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EVERYDAY

Vol.33 No.3

PRACTICAL ELECTRONICS

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Keep track of MIDI codes

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For Delta and V-tail planes

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Be prepared for power cuts

BAT BAND CONVERTER

Listen to bats' radar

PLUS

TEACH-IN 2004

Part 5 - Logic Gates as Switches

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

VOL. 33. No. 3 MARCH 2004
Cover illustration by jgr22

EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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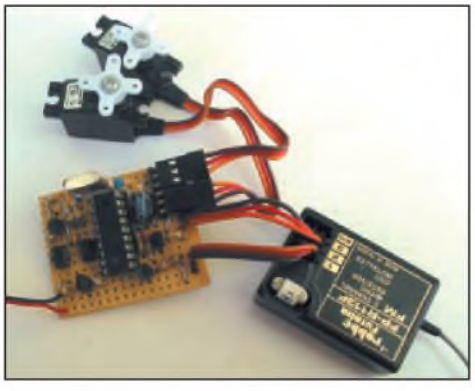

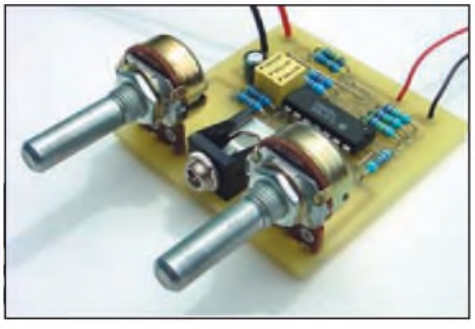

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NEXT MONTH

EXPERIMENTAL SEISMOGRAPH LOGGER

Although seismographs are widely used to monitor naturally occurring earthquakes, they can be used to monitor any *shaking of the earth, including movement caused by man's activities. This PIC-controlled seismograph responds to any vibrational displacement between two halves of a sensor pair.*
The PIC samples the data at 25Hz, constantly outputting it as a serial stream suitable for input to a PC computer at 9600 baud and storage to its hard drive at a rate selected by the user. It can also store the data to an optional on-board set of non-volatile serial memories, for later download to a PC as a complete block whenever desired, at intervals of hours, days, or even months.
At the PC, specially written software allows the data recorded by both techniques to be selectively displayed on screen. It is also in a format suited to further analysis by Microsoft Excel or similar spreadsheet and graphing display software. It is believed that the software is compatible with Windows platforms 95, 98, ME, XP, NT and 2000, as long as the PC has a COM port.
The electronics and software could also be used with an existing seismograph assembly if its sensor system outputs a d.c. voltage in the range of 0V to +5V.

USB TO PIC MODULE REVIEW

Any computer purchased in the last few years is almost certain to be fitted with one or more USB (Universal Serial Bus) connectors. The intent of USB is to replace ageing parallel and serial interfaces in computer systems. While not the fastest form of computer interface, USB is designed to be easy to set up, user-friendly, and possesses a bus architecture which enables data from many devices to be funnelled into and out of a computer in an orderly manner.
This review describes a USB to PIC interface module, the DLP-245PB, which is marketed by DLP Design. The interface can transfer data to and from the host computer at up to two megabits per second.

PIC MOON CLOCK

This design uses 12 l.e.d.s arranged in a circle to display the phases of the Moon, waxing, waning, full or new. The circuit construction and software are suitable for beginners. Its designer has worked at the Time and Frequency section of the National Physical Laboratory – and was once a Time Lord*!*

SEMICONDUCTOR CLASSIFICATION DATA

Semiconductor devices are classified using a unique part numbering system. Several schemes are in use, including the American Joint Engineering Device Engineering Council (JEDEC) system, the European Pro-Electron system, and the Japanese Industrial Standard (JIS) system. In addition some manufacturers have adopted their own coding schemes. Next month we provide an explanation of the three main coding systems and itemise the prefix code letters used by manufacturers when numbering their semiconductor devices.

