device.

To restart the unit on the beat when using it in conjunction with a device that does not output song position messages, simply press Restart switch S3 when required.

This relatively simple project highlights once more how powerful PIC microcontrollers are. Most of the software code for the project consists of the look-up tables, yet the result is a remarkably useful device. It should prove ideal for the home-studio musician wanting a timing indicator that is a great improvement over the limited options usually available.

RESOURCES

The software for the MIDI Synchronome 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** (folder path **PICs/MIDI synchronome**).

Read this month's *Shoptalk* page for information on component buying for the MIDI Synchronome. □

PIC N' MIX

ANDREW JARVIS

Our periodic column for your PIC programming enlightenment

A potted history of *EPE Toolkit* and an overview of other low cost programmers

EVERYBODY seems to be programming these days. Not too long ago it was largely professors and engineers who were the most active in the field, but times change. With all this Internet activity it's no surprise that Visual Basic is so popular, being a natural progression from HTML and scripting, and it's great that so many people are willing to attempt PIC programming despite it being perceived as a little further up the learning curve.

If you're one of them, then know that embedded development is certainly different to the PC world you might be used to, but not much harder. It just requires a slightly different approach and a little more patience with the tools and the debugging. All you need to get started is a low cost programmer and some software to drive it. Before you know it you'll be quoting your age in hexadecimal and laughing at binary jokes.

GREAT HEXPECTATIONS

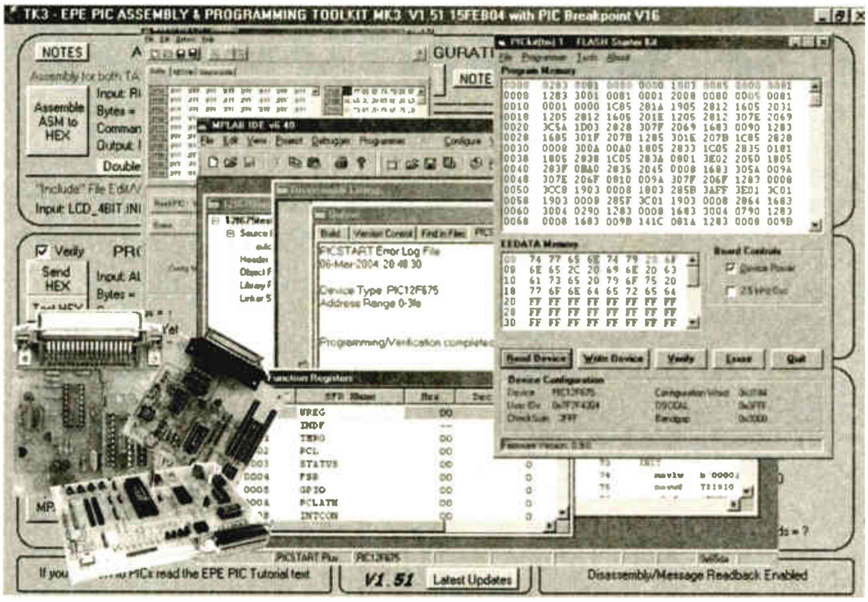
A low cost programmer in this context isn't somebody who will write your application code for you on the cheap, it's the tool you need to put the PIC into programming mode and get your code out of the PC and down onto the device. There are various ways to do this, but most solutions usually boil down to two important parts – the hardware that you plug your PIC into, and the software that you run on your computer to move the code around and view the result.

Hardware can range from "zero parts" (but usually at least a single resistor) to feature rich development boards; software from the full IDE (integrated development environment) with integrated compiler/assembler to simple download utilities. In many cases the software and hardware component parts are interchangeable, something we'll demonstrate with the *EPE Toolkit TK3* programming system in the coming months. Over time, you will come to love your chosen arrangement like a favourite pair of slippers, and find it equally comforting as the midnight oil burns away.

If you ever Google the net on this subject, it's difficult to avoid reference to what are popularly known as "Tait" style programmers. This has become a catch-all phrase for simple parallel port designs like the early *EPE* projects, named after the internet publication of David Tait's classic 16C84 programmer with associated FAQ/links pages. Definitely worth reading. (Unfortunately, they are no longer updated and have been removed from their original home, but they are still possible to locate quite easily – try the *piclist* **www.piclist. com** for starters).

STARTER FOR 1010

It was Derren Crome who introduced the first PIC programmer to *EPE (Simple PIC16C84 Programmer)* in February '96. Based on DOS, it required only a few components (in addition to a PSU) and used shareware assembly language and programming software. John Becker then created the original *EPE PIC Tutorial*, published between March and May '98, and later what would become the *Toolkit* series of programmers, in response to the thousands of queries asking how to program PICs.



Toolkit Mk1 appeared in July '98, with its own assembly and programming software. *Toolkit Mk2* was published in May and June of '99 following the introduction of PIC16F87x devices, which it could handle in addition to the PIC16x84. Also in this release were disassembly, verification and the ability to read/write the PIC's EEPROM. Visual Basic then created an opportunity to add lots of new features not possible with *Mk2*, and the popular *TK3* was the result, published in October and November 2001 and with several updates since then. The rest, as they say, is history.

Of course, there are lots of other DIY programmers out there – each with their own set of passionate enthusiasts. If you want to build your own you should certainly consider them, but remember to compare like with like when you look around. Cost, support and quality vary enormously.

Something to bear in mind if you decide to build a "Tait" style programmer is the ultimate disappearance of the PC parallel port in favour of USB and Firewire. You might find your pride and joy sidelined when you next upgrade the PC! There are other issues as well with software that writes directly to the parallel port being unsupported by some Windows versions (notably 2000 and XP) – but workarounds for this are well publicised.

WOULD YOU LIKE THAT WRAPPED?

Despite the hobbyist in you no doubt suggesting that there is no alternative to building a DIY programmer, you might reasonably ask yourself if you have time to be bothered with the maintenance they sometimes bring – particularly if it is just a means to an end and all you really want is the programmed PIC in your circuit with little regard for how it gets there. Perhaps you just want to be able to send it back if it goes wrong, or be sure that if your code isn't working, you don't spend hours debugging the debugger. If you don't want to customise the hardware or tinker with the software, there are some good shrink-wrapped alternatives.

Microchip's entry-level programmer is the affordable PICkit 1. This is a particularly interesting example because you can read all about it from application note AN258, including how it was designed and put together around the USB enabled PIC16C745. In addition, you can download the firmware for this PIC and the Visual Basic source code for the GUI. If you get the user's guide (40051c.pdf) as well, you'll even get the circuit diagram, which doesn't leave much else left to understand about it. The only down side is that PICkit 1 is very limited, supporting just the 8-pin and 14-pin flash families.

If you think that you and PICs will become inseparable, then your choice should be flexible enough to grow with you as new devices become available. Although certainly not "low cost", Microchip's PICSTART Plus development programmer sets the pace here, supporting most DIP packaged devices as they become available. The firmware for it is flash upgradeable and reprogrammed directly from the MPLAB IDE at no extra cost (but you need hardware revision R20 or later for this feature – if you're thinking of buying a new one be sure to ask).

Interestingly, some third party programmers claim compatibility with PICSTART Plus, and therefore MPLAB for a much-reduced price. The Warp-13 from Newfound Electronics is one example I found listed that you can apparently use from the Microchip IDE or its own proprietary GUI. You might find others – search through the third party developer tools (**www.microchip.com/1010/pline/tools/tparty/index.htm**).

I'm curious to know how these are kept in sync with the firmware versions and/or protocol revisions expected by the IDE. Unlike the PICkit 1, I could find no "official" source for the PICSTART Plus protocol. Other programmers that crop up regularly include the PICALL and P16PRO from Quasar Electronics and the EPIC from RF Solutions, but there are hundreds more, like those from Forest Electronic Developments – have a good look around.

KICKSTART DEVELOPMENT

Some PICs can program themselves, with the help of a bootloader (a small program already resident on the chip that the PC talks to). This is what the PICAXE system does. If you can't make a decision about a programmer, or you're not sure if PICs are for you, then consider this a gentler introduction and one that eliminates the problem while you decide.

PICAXE microcontrollers receive your code using a direct serial link from the PC. All the software you need to create the program is free so it's easy to get started, but note that your choice of PIC is limited and some pins or features that you need may be unavailable. You can get them from the Revolution Education website **www.rev-ed.co.uk**, and they featured in a series of projects presented in *EPE* Nov '02 to Jan '03. They are also featuring in the current *Teach In 2004* series.

PIC RESOURCES

The published texts and software for the *EPE PIC Tutorial V2* and *EPE PIC Toolkit TK3* programmer, are available on the *PIC Resources V2* CD-ROM, available from the Editorial address for £14.95 inclusive.

NEXT TIME

In the next issue Andrew examines "Hello World" for PICs – how to flash an l.e.d. using timing loops, analysing instruction cycles and their timing with respect to delays – a subject dear to many reader's inquisitive appetites!

SHOP TALK

with David Barrington

Body Detector

Regarding components for the *Body Detector* project, the author advises us that, "if possible, capacitors C1 and C3 should have a zero temperature coefficient or NPO (0 ppm/°C)". In other words – you need low loss, close tolerance and high stability types, as used for temperature compensation in tuned circuits.

A miniature zero-rated temperature coefficient capacitor of the required 4·7pF value is currently listed by **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***) under their low-k ceramic plate range, code 08-1206, and by **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***), code 540-025. We also notice that **RS Components** (☎ ***01536 444079*** or ***rswww.com*** – credit card only) list a 10pF sub-min., zero rated, ceramic plate capacitor, code 126-809. Although this is double the value specified, the author indicates this would be OK in this circuit. Alternatively, two could be wired in series to give the required value of 5pF. However, we would point out that RS have a minimum order quantity on this range of 10.

The 12V d.c. coil, d.i.l. relay used in the model is a miniature Telecom TX series type with integral diode to reduce back-e.m.f. It has two sets of changeover contacts, which are rated 60W (2A/30V d.c.) maximum. This relay was purchased from RS, code 178-1924. You can, of course, use a different relay, with contact ratings to suit your application, but you will need to check its pinout against the p.c.b. arrangement.

The small printed circuit board is available from the *EPE PCB Service*, code 449 (see page 431).

MIDI Synchronome

Nearly all of the components to construct the *MIDI Synchronome* project should be widely available. The 6N139 Darlington opto-isolator is listed by **Cricklewood Electronics** (☎ ***0208 452 0161***), code as type number, and **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***), code 622-075.

The 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 431). 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** (path **PICs/MIDIsynchronome**).

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, PO Box 3103, Sheffield, South Yorks, S11 7WW.** Payments should be made out to *David Clark*, in £ sterling *only* and drawn on a British bank, UK postal orders are also accepted.