PLUS **TEACH-IN 2004 – PART 6 SOUND LEVEL MEASUREMENT**

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Will program virtually ALL 8 to 40 pin PICs plus certain ATMEL AVR, SCENIX SX and EEPROM 24C devices. Also supports In System Programming (ISP) for PIC and ATMEL AVRs. Free software. Blank chip auto detect for super fast bulk programming. Requires a 40-pin wide ZIF socket (not included)
Kit Order Code: 3144KT – **£54.95**
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ATMEL 89xxx Programmer

Uses serial port and any standard terminal comms program. 4 LEDs display the status. ZIF sockets not included. Supply: 16VDC.
Kit Order Code: 3123KT – **£29.95**
Assembled Order Code: AS3123 – **£34.95**

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket and USB Plug A-A lead extra. 18VDC.
Kit Order Code: 3149KT – **£29.95**
Assembled Order Code: AS3149 – **£44.95**

Introduction to PIC Programming

Go from a complete PIC beginner to burning your first PIC and writing your own code in no time! Includes a 49-page step-by-step Tutorial Manual, Programming Hardware (with LED bench testing section), Win 3.11–XP Programming Software (will Program, Read, Verify & Erase), and a rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). Connects to PC parallel port.
Kit Order Code: 3081KT – **£14.95**
Assembled Order Code: AS3081 – **£24.95**

ABC Mini Microcontroller Board

ABC Mini Starter Pack

Currently learning about microcontrollers? Need to do more than flash a LED or sound a buzzer? The ABC Mini Starter Kit is based on ATMEL's AVR 8535 RISC technology and will interest both the beginner and expert alike.
Beginners will find that they can write and test a simple program, using the BASIC programming language, within an hour or two of connecting it up. Experts will like the power and flexibility of the ATMEL microcontroller, as well as the ease with which the board can be "designed-in" to a project.
The ABC Mini STARTER PACK includes everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled ABC Mini Board with parallel and serial cables for connection to your PC. Windows software included on CD-ROM features an Assembled, BASIC compiler and in-system programmer.
Order Code ABCMINISP – **£49.95**
The ABC Mini boards only can also be purchased separately at £29.95 each.

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have.
See website for full details. Suitable PSU for all units: Order Code **PSU203** – **£9.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 TXs can be learned by one Rx (kit includes one Tx but more available separately). 4 indicator LEDs.
Rx: PCB 77x85mm, 12VDC/6mA (standby).
Two & Ten Channel versions also available.
Kit Order Code: 3180KIT – **£41.95**
Assembled Order Code: AS3180 – **£49.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes one DS1820 sensor and four header cables.
Kit Order Code: 3145KT – **£22.95**
Assembled Order Code: AS3145 – **£29.95**
Additional DS1820 Sensors – **£3.95 each**

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

NEW! DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12VDC.
Kit Order Code: 3140KT – **£39.95**
Assembled Order Code: AS3140 – **£59.95**

Serial Port Isolated I/O Module

Computer controlled 8-channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130 x 100 x 30mm. Power: 12VDC/500mA.
Kit Order Code: 3108KT – **£54.95**
Assembled Order Code: AS3108 – **£64.95**

Infra-red RC 12-Channel Relay Board

Control 12 on-board relays with included infra-red remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12VDC/0·5A.
Kit Order Code: 3142KT – **£41.95**
Assembled Order Code: AS3142 – **£59.95**

PC Data Acquisition & Control Unit

Monitor and log a mixture of analogue and digital inputs and control external devices via the analogue and digital outputs. Monitor pressure, temperature, light intensity, weight, switch state, movement, relays, etc. with the apropriate sensors (not supplied). Data can be processed, stored and the results used to control devices such as motors, sirens, relays, servo motors (up to 11) and two stepper motors.

Features

- 11 Analogue Inputs – 0·5V, 10 bit (5mV/step)
- 16 Digital Inputs – 20V max. Protection 1K in series, 5·1V Zener
- 1 Analogue Output – 0-2·5V or 0-10V. 8 bit (20mV/step)
- 8 Digital Outputs – Open collector, 500mA, 33V max
- Custom box (140 x 110 x 35mm) with printed front & rear panels
- Windows software utilities (3·1 to XP) and programming examples
- Supply: 12V DC (Order Code PSU203)

Kit Order Code: 3093KT – **£69.95**
Assembled Order Code: AS3093 – **£99.95**

Cool New Kits This Winter!

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

NEW! EPE Ultrasonic Wind Speed Meter

Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

Specifications

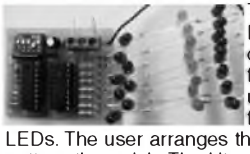
- Units of display: metres per second, feet per second, kilometres per hour and miles per hour
- Resolution: Nearest tenth of a metre
- Range: Zero to 50mph approx.

Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see web site for full details). Power: 9VDC (PP3 battery or Order Code PSU203).
Main PCB: 50 x 83mm.
Kit Order Code: 3168KT – **£34.95**

NEW! Audio DTMF Decoder and Display

Detects DTMF tones via an on-board electret microphone or direct from the phone lines through an audio transformer. The numbers are displayed on a 16-character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based.
Supply: 9-12V DC (Order Code PSU203).
Main PCB: 55 x 95mm.
Kit Order Code: 3153KT – **£17.95**
Assembled Order Code: AS3153 – **£29.95**

NEW! EPE PIC Controlled LED Flasher



This versatile PIC-based LED or filament bulb flasher can be used to flash from 1 to 160 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 superbright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher by Steve Challinor, *EPE* Magazine Dec '02. See website for full details. Board Supply: 9-12V DC. LED supply: 9-45V DC (depending on number of LED used). PCB: 43 x 54mm.
Kit Order Code: 3169KT – **£10.95**

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

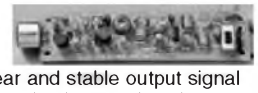
FM Bugs & Transmitters

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

MMTX' Micro-Miniature 9V FM Room Bug

Our best selling bug! Good performance. Just 25 x 15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band.
Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT – **£8.95**
Assembled Order Code: AS3051 – **£14.95**

HPTX' High Power FM Room Bug



Our most powerful room bug. Very Impressive performance. Clear and stable output signal thanks to the extra circuitry employed.
Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip suppied). 70 x 15mm.
Kit Order Code: 3032KT – **£9.95**
Assembled Order Code: AS3032 – **£17.95**

MTTX' Miniature Telephone Transmitter

Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire – uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20 x 45mm.
Kit Order Code: 3016KT – **£7.95**
Assembled Order Code: AS3016 – **£13.95**

3 Watt FM Transmitter

Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 3 watts of RF power. Can be used with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45 x 145mm.
Kit Order Code: 1028KT – **£22.95**
Assembled Order Code: AS1028 – **£34.95**

25 Watt FM Transmitter

Four transistor based stages with a Philips BLY89 (or equivalent) in the final stage. Delivers a mighty 25 Watts of RF power. Accepts any line level audio source (input sensitivity is adjustable). Antenna can be an open dipole, ground plane, 5/8, J, or YAGI configuration. Supply 12-14V DC, 5A. Supplied fully assembled and aligned – just connect the aerial, power and audio input. 70 x 220mm.
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3143KT – 10W Stereo Amplifier £9.95
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3102KT – 4-Ch Servo Motor Driver £15.95
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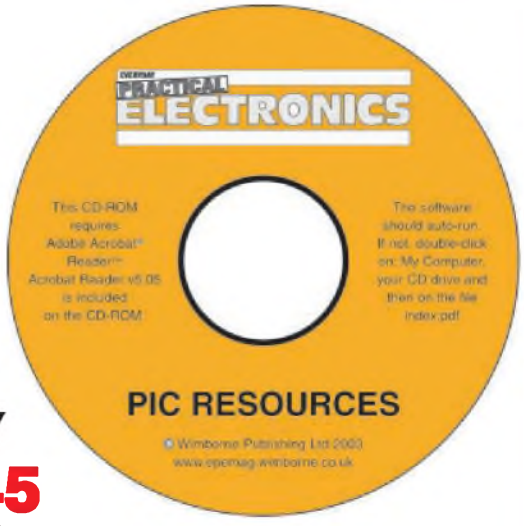

A companion to the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

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- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

Plus these useful texts to help you get the most out of your PIC programming:

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- Additional text for EPE PIC Tutorial V2, John Becker, unpublished

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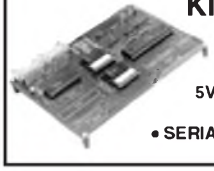
- High stability drift cancelling
- Easy to build & use
- No ground effect, works in seawater
- Detects gold, silver, ferrous & non-ferrous metals
- Efficient quartz controlled microcontroller pulse generation
- Full kit with headphones & all hardware

KIT 847 .....£63.95

68000 DEVELOPMENT TRAINING KIT

- NEW PCB DESIGN
- 8MHz 68000 16-BIT BUS
- MANUAL AND SOFTWARE
- 2 SERIAL PORTS
- PIT AND I/O PORT OPTIONS
- 12C PORT OPTIONS



KIT 621
£99.95
• ON BOARD 5V REGULATOR
• PSU £6.99
• SERIAL LEAD £3.99

Stepping Motors

MD100..Std 100 step..£9.99
MD200...200 step...£12.99
MD24...Large 200 step...£22.95

PIC PIPE DESCALER

- SIMPLE TO BUILD
- SWEPT FREQUENCY
- HIGH POWER OUTPUT
- AUDIO & VISUAL MONITORING

An affordable circuit which sweeps the incoming water supply with variable frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve lathering ability by altering the way salts in the water behave.
Kit includes case, P.C.B., coupling coil and all components.
High coil current ensures maximum effect. L.E.D. monitor.