You will need to purchase a fairly large "expensive" piece of stripboard and cut it down to size. However, looking at the component layout diagram, there appears to be plenty of "space-saving" room to reduce its size and cost quite considerably.

PIC QuickStep

The low-profile conductive plastic type potentiometer used in the PIC *QuickStep* project is one listed for p.c.b. mounting, via a mounting bracket, and came from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 68-1504. You can, of course, use a standard miniature, p.c.b. mounting, rotary carbon type in its place. They also supplied the single row 2·54mm jumper links and p.c.b. header plugs.

Some readers may experience difficulties in finding the Zetec ZTX653 2A *npn* transistor. It is certainly listed by **Cricklewood** (☎ ***0208 452 0161***), code as type number, and **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***), code 710-540.

For those readers unable to program their own PICs,. preprogrammed PIC16F628 microcontrollers (two separately programmed – as a pair) can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £9.80 each pair (overseas add £1 p&p). The 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 431). It is also available *Free* via the Downloads click-link option on the *EPE* home page when you enter our main web site at **www.epemag.wimborne.co.uk** (take path **PICs/QuickStep**).

The printed circuit board is available from the *EPE PCB Service*, code 448 (see page 431). Incidentally, if you are looking for a low-voltage stepper motor you might like to investigate the ones stocked by Magenta (see above and their advertisement).

Crafty Cooling

During our search for possible parts for the "experimental" *Crafty Cooling* project, we were pleased to find the following information regarding the supply of Peltier modules. Before you purchase a module, check that it is a "factory" sealed unit – see text.

Our regular advertiser **Bull Group** (☎ ***0870 7707520*** or ***www.bull-net.co.uk***) has an interesting picture and details, including a manual, for a Peltier module – see inside front cover. Likewise, **Greenweld Ltd** (☎ ***01277 811042*** or ***www.greenweld.co.uk***) currently stock two types: a 17W device, code CDT0098, and a 33W module, code CDT0255. They are listed on their new web site at: ***www.sciencestore.co.uk***. They are also able to supply heatsinks and cooling fans.

No doubt readers should be able to select a suitable 12V fan from the many sold for cooling computer power supplies or microprocessor i.c.s.

Finally, it is impossible to say how quickly the "cooler" will cool the drink, but, unless you are desperate for a drink, time will not be a major factor. To give an idea, the prototype takes less than an hour.

Teach-In '04 – Part 8

Readers wishing to experiment with the PIC-controlled *Movement Detector* (Fig.8.11), part of this month's *Teach-In '04* instalment, a preprogrammed PIC microcontroller 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 8, Fig.8.11. 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 431 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**; 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***).

PLEASE TAKE NOTE

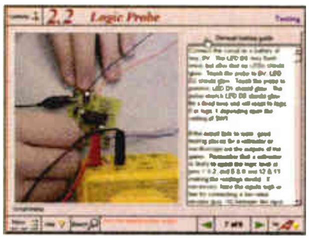
Toolkit TK3 Software Update

The latest version, in which minor changes have been made to the "PIC Breakpoint" facility, has been placed on the Downloads site.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS



Logic Probe testing

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

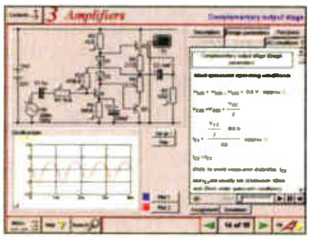
ELECTRONIC CIRCUITS & COMPONENTS V2.0

VERSION 2

Circuit simulation screen

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

ANALOGUE ELECTRONICS

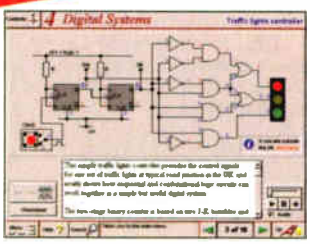


Complimentary output stage

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

DIGITAL ELECTRONICS V2.0

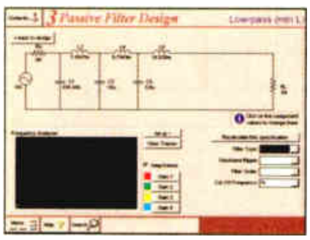
VERSION 2



Virtual laboratory – Traffic Lights

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

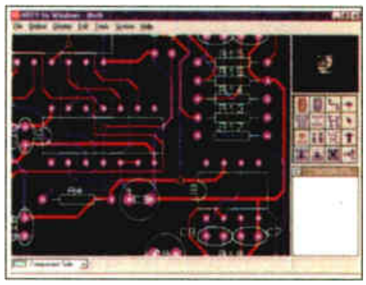
FILTERS



Filter synthesis

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

ELECTRONICS CAD PACK



PCB Layout

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

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

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

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

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student .... **£45 inc VAT**
Institutional (Schools/HE/FE/Industry) .... **£99 *plus* VAT**
Institutional 10 user (Network Licence) .... **£199 *plus* VAT**
Site Licence .... **£499 *plus* VAT**

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

PICmicro TUTORIALS AND PROGRAMMING

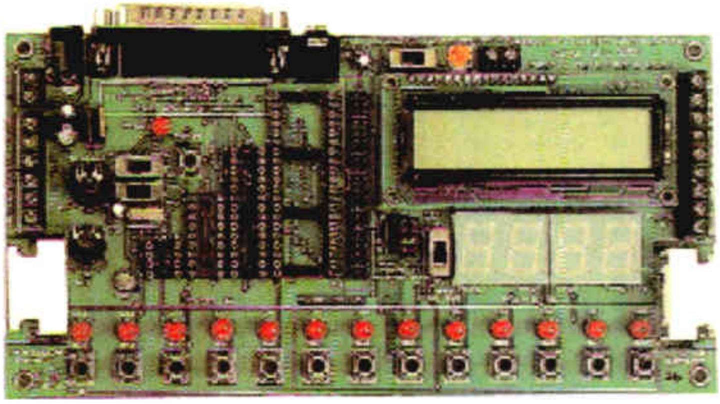
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 13 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- All inputs and outputs available on screw terminal connectors for easy connection



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

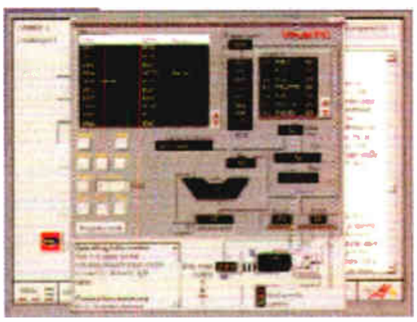
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



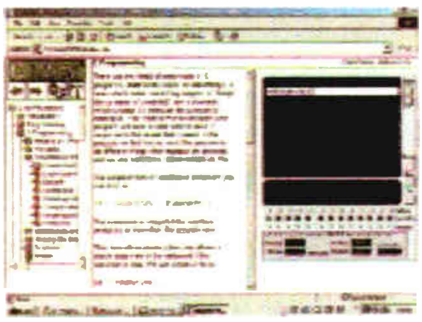
Virtual PICmicro

'C' FOR PICmicro VERSION 2

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

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



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

FLOWCODE FOR PICmicro

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

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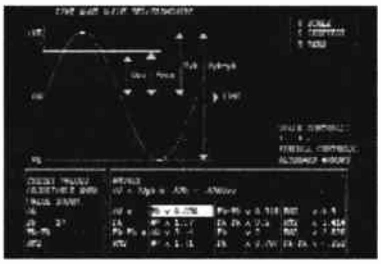

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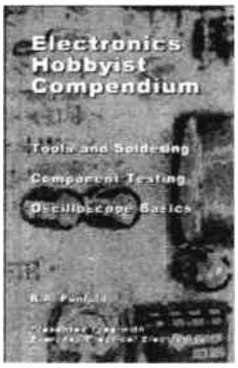

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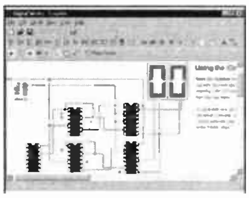

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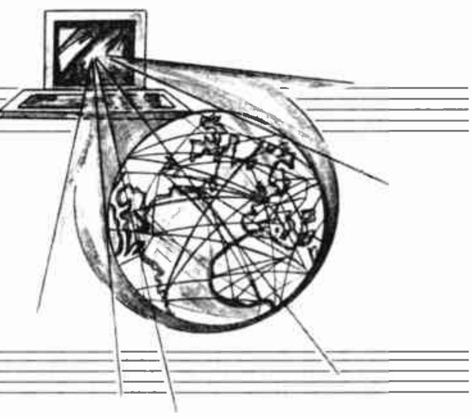


NET WORK

ALAN WINSTANLEY

MOST internet users have a favourite search engine to help pinpoint information of some sort or other: when we wanted to know about the National LM12 power op.amp, all we needed to do was "google" directly to the PDF data sheet, an action performed with Google's usual speed (< 1 second) and efficiency (no. 1 link). Much better than agonising over the accuracy of data and pinouts drawn in mail order catalogues!

Alta Vista

When Google was just a minor beta product and the web was many magnitudes smaller, many 'net enthusiasts cut their search engine teeth on Yahoo! (**www.yahoo.com**) or Alta Vista (**www.altavista.com**). The latter started life as Digital Equipment Corporation's fabulous demonstration of DEC computing power, before being hived off to Compaq: Alta Vista is now owned by Yahoo! Its results are very different from those shown by Google: Alta Vista's new slimmed-down interface failed our LM12 data sheet test completely. After floating the idea of free 0800 dial up access in the UK, a disaster that ended with the departure of Managing Director Andy Mitchell in 2000, it is a pity that Alta Vista seems to have all but disappeared from the UK mainstream user's search engine toolbox: most folks google instead.

Google (**www.google.co.uk** and other countries) is the ubiquitous engine that started life as a mathematical exercise intended to index the data available on a burgeoning world wide web. Google's clean bloat-free non-portal style proved popular and it became the largest "true" search engine in the world. It was even awarded the accolade of having a verb created in its honour (guilty, see above). Following a radical (and some say near-disastrous) re-indexing exercise earlier this year (known in the trade as doing the "Google Dance"), Google is going through a phase when many web sites that had previous featured well in its database have lowered or lost their rankings altogether.

For reasons that dismayed many web site owners, Google suddenly displayed search requests based on new criteria. A number of analytical web sites sprang up that highlighted the dramatic "before and after" (good and bad, respectively) effect that was seen after the rebuild. For the first quarter of 2004 there was near panic in many quarters, because many web site owners who relied on Google for trade suddenly found that they were invisible to inquisitive web users: only now are web site rankings and relevance improving again.

At one time, Google could do no wrong, but its most recent suggestion of free web-based email (dubbed *Gmail*) to rival Hotmail has been widely criticised, not least because of the suggestion that the contents of Gmails might be scanned by Google in search of keywords, which could then trigger some corresponding advertising mails. The fact that it may not be possible to delete ones' personal Gmail from the Google servers has also alarmed privacy groups considerably.

Google plays its financial cards close to its chest. With a widely-speculated share-offering looming larger, the danger is that they may talk up its value and move away from its roots by adopting an altogether more commercial approach, so watch out for headline-grabbing announcements from Google in coming months.

MSN and Yahoo

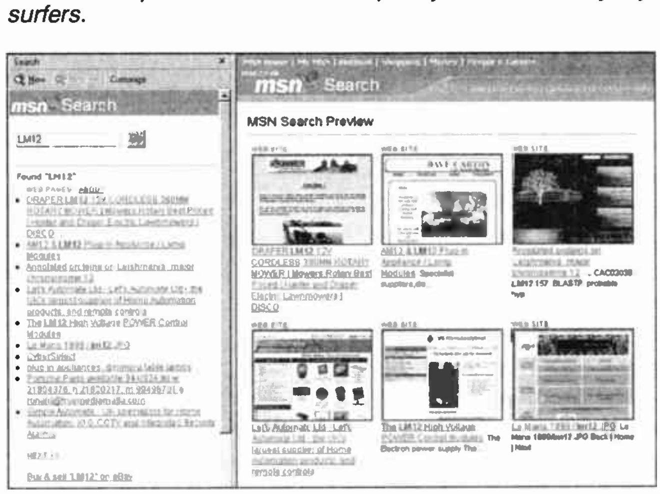
MSN (**www.msn.co.uk** and other countries) is also one of the big three search engines and is often overlooked; it's the magnifying glass icon in the MSIE toolbar. It has some attractive features, including an interesting preview thumbnail image of web site homepages. Just like Alta Vista, a search on MSN for "LM12" failed to deliver any links to National Semiconductor, not surprisingly as both engines currently get their search engine results via Yahoo!'s Overture.com and Inktomi.com, yet another Yahoo! acquisition.

It has been all-change at Yahoo! and "Yahoogle" is no more: there can be no doubt that Yahoo! is now gunning for Google. Yahoo! has previously traded on its own directory of web sites and used Google to provide its "other results" – so that if a search for an LM12 drew a blank in Yahoo!'s directory, then there was at least a chance that Google could provide alternative links. Yahoo! has now dumped Google and is focusing on competing head-to-head with it instead. Yahoo! owns Alta Vista, Overture, FAST and Inktomi so there is a heavy focus on pay-per-click advertising services.

In summary, the top three search engines continue to be Google, Yahoo! and MSN. Google looks set to become more commercialised (watch out for an IPO – initial public offering – announcement, and more headline-grabbing news as Google's corporate machine swings into action). For general mainstream searching, the emphasis is shifting towards Yahoo! which is evidently gearing up to compete for the top slot. Third place goes to MSN, the default search engine found in MSIE.

Next month I'll be suggesting a fourth search engine that powers some other well-know search sites, and asking the question: did it pass our LM12 test? You can email comments to **alan@epemag.demon.co.uk**.

The Yahoo! portal web site offers plenty to do for everyday surfers.



The MSN search engine has a preview option to display small images of web pages.

EPE Tutorial Series

TEACH-IN 2004

Part Eight – Movement Detection

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

MOVEMENT detection is the general heading for this month's *Teach-In*. It is a term which has many interpretations. Here we shall first place the emphasis on detecting whether or not a specific signal is being generated. We touched on this last month when briefly examining the concept of missing pulse detection.

In the example given, the pulse was that output periodically by a radio transmitter as an indication that it was working. If the signal was picked up by the receiver, this confirmed that the receiver was also working. If neither was true, i.e. the required pulse was missing, then a fault condition was signalled.

The classic use of a missing pulse detector is in heart beat monitoring. If the time between two consecutive heart beats is longer than permitted by the circuit, an alarm sounds.

There are many other applications. For example, you may have an alarm system in a shed or garage linked to your house via a pair of radio modules (discussed in Part 7). If you send a continuous radio message to indicate that all is well, you will be jamming all other devices on the same radio frequency. If you send a radio signal only when the alarm is triggered, you will have no way of knowing that the radio link is actually working.

The solution, as we outlined last month, is to send a short radio signal at intervals. Your receiving circuit is then programmed to look for the regular signal, and if no signal is received, the alarm is sounded.

Systems such as heart beat monitors, or the DVT (Deep Vein Thrombosis) warning system we discuss later, rely on pulses generated by your body, or generated by movement. But some systems (e.g. radio linked alarms) need an electronically generated pulse, and so we will begin by examining circuits designed to generate regular pulses.

ASTABLES

We first examined astables in Part 4 when discussing logic gates. Last month we illustrated a practical use for a logic gate astable, employing it as the transmitter control device. Astables can also be constructed using a pair of transistors as shown in Fig.8.1.

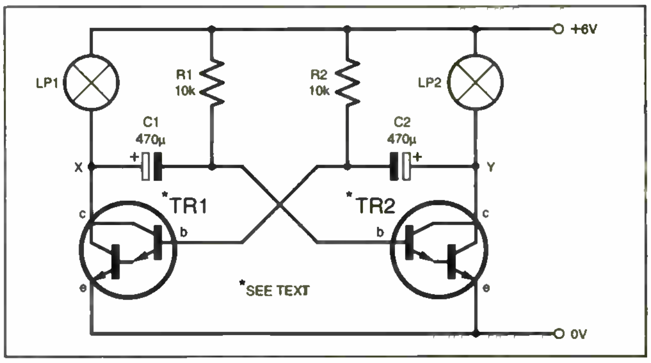


Fig.8.1. An astable (oscillator) formed around two Darlington transistors.

If two bulbs, LP1 and LP2, are employed (e.g. 6V torch bulbs) then the transistors should be *npn* Darlington types, such as the TIP122. If l.e.d.s (with series resistors of say 330Ω) are employed then any pair of high-gain *npn* transistors may be used.

A good starting point for the resistor/capacitor values is: R1 = R2 = 10kΩ, and C1 = C2 = 470µF. Note that the capacitors are electrolytic and so the positive side of each must be the way round indicated. The supply voltage should match the bulbs used, so a 6V supply is ideal with the bulbs suggested. A photograph of the test circuit is shown in Photo 8.1

At power-on one transistor will turn-on faster than the other. We will assume it is TR1, and so bulb LP1 lights up. Hence point *X* will be at 0V. Any sudden change of voltage is transferred across a capacitor, C1 in this case, and so the base (b) of TR2 will be at 0V, keeping TR2 switched off. Hence the voltage at point *Y* will be at 6V, and the base of TR1 will remain positive enough to keep it switched on.

Since the upper side of resistor R1 is at 6V, and its lower side is at 0V, current will flow through it and into capacitor C1, which will charge up accordingly. (You may notice that C1 will become charged with its polarity the wrong way round, but it will only be for a short time, with a maximum reverse differential of only about 1·4V, the turn-on voltage at the base of transistor TR1.)

After an interval, the base of TR2 will become positive enough for this transistor to switch on. Now bulb LP2 will light, and point *Y* will fall to 0V. This sudden change will transfer across to capacitor C2, hence switching off TR1 and its bulb, LP1.

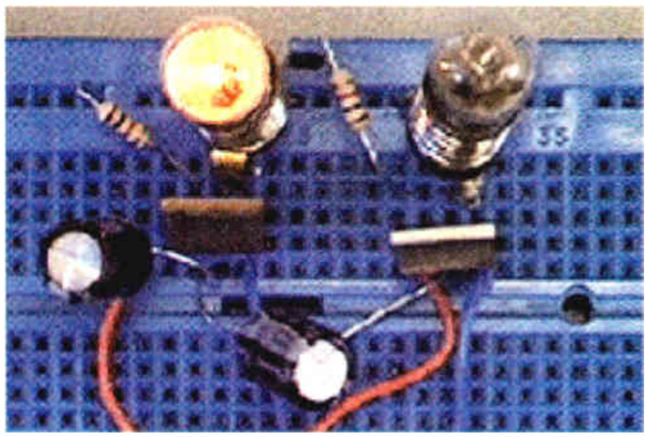


Photo 8.1. Breadboard layout of the circuit in Fig.8.1.

Current will now flow through resistor R2, slowly charging C2 until the circuit reverts to its original state. Note that the values of R1 and C1 determine the time for which lamp LP1 is lit, and R2 and C2 control the time for which LP2 is lit.

MARK/SPACE RATIO

Using the values indicated earlier, the mark/space ratio will be equal. The concept of mark/space ratio was explained last month in Part 7. Fig.8.2a illustrates the voltage at point *Y* with the component values suggested earlier. The voltage at point *X* will be similar but the exact opposite of that at point *Y*.

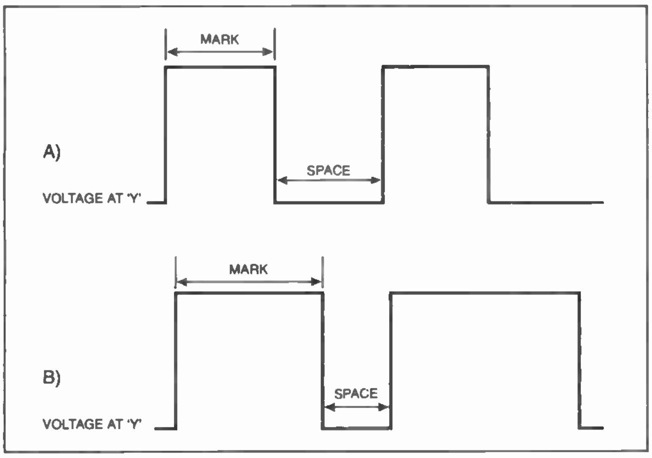


Fig.8.2. Illustrating the waveforms generated by the circuit in Fig.8.1.

Now if resistor R2 is reduced in value to, say, 4·7kΩ then LP2 will be lit for a shorter time than LP1, and so the voltage at *Y* will remain positive for longer, as shown in Fig.8.2b. The mark/space ratio is about 2:1.

WARNING: Do not reduce the value of either resistor to less than 1kΩ or you may damage the transistor. If you use values greater than 10kΩ, you may find that the transistors fail to switch on. It may be safer to experiment with the values of the capacitors since a wide range of values may be safely employed.

The circuit is simple, though crude. Even if the bulbs are replaced with resistors, it is quite current-hungry, and points *X* and *Y* do not switch cleanly between positive and 0V. But it illustrates the point, and can be fun, particularly if a loudspeaker or headphone (impedance 64Ω or more) is connected in place of one of the lamps. You should hear a clicking sound. Try reducing both capacitors to, say, 100nF in order to speed up the frequency by over 1000 times. You should hear a musical note, or at least the sound of a motor bike!

555 TIMER

Another very popular astable is that based on an i.c. known as a *555 Timer.* Although other timers are available, including the CMOS 7555 timer, the 555 remains common in project work, and still features in many electronics examination syllabuses. The pinouts for the 555 (and 7555) timer are shown in Fig.8.3.

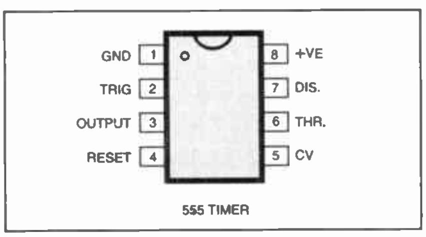


Fig.8.3. Pinouts for the 555 timer.

The pin functions are:

1. GND. Power supply ground (0V)
2. TRIG. Triggers timing cycle when connected briefly to 0V
3. OUTPUT. Goes high during timing cycle
4. RESET. Resets the timer when connected to 0V
5. CV. Control voltage. Can be used to modulate the timer, but is normally connected via a small value capacitor to the 0V line, although it is often left unconnected
6. THR. Sets the threshold voltage at which the timer is reset
7. DIS. The pin through which the external timing capacitor is discharged
8. +VE. The positive power supply pin, with a voltage range of typically 4·5V to 16V

The output current that can be sunk or sourced is typically 100mA, but some variants can handle 200mA.

The 555 is manufactured by a number of companies and the type number will be prefixed by that manufacturer's code, e.g. NE555, LM555, TS555. A full datasheet for the National Semiconductor LM555 is available from **www.national.com/DS/LM/LM555.pdf**. This datasheet also gives application examples of how the 555 can be used in a variety of modes.

Pin 4 (reset) is negative-triggered. In other words, if pin 4 is made positive, it has no effect on the timer, but if pin 4 is briefly connected to 0V, the timer is reset. Pin 2 (trigger) is also triggered by a negative signal.

ASTABLE CIRCUIT

An example of how a 555 timer is employed in astable mode is shown in Fig.8.4. The purpose of the circuit is to make l.e.d. D1 flash on and off at a rate determined by the values of resistors R1, R2 and capacitor C1.

The control voltage (CV) input, pin 5, is not required and is left unconnected. Pin 4 (reset) is connected to the positive line to allow the timer to operate (the opposite of reset mode).

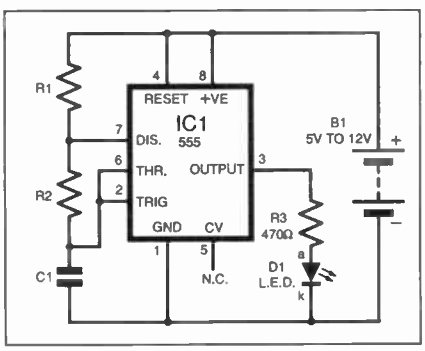


Fig.8.4. A 555 timer used in astable mode.

At power-on, the voltage across capacitor C1 is at 0V, so holding low pins 6 and 7 (threshold and discharge). This causes the timer to start its timing cycle, during which output pin 3 is held high, causing l.e.d. D1 to turn on, buffered by resistor R3. Pin 7 (discharge) is internally disconnected by the i.c.

Current flows through resistors R1 and R2, charging up capacitor C1. Pin 6 monitors the voltage on C1 and when this reaches two-thirds of the supply voltage, the i.c. simultaneously resets output pin 3 low, and internally connects pin 7 to 0V. Current now flows back through R2, discharging the capacitor via pin 7. Pin 2 monitors this voltage, and at one-third of the supply voltage, output pin 3 switches high again, pin 7 disconnects internally, and the cycle repeats.

On a 12V supply, for example, capacitor C1 charges to 8V and discharges to 4V, oscillating between these levels. The capacitor charges via R1 and R2, but discharges via R2 alone. So for a given value of C1, the time for which pin 3 is high is determined by the total resistance of R1 + R2, but the time for which output pin 3 is low is determined only by R2. By changing the relative values of resistors R1 and R2, the mark/space ratio can be adjusted.

The oscilloscope waveforms in Photo 8.2 illustrate the behaviour of the timer during a timing cycle. The lower waveform is that at the junction of capacitor C1 and pins 2 and 6, and the upper is the output at pin 3.

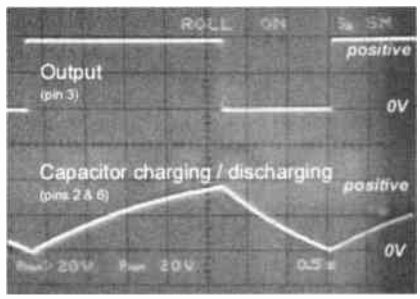


Photo 8.2. Waveforms for the circuit shown in Fig.8.4.

The time, T1, for which the output is high is given by:

$$T1 = 0{\cdot}7 \times (R1 + R2) \times C1$$

The time, T2, for which the output is low is given by:

$$T2 = 0{\cdot}7 \times R2 \times C1$$

Units must be in seconds, ohms and farads, or in seconds, MΩ and µF.

Notice that resistor R2 appears in both formulae; hence if you wish to obtain an almost equal mark/space ratio, make R2 large (e.g. 1MΩ) and R1 small (e.g. 1kΩ).

The circuit is ideal if you wish to obtain an unequal mark/space ratio, as is often required in "missing pulse" circuits. But note that in this simple arrangement, T1 (output high) is always longer than T2 (output low). If R1 and R2 are equal, then T1 will be twice T2 (look at the two equations to confirm this). If R1 is nine times the value of R2 then the mark/space ratio will be 10:1.

CONSTRAINTS

For reliable operation, resistor values should be between 1kΩ and 1MΩ. The capacitor value can be as small as necessary, but in this application values of 1μF and above will probably be needed to make the astable rate slow enough for the flashing of l.e.d. D1 to be obvious. If an electrolytic capacitor is used, ensure that it is the correct way round with its positive lead joined to resistor R2.

Electrolytic capacitors are quite inaccurate in value, and so do not expect your actual results to agree perfectly with your calculations. If accuracy is important, R2 could be a variable resistor, to allow precise setting. Also note that electrolytic capacitors tend to be "leaky" (i.e. not good insulators) and this will increase the actual timing period. In fact, with values of over 1000μF, predictable results are quite difficult to achieve.

Longer and more accurate delays are generally achieved by employing an astable with a fairly high frequency, which allows the use of non-electrolytic (and hence more stable and reliable) capacitors to be used. The pulses from the astable are then output to a dividing circuit. The result can be a very accurately timed output.

555 MONOSTABLE

If a short pulse followed by a long gap is required, a monostable can be employed together with an astable. The mark/space ratio of the monostable is unimportant, and this simplifies the circuit design. Whenever the output of the astable switches from, say, 0V to positive, the monostable is triggered, and can be set to produce a single very short pulse.

Monostable circuits were looked at in Part 4, in which logic gates were used. The basic monostable arrangement using a 555 timer is shown in Fig.8.5. Resistor R1 can be any value from 1kΩ to 1MΩ, its purpose is simply to keep pin 2 positive unless the switch (S1) is pressed. Resistor R2 (value R) together with capacitor C1 (value C) sets the period (T) for which the output is high, according to the formula:

T in seconds = 1·1 × R × C

Again, R is in ohms and C in farads, although, as before, a useful shortcut is to measure R in MΩ and C in μF.

As in the astable circuit, an l.e.d., D1, shows the state of the output, and is buffered by resistor R3.

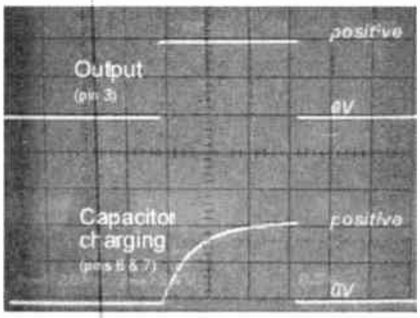


Photo 8.3. Waveforms for the circuit shown in Fig.8.5.

The oscilloscope photograph in Photo 8.3 shows the results obtained with the circuit in Fig.8.5. When the circuit is stable, output pin 3 is at 0V, and discharge pin 7 is internally connected to 0V. When trigger pin 2 is connected to 0V for a moment (e.g. by pressing switch S1), output pin 3 goes high, and the discharge pin internally disconnects itself. Hence current flows through resistor R2 and charges capacitor C1, as shown in the lower waveform. Threshold pin 6 monitors this rising voltage, and at two-thirds of the supply voltage, pin 3 switches back to 0V and pin 7 internally connects to 0V again.

CONSTRAINTS

As before, resistor values should be between 1kΩ and 1MΩ, and rather unpredictable results will be obtained with capacitors greater than 1000μF. Remember that if an electrolytic capacitor is used, its positive side should be connected to R2. In theory, the i.c. is capable of timings up to one hour, but in practice you will be lucky to achieve this, though you will at least win a gold-star for patience!

However, in our application, the monostable is required to provide a short pulse, and so testing should not be tedious. We will now show how to join the monostable and astable together.

circuit is shown in Fig.8.6. We have retained the l.e.d.s, D1 and D2, to show that the circuit is working, but in practice they may not be required, in which case their series resistors (R3, R5) are also redundant. The values of resistors R1 and R2, and capacitor C1 will provide the following timings at IC1 pin 3:

High = 0·7 × (0·47MΩ + 0·47MΩ) × 100μF = 65·8 secs
Low = 0·7 × 0·47MΩ × 100μF = 32·9 secs
Hence total period (full cycle) = 98·7 secs

In other words, IC1 will supply a rising pulse (or falling pulse) approximately every 100 seconds. The rising pulse will be ignored by IC2, but the falling pulse will trigger the input (pin 2) of IC2. The values of R4 and C2 are chosen to provide the following time for a high pulse at IC2 pin 3:

High = 1·1 × 0·1MΩ × 1μF = 0·11 secs

So l.e.d. D2 will flash for about one-tenth of a second every 100 seconds, approximately.

POSSIBLE PROBLEMS

The 555 timer is very popular, but has some deficiencies, such as rather high current consumption (about 10mA) and the tendency to cause voltage spikes on the power lines every time its output switches high or low. These spikes can upset other devices. So, without preventative measures, you could find that IC2 might be triggered at the wrong times.

However, capacitors C3 and C4 across the power lines in Fig.8.6 help to provide a stable supply for the system. Pin 5 (CV) of each timer can also be decoupled beneficially by connecting 10nF capacitors (C5 and C6) between them and 0V.

If all else fails, the CMOS versions of the 555, such as the TLC555CP or ICM7555, are much less troublesome in this respect, and can be directly substituted in this circuit. Also, consider using a dual-timer such as the NE556 (or the CMOS version ICM7556), which houses two timers in a single package, at virtually the same price.

A breadboarded test assembly of the circuit in Fig.8.6 is shown in Photo 8.4 (but excludes capacitors C4, C5 and C6.

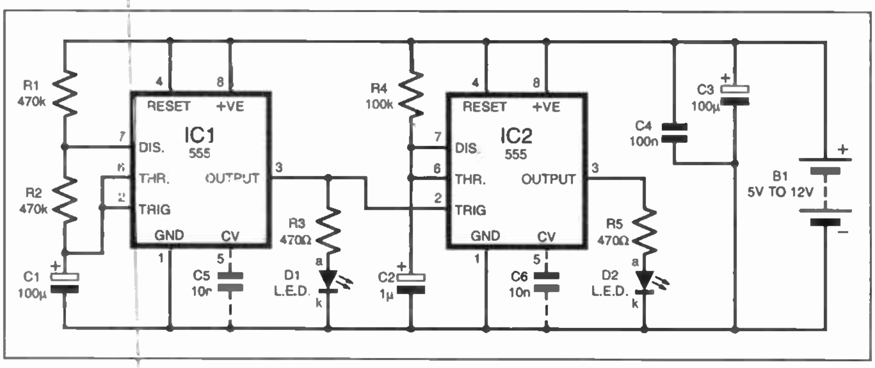


Fig.8.6. Combined astable and monostable circuit.

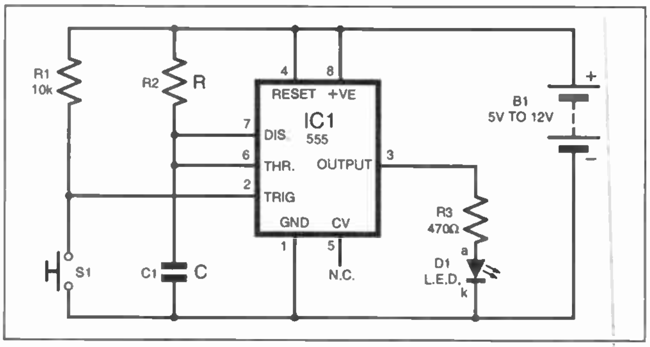


Fig.8.5. A 555 timer used in monostable mode.

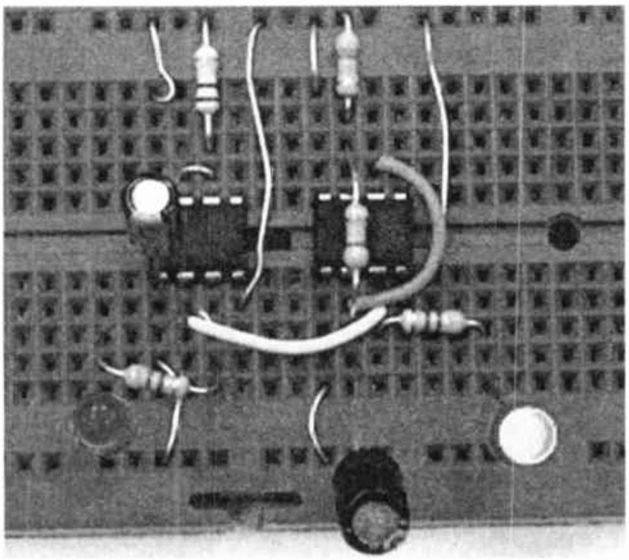
TIMED PULSES

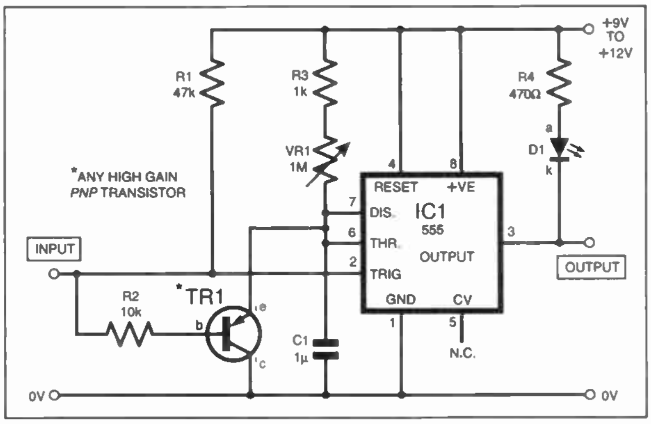
As said before, the 555 timer requires a negative-going (0V) pulse at pin 2. Since the astable will be switching continuously between 0V and high and back to 0V, this is not a problem.

The combined astable-monostable

DETECTING MISSING PULSES

We examined a basic missing pulse detector last month, but we will now





Above: Fig.8.8. A missing pulse detector based on a 555 timer.

Left: Photo 8.4. Breadboard layout of the circuit in Fig.8.6.

consider more elegant ways of achieving the same end. The principle is simple: make a timing circuit, but allow the pulse to reset the circuit before the timing cycle is complete.

A simple timer can be made using a single transistor, as shown in Fig.8.7. The transistor, TR1, can be any high gain *npn* type, a Darlington-pair such as a TIP122 will offer slightly longer timings since its turn-on voltage is 1·4V rather than 0.7V for a "normal" bipolar transistor.

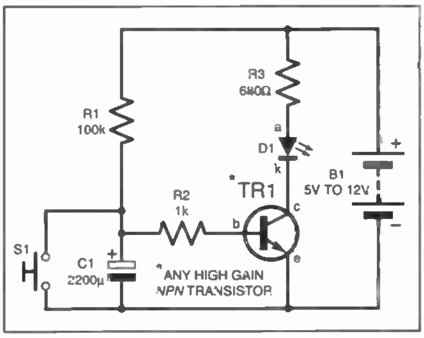


Fig.8.7. Single-transistor timing circuit.

When switch S1 is pressed, the voltage at the junction of resistors R1, R2 and capacitor C1 is pulled to 0V. Hence TR1 is turned off, and so too is l.e.d. D1. When the switch is released, current flowing through R1 will cause C1 to charge. This rising voltage will make TR1 turn on once it reaches the threshold of about 0·7V. The delay between releasing the switch and l.e.d. D1 lighting up will depend upon the values of R1 and C1.

If the switch is pressed at regular intervals, capacitor C1 will never charge sufficiently to turn on the transistor, and so l.e.d. D1 will never be turned on. When you stop pressing the switch, the circuit will then "time out", causing D1 to light.

This is the principle of classic heart-beat monitoring. Imagine your heart triggering a sensor just like pressing a switch; if your heart stops, the l.e.d., or a warning buzzer, will switch on.

DEFICIENCIES

Transistor TR1 turns on at about 0.7V, and even a large capacitor will quickly charge to this level. Hence the timed period will be quite short. If you try to increase the value of resistor R1, there will come a point when insufficient current is available to switch on the transistor properly.

Using an *npn* Darlington transistor instead of a normal bipolar type will help, because of its higher turn-on threshold of about 1·4V, but the method just described is presented to illustrate the principle, rather than provide a useful circuit. We could improve the circuit by adding more transistors, but there are other much better methods waiting in the wings.

RE-ENTER THE 555

The 555 in its monostable mode is ideally suited to this application, and the CMOS 7555 equivalent mentioned earlier will offer low current consumption as well. A possible arrangement is shown in Fig.8.8.

Transistor TR1 is a normal high-gain *pnp* type. This means that if the voltage on its base (b) is more positive than the voltage at its emitter (e) minus 0·7V, it will be turned off. In other words, for a 9V power supply, and with TR1's emitter held at 9V via resistor R3 and potentiometer VR1 (capacitor C1 fully charged), TR1 will only turn on if its base is at 9V – 0·7V = 8·3V approximately. If the base voltage is greater than 8·3V, TR1 will be turned off.

In Fig.8.8, TR1's base is normally held at 9V via resistors R1 and R2, and so it is turned off. If the signal input is briefly connected to 0V, the transistor will turn on and discharge capacitor C1. The 555 will also be triggered and will start the timing cycle.

Assuming that the input returns high almost immediately following it being taken low (i.e. just a short trigger pulse), the timing cycle will finish at the end of the set period, unless further 0V pulses are received at the input. Hence the output will remain high, indicating that "all is well", but if the pulses stop, the output will go low.

The values of capacitor C1, resistor R3 and potentiometer VR1, set the timing period, after which the alarm is raised. The purpose of using a variable resistor is so that the timing period can be adjusted; you could use a single resistor in place of R3/VR1 if preferred, as in previous circuits. However, a 1MΩ pot or preset for VR1 will provide a wide range of timings.

Resistor R3 is needed in case VR1 is reduced to zero resistance, a condition that would cause a short-circuit via TR1.

Whilst in this area, some readers may wonder at the wisdom of discharging C1 directly through TR1. If in doubt, a resistor (say 100Ω) could be connected in series with the emitter of TR1, but this should not be necessary with smaller value capacitors e.g. 100μF or lower. For larger values of capacitance, the buffering resistor may be more essential to reduce the current flow, as was done in the circuit of Fig.7.12 last month (R5). The value of this resistor, though, will affect the rate at which C1 discharges.

NEGATIVE LOGIC

Note that "negative logic" applies in this circuit. In other words, the input looks for negative-going (0V) pulses, and the output is normally positive (high), but switches to 0V to signal an alarm condition (i.e. missing pulses). In this circuit, l.e.d. D1 indicates the alarm condition, turning on when IC1 output pin 3 goes low.

As mentioned earlier, the 555 timer tends to be upset by stray pulses in a circuit, and is rather prone to generating its own stray pulses. The CMOS version is much better in this respect, and if you wish to employ a buzzer at the output, you may have to use the CMOS version, or add capacitors (say 100nF) across the power lines to "soak up" the interference. The next missing pulse detector is far less prone to this type of interference.

DIGITALLY DETECTING PULSES

The circuit shown in Fig.8.9 employs four 2-input NOR gates as a missing pulse detector. The pin numbers are for a CMOS 4001B, and the circuit can be powered from a 5V to 12V supply. Gates from the CMOS 74HC series (i.e. 74HC02) will also work, but note that the pin numbers are different, and the supply must be between 4V and 6V.

At the heart of the circuit is a monostable, comprised of gates IC1a and IC1b. This type of monostable was described in detail in Part 4. The timing period is set by the values of capacitor C1 and resistor R2, according to the formula:

Time in seconds = 0·7 × R × C

By employing the usual shortcut of measuring R in MΩ and C in μF, the period set by the values shown in Fig.8.9 is

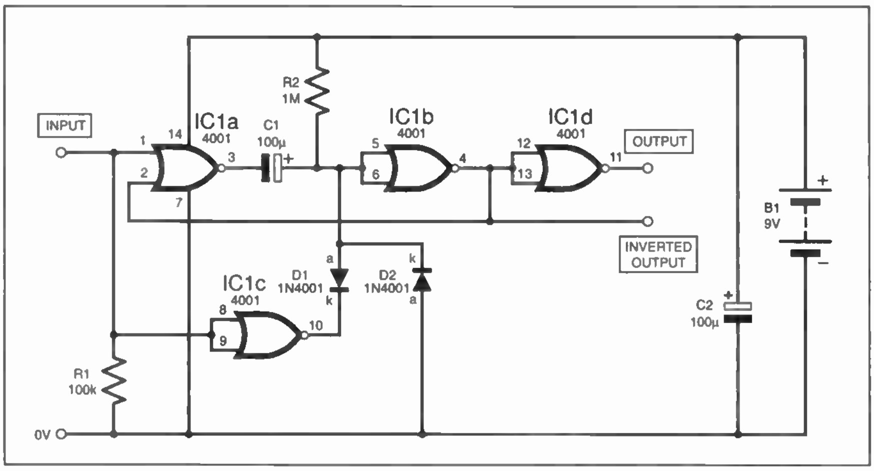


Fig.8.9. A missing pulse detector based on NOR gates.

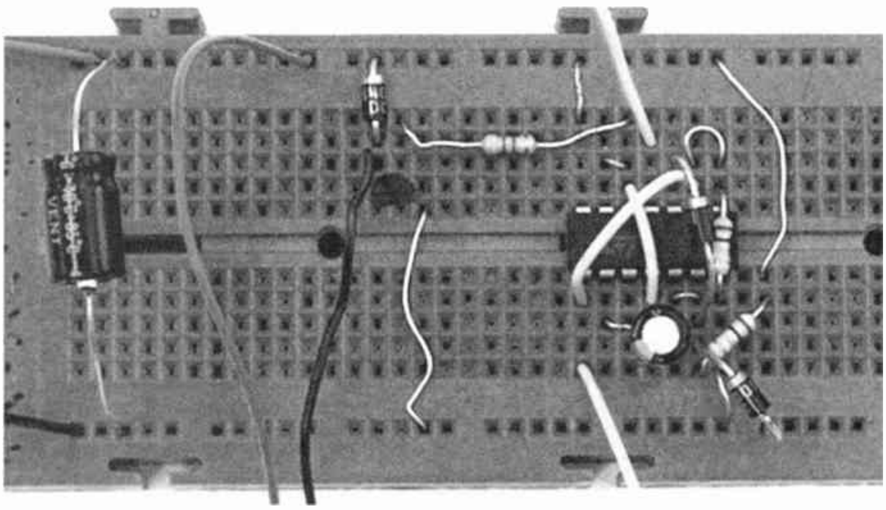


Photo 8.5. Breadboard layout of the circuit in Fig.8.9.

70 seconds. In practice, the timing is affected by the tolerance (accuracy) of the component values, and your electrolytic capacitor may well have a tolerance of 50%.

If a shorter period is required, the value of C1 (or R2) can be reduced, and if longer periods are needed, C1 can be increased. Note that it is unwise to use values greater than 1000μF and 1MΩ since electrical leakage through the capacitor will become a factor. If you require a variable period, a potentiometer can be used as a variable resistor. In this case it is wise to include a low-value (e.g. 1kΩ) fixed resistor in series with it as shown previously (Fig.8.8).

DETECTING PULSES

The pulse input at IC1a pin 1 is held at 0V by resistor R1, and so the output from IC1b pin 4 will also be at 0V (full details of the monostable are in Part 4), hence IC1d pin 11 will be high.

As described in Part 4, a positive-going pulse received at IC1a input pin 1 will cause IC1b pin 4 to go high, so setting IC1d pin 11 low. If another pulse is received in say 30 seconds, IC1c output pin 10 will go low, and current will flow via D1, discharging C1 in the process. Hence if the input is pulsed high, or remains high, IC1d output pin 11 will remain low.

If a pulse is *not* received at the input, then after 70 seconds (in this case) the output from pin 11 will go high again, indicating an alarm condition.

Diode D1 is needed to prevent IC1c pin 10 charging up the capacitor, and D2 is to prevent the input pins 5 and 6 going negative (i.e. below 0V) if pin 10 (or pin 3) switches to 0V when pins 5 and 6 are already at 0V. Although logic gates include built-in input protection diodes, D2 is there to reinforce the protection, just in case!

The output at IC1d pin 11 goes high to indicate an alarm condition. The "inverted output" at IC1b pin 4 goes *low* to indicate an alarm condition. This may be useful in some applications.

It is possible to drive a low-current l.e.d. directly from IC1d pin 11 via a suitable ballast resistor. There is insufficient current available to satisfactorily drive a normal l.e.d. Do not attempt to drive an l.e.d. directly from the inverted output since it may disrupt the voltage fed back to pin 2.

If you wish to use a buzzer or bright l.e.d. etc., a single transistor interface should be employed, in the manner shown in Part 7 Fig.7.4, for example. Photo 8.5 shows a breadboard assembly of Fig.8.9 plus the components for a buzzer driving interface.

MOVEMENT DETECTION

The medical condition Deep Vein Thrombosis (DVT) is caused by a lack of movement, when sitting for long periods on an aircraft for example. When the legs are inactive for a long period, potentially fatal blood clots can form in the vein. We shall now describe a simple system which can give a warning if limbs are motionless for too long.

There are many techniques for monitoring movement. We shall first show how a vibration switch can be used in this context, providing output signals which can be monitored by the missing pulse detector circuits already described.

One form of vibration switch is shown inset in Fig.8.11. Two types are available, one with mercury inside, the other without. *As mercury is a toxic substance, only the non-mercury type must be used.*

In the photo there appears to be only one connection on the device, but the other connection is the metal casing – to which a wire can be soldered with care. Some vibration switches already have a wire fixed to the casing. A vibration switch differs from a tilt switch in that it can be in any position and will still detect movement. Hence it is ideal in this application.

The contacts of a vibration switch are normally open (unconnected) and close briefly when the switch is moved. So in the DVT application, the switch generates the pulses, a detection circuit monitors them, and sounds a warning if movement stops for too long a period.

The two circuits in Fig.8.10 show alternative ways of "conditioning" the vibration sensor's output prior to applying it to the main detector circuit. The arrangement Fig.8.10a produces positive-going (from low to high) pulses when the switch is vibrated. Resistor R1 ensures that the output is at 0V unless the switch is moved. Capacitor C1 removes any interference which is induced into the system, particularly if long wires are employed to link the switch to the circuit.

In Fig.8.10b the resistor holds the output high, unless the switch is vibrated, at which point the output pulses to 0V. This is useful for circuits or devices which require negative-going (from high to low) trigger pulses, such as the 555 timer. Note that some circuits may already have an internal resistor to bias the input high or low, in which case resistor R1 may be omitted.

PIC SOLUTION

Any of the missing pulse detectors previously described could be employed with one or other of the vibration switch circuits in

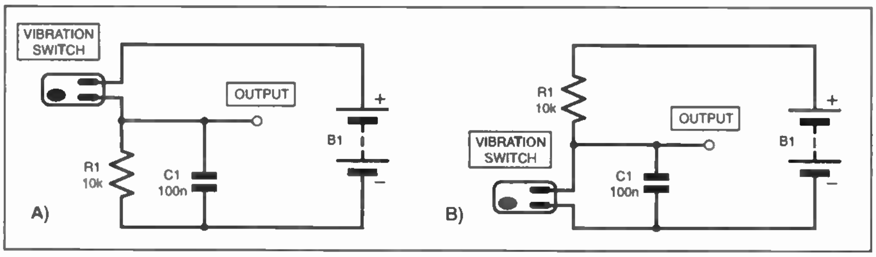
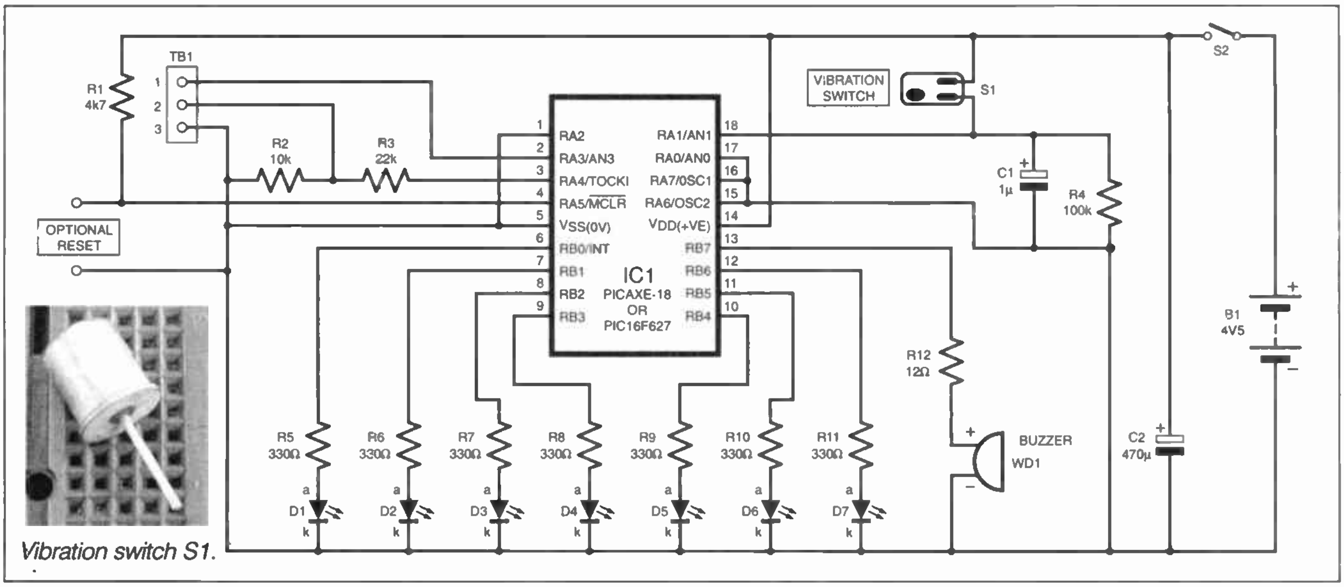


Fig.8.10. Two methods for "conditioning" the pulses from a vibration switch.



Vibration switch S1.

Fig.8.11. Circuit diagram for a PIC-controlled movement detection circuit.

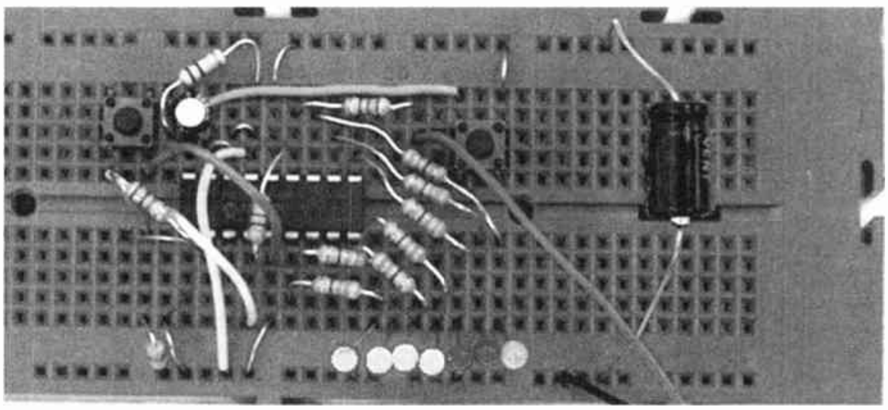


Photo 8.6. Breadboard layout of the circuit in Fig.8.11.

Fig.8.10. However, PIC microcontrollers can provided a more sophisticated method. This allows the easy provision of a "count-down", i.e. a set of l.e.d.s which indicate the period of time before sounding the alarm. Whilst it is possible to design a non-PIC circuit with a set of l.e.d.s, the PIC provides the simplest and most flexible method.

The arrangement described now is based on the PIC variant known as the PICAXE-18, but a PIC16F627 (or PIC16F628) can be used if preferred. Details of the PICAXE-18 were discussed in Part 5, but in brief, these devices allow a program to be written in a form of BASIC, then downloaded directly into them via a serial lead from a PC.

This provides immense flexibility since the program can be modified and downloaded repeatedly, without the user having to worry about more conventional PIC programming techniques. For those who have such PIC programming facilities, however, a HEX file suitable for PIC16F627 devices is also available. For both options see later.

PIC CIRCUIT

The circuit schematic is shown in Fig.8.11. The pin notations used here are those for the PIC16F627/8. The PIC, IC1, includes a built-in clocking oscillator.

Terminal block TB1 is the PICAXE-18 serial programming connector. It may be omitted if programming is to be done with a standard PIC programmer and a PIC16F627, or if the chip is purchased ready-programmed. However, it is necessary to retain R2 and R3 since these hold pin RA4 at 0V when not in use.

Resistor R1 biases the $\overline{\text{MCLR}}$ pin high, for normal running mode. If required, resetting can be achieved by bridging the Optional Reset connections briefly with a metal object, such as a screwdriver blade.

Vibration switch S1 is connected to pin RA1, which is configured as an input. Its pull-down resistor R4 has been increased to 100kΩ (compared with Fig.8.10), and capacitor C1 has been increased to 1μF. The purpose of both changes is to lengthen the time for which input pin RA1 is held high after the vibration switch has been triggered, since the state of RA1 is checked by the program periodically rather than continuously.

Pins RB0 to RB6 are used as outputs to drive the set of l.e.d.s, D1 to D7. Note that D7 (a green l.e.d. in the prototype) indicates that the vibration sensor has been detected, and D1 to D6 (red) indicate the "countdown". The final output, RB7, is reserved for the buzzer or other warning device, WD1. Resistors R5 to R11 limit the flow of current through the l.e.d.s. R12 prevents a surge of current through the buzzer, which might upset the working of the PIC. In practice R12 is probably unnecessary, and could be bridged by a wire link.

The circuit may be powered at between 4·5V and 6V. The latter value **must not** be exceeded. Capacitor C2 provides power line decoupling (smoothing) for the circuit.

At switch-on, l.e.d.s D1 to D6 are all turned on, indicating that the maximum timing period is allowed. The program then checks the vibration switch repeatedly during a timing loop. The total time allowed before the alarm is sounded is six minutes. This may seem rather short, but readers with programming facilities can increase it if preferred by adding more steps in the timing loop. The l.e.d.s indicate the countdown progress, successively turning off at about one minute intervals.

RESOURCES

Pre-programmed PIC microcontrollers for the circuit in Fig.8.11 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 8. 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**.

PICAXE programming software can be obtained from: Revolution Education, Dept. *EPE*, 4 Old Dairy Business Centre, Melcombe Road, Bath BA2 3LR.

The telephone number is: 01225 340563, and their website is at **www.rev-ed.co.uk**.

PART 7 CORRECTION

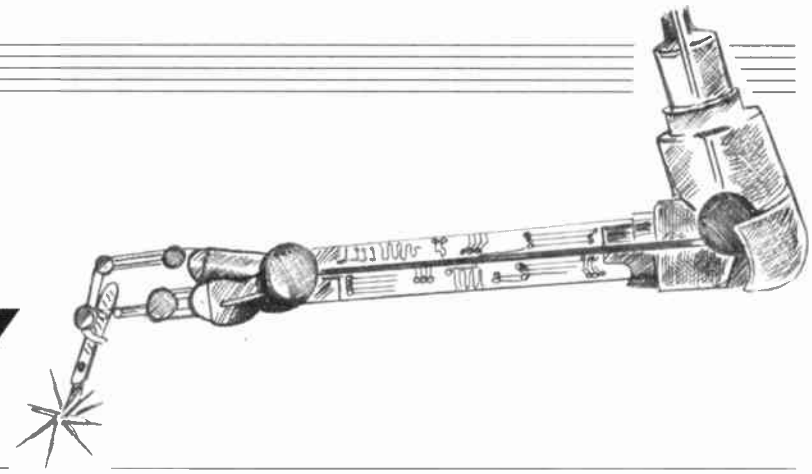
The p.c.b. in Fig.7.16 was designed for a BC184L transistor (TR1) and its pin notations should read *e, c, b* from top to bottom.

NEXT MONTH

In Part 9 next month we examine hard-wired and logic gate control of lock and alarm systems, including the use of thyristors and matrixed keypads, and how to use a PIC to decode keypad signals.

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

This month, our intrepid surgeons look at some options for motor control using power op.amps, some brazen terminology and a current flow mystery

Power Op.Amps

Robert Penfold used the now obsolete L165D power op.amp for motor control in a number of his books and articles and I need a modern replacement. Could the low cost, readily available TDA2006V audio amp i.c. be used as an op.amp? For an H-bridge single rail 12V supply, the TDA2005M twin op.amp looks like being able to drive a motor at, say 3A.

I have in mind both PWM and d.c. servo feedback control. Would they work, and if so how? Or am I pipe-dreaming? **Dave McCloy.** *P.S. Many thanks for the excellent articles!*

The TDA2006 is an audio power amplifier i.c. delivering 12W into 4 ohms and 8W into 8 ohms from a 12V supply. Two TDA2006s can be used in a bridge configuration to deliver 24W.

Although the internal circuitry of the TDA2006 is similar to that of a basic op.amp, the device is optimised for use as an audio power amplifier. It is not meant for general-purpose use and the TDA2006 datasheet provides three specific circuits for split supply, single supply and bridge amplifiers that the manufacturers recommend. The datasheet also provides a p.c.b. layout and details of the effect of changing component values in the circuits provided. The split supply TDA2006 circuit is shown in Fig.1 (courtesy ST Microelectronics).

One could experiment using the device as an op.amp, but problems such as instability and poor common mode input range may be experienced. It is possible that the TDA2006 would not perform well at d.c. as it is not intended for this purpose, whereas op.amps are usually designed for good d.c. performance.

In Comparison

For applications other than audio – such as the motor controller you have in mind – it would be better to use a power op.amp such as the LM12 or LM675 from National Semiconductor. Both these devices are suitable for circuits such as servos and motor speed controllers.

The LM12 can deliver up to 80W, up to ±10A and operates from a total supply of 15V to 60V (±30V) and can be used in circuits with a closed loop voltage gain down to unity (×1). The LM675 is a lower power device delivering up to 20W, up to ±3A and operating from a total supply of 16V to 60V. It is designed for use with closed loop voltage gains down to ×10; the use of gains below this value may cause oscillation to occur.

In comparison, the TDA2006 is like an op.amp in that it is a high open-loop gain amplifier operated with negative feedback to set a much lower circuit gain. The TDA2006 is usually operated with a voltage gain of ×32 and can be used with minimum gain of about ×16.

The minimum gain of a high open-loop gain amplifier with negative feedback is set by the point at which the amplifier becomes unstable. At high frequencies, phase shifts in the circuit convert this negative feedback into positive feedback. More negative feedback means lower circuit gain, but also

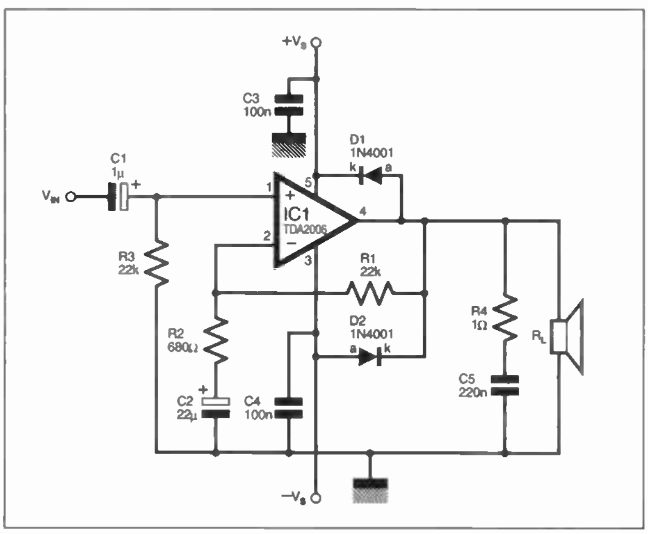


Fig.1. A TDA2006 split supply amplifier circuit from the i.c. datasheet. (Courtesy ST Microelectronics.)

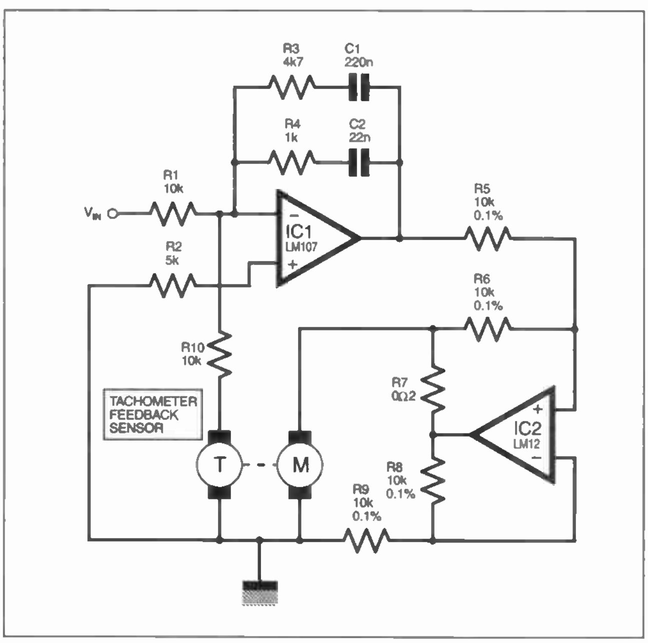


Fig.2 (right). A typical LM12 power op.amp motor control circuit. This is a servo with motor speed proportional to input voltage. A good common *earth/ground return point must be provided to avoid introducing "earth loops".* (Courtesy National Semi.)

means more positive feedback at the frequencies at which the phase shift is sufficient. Thus, the lower the gain, the more unstable the circuit is likely to be.

The minimum gain is determined by the level of *compensation* built into the amplifier. This makes sure that the gain falls off at high frequencies before the phase shift is sufficient to cause problems. More compensation means that a greater range of low gain circuits can be built, but reduces bandwidth at any given gain.

Servo Controller

The circuit diagram shown in Fig.2 is for a servo circuit using the LM12 power op.amp taken from the National Semiconductor datasheet: a number of products are available for this purpose, often classified under the sub-heading of "motion control". The motor speed is proportional to the input voltage: note that the motor (the "M" symbol) has a tachometer (the "T" symbol) that provides a feedback signal to the controller.

The power op.amps are happy to drive resistive and inductive loads such as loudspeakers and motors, and the LM12 TO3 package would handle reactive loads of 800 watts peak without the need to de-rate; however, they have difficulty with capacitive loads. Capacitive loads interact with the feedback in such a way as to cause potential instability.

Again, the lower the gain, and the greater the level of feedback in use, then the more problematical capacitive loads become. For unity gain, the LM12 can handle 0·01μF and both op.amps can handle 1μF in circuits with a gain of 10. To drive large capacitive loads, connect a low value resistor (typically 5 ohms to 10 ohms) in series with an inductor (typically 4μH or 5μH) between the amplifier output and the load.

All power circuits require great care to be taken with power supply design and standards of construction. Supply leads for all these devices should be bypassed by low inductance capacitors (e.g. C3 and C4 in Fig.1 – not shown in Fig.2). The LM12 may need capacitors as large as 470μF or more close to the device for high quality operation. At least 20μF should be used. Good ground returns to a *common* point must be provided if the accidental introduction of earth loops is to be avoided.

Clamp Down

For all three devices, output clamp diodes should be included when driving inductive loads such as motors, solenoids and loudspeakers (e.g. D1 and D2 in Fig. 1, not shown in Fig. 2). For some motor-driving applications it also helps to put a diode in series with the negative supply lead. This diode must be able to dissipate continuous power depending on the supply current and may need to be on a heatsink. The clamp diodes only dissipate transient power and so they should not require heatsinking, but they need to be able to withstand high transient currents.

As with all power circuits good thermal design is also required when using any of the three devices discussed here. All the devices feature internal thermal shutdown protection circuits so they should survive situations which cause them to overheat, but the circuit will not be operating when the i.c. is shut down.

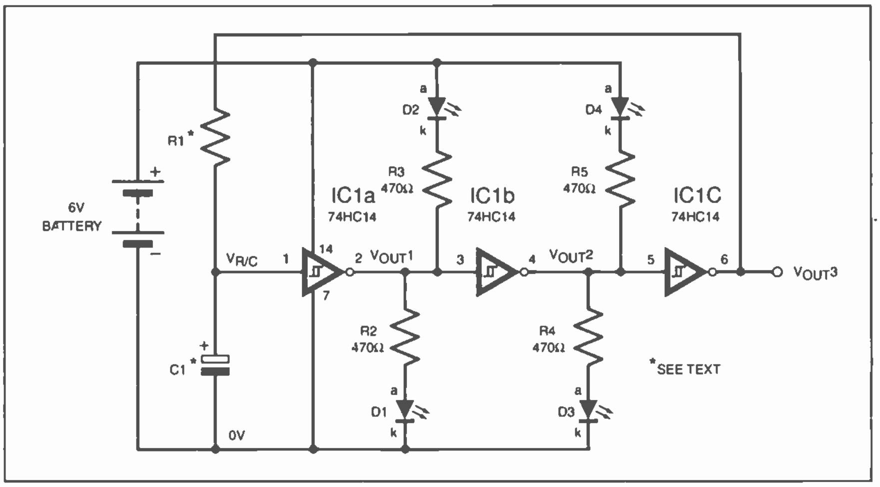


Fig.3. Original Schmitt trigger-based circuit diagram (Fig.2.15) from the EPE Teach-In 2000 (Part 2) *series. The complete series (plus the interactive software) is available on a single CD-ROM – see* CD-ROMs for Electronics *or* Direct Book Service *pages.*

The datasheet provides more details and can be fetched from the National web site (**www.national.com**) – or type "LM12" into *Google*. *I.M.B.*

Brazen Terminology

Thank you very much for the notes on "soldering" and I hope the material will help my civil engineering students to learn the basics. I would be thankful if you could kindly mail sketches of the soldering "set up" and some similar explanations on "brazing" and incidentally the glossary of terms including "solidus" and "liquidus". Thank you for providing the learning material. **Prof. V.R. Vivekanandan,** ***Periyar Maniammai College of Technology for Women, Thanjavur, India.***

The *Basic Soldering Guide* on our web site (**www.epemag.wimborne.co.uk** – go to Resources) continues to provide beginners everywhere with a very fundamental introduction to electronics soldering: it rates as being the most popular resource of its type on the internet. I'm afraid that no sketches are available to send you but hopefully the online step-by-step photos will explain the use of a soldering iron and desoldering pump.

The terms *solidus* and *liquidus* in this electronics context relate to the melting or solidifying points of solder: solidus is the *highest* temperature at which the solder is completely solid, before it starts to flow. Liquidus is the *coolest* temperature at which it is completely liquid, before it starts to harden.

I have been asked a number of times by readers and internet users to explain what exactly "brazing" is. Brazing uses higher temperatures than can be achieved with a soldering iron, and is a technique used in metal fabrication work, using suitable gas torches and adding non-ferrous alloy wire as a filler, to bond metals together. This is less aggressive than welding and is suited to more precise work.

If you have a mini gas torch of the type supplied with e.g. soldering tips or hot air blowers, note that the hottest part of a butane flame is the inner blue tip, where the gas is being burnt. Because the temperature needed is typically >425 degrees Celsius, ordinary solder cannot be used, and specialist alloy wire should be used instead. (I did however witness a car mechanic brazing a small steel plate onto a car body repair, using some coat hanger wire as the "alloy".) *A.R.W.*

Current Flow

Reader **Pete Barber** (in the EPE Chat Zone) recently asked:

I am learning electronics and am currently up to the Capacitors section of EPE Teach-In 2000. *I am building the Schmitt trigger-based oscillator (Fig. 2.15 on page 922,* EPE *Dec '99), see Fig.3. Looking at the ancillary circuitry, my Schmitt trigger has an l.e.d. in series with a 470 ohm resistor connected between the positive rail and the output pin.*

My question is, given that an output pin is used, how can the current flow into it to make the l.e.d. light?

This relates to the subject of "sourcing" and "sinking" current, which was dealt with in more detail in the Jan '04 issue of *Circuit Surgery*. To recap, some (but not all!) integrated circuits are capable of sinking current to 0V via their output pins. Indeed, some devices are optimised to sink current rather than source it from a "high" output. In your experiment, current can sink into the Schmitt trigger and illuminates the l.e.d. along the way.

Apart from having a logic "high" or logic "low" state when the output will either source or sink current respectively, another class of driver has a third state equivalent to an "open circuit" where the output is disconnected completely. These are termed "tri-state" devices and they can be used for controlling the flow of data on a data bus. An example is the 74HCT574 i.c. which has eight tri-state latches. *A.R.W.*

Circuit Surgery will wherever possible offer advice or pointers to readers, but we cannot guarantee to do so, and the ease with which queries can be sent by email does nothing to help! It is not always possible to offer either quick "snap" or considered answers to every circuit, especially if it would be necessary to build or simulate the circuit, but we do read every letter, reply where we can and we publish a selection of your queries every month. You can send your emails to **alan@epemag.demon.co.uk**.

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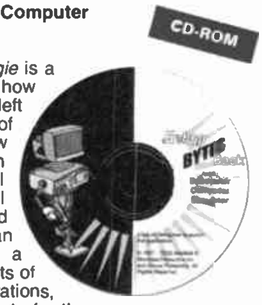

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The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.
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Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explainend, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

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Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

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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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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

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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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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.

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Project Building

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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.

138 pages **Order code BP371** **£5.45**

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R. A. Penfold

While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

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 the individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

138 pages **Order code PC116** **£5.45**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold

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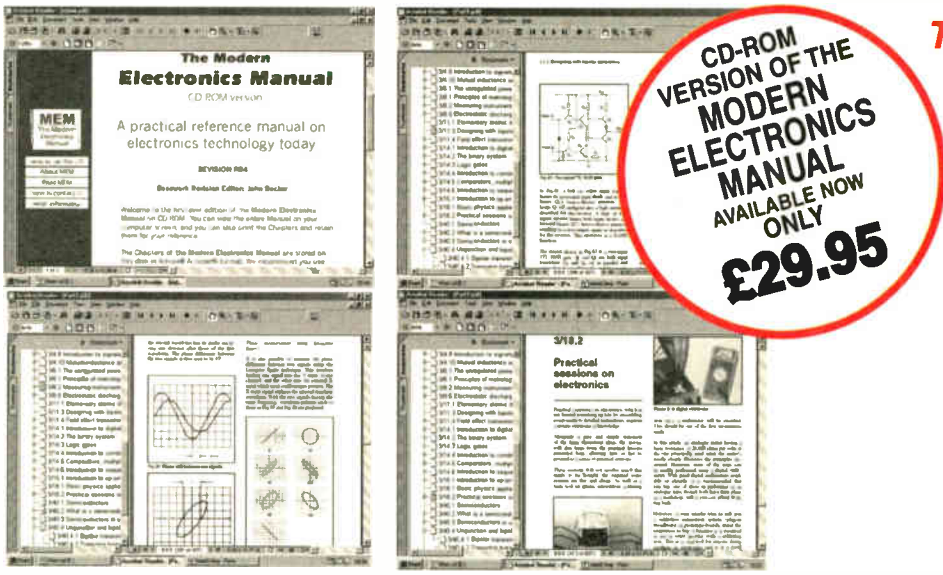

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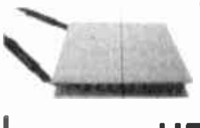

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