KIT 868 ..... £22.95 **POWER UNIT.....£3.99**

MICRO PEsT SCARER

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**

Plug-in power supply £4.99

KIT 867.....£19.99
KIT + SLAVE UNIT.....£32.50

WINDICATOR

A novel wind speed indicator with LED readout. Kit comes complete with sensor cups, and weatherproof sensing head. Mains power unit £5.99 extra.

KIT 856.....£28.00

★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

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.

KIT 866. . Full kit including four electrodes £32.90

1000V & 500V INSULATION TESTER

Superb new design. Regulated output, efficient circuit. Dual-scale meter, compact case. Reads up to 200 Megohms.
Kit includes wound coil, cut-out case, meter scale, PCB & ALL components.

KIT 848.....£32.95

EPE TEACH-IN 2000

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.*

***TEACH-IN 2000* -**

KIT 879 £44.95
MULTIMETER £14.45

SPACEWRITER

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.

NEW WITH PIC16F84 EEPROM CHIP & SOFTWARE DISK

KIT 849 .....£16.99

12V EPROM ERASER

A safe low cost eraser for up to 4 EPROMS at a time in less than 20 minutes. Operates from a 12V supply (400mA). Used extensively for mobile work - updating equipment in the field etc. Also in educational situations where mains supplies are not allowed. Safety interlock prevents contact with UV.

KIT 790 .....£29.90

SUPER BAT DETECTOR

1 WATT O/P, BUILT IN SPEAKER, COMPACT CASE
20kHz-140kHz
NEW DESIGN WITH 40kHz MIC.

A new circuit using a 'full-bridge' audio amplifier i.c., internal speaker, *and* headphone/tape socket. The latest sensitive transducer, and 'double balanced mixer' give a stable, high performance superheterodyne design.

KIT 861 .....£27.99
ALSO AVAILABLE Built & Tested. . . **£42.99**

MOSFET MkII VARIABLE BENCH POWER SUPPLY 0-25V 2·5A

Based on our Mk1 design and preserving all the features, but now with switching pre-regulator for much higher efficiency. Panel meters indicate Volts and Amps. Fully variable down to zero. Toroidal mains transformer. Kit includes punched and printed case and all parts. As featured in April 1994 *EPE*. An essential piece of equipment.

Kit No. 845 .....£64.95

ULTRASONIC PEsT SCARER

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.

- KIT INCLUDES ALL COMPONENTS, PCB & CASE
- EFFICIENT 100V TRANSDUCER OUTPUT
- COMPLETELY INAUDIBLE TO HUMANS
- 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

NEW

- Full kit with ALL hardware and electronics
- As featured in *EPE* Feb '03 – KIT 910
- Seeks light, beeps, avoids obstacles
- 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

- ZERO VOLT SWITCHING
- OPTO ISOLATED 5 Amp
- 12 KEYPAD CONTROL
- HARD-FIRED TRIACS
- WITH SOURCE CODE
- SPEED & DIMMING POT.
- 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!

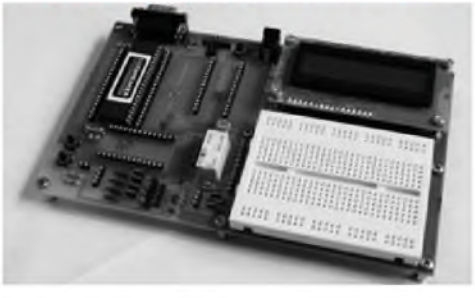
8-CHANNEL DATA LOGGER

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

- Icebreaker uses PIC16F877 in circuit debugger
- Links to Standard PC **Serial** Port (lead supplied)
- Windows™ (95+) Software included
- Works with MPASM and MPLAB Microchip software
- 16 x 2 L.C.D., Breadboard, Relay, I/O devices and patch leads supplied

As featured in March '00 *EPE*. Ideal for beginners AND advanced users.
Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time.
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**

EPE TEACH-IN 2004

THE LATEST SERIES – STARTED NOV '03
ALL PARTS INCLUDING PROTOTYPE BREADBOARD AND WIRE – AS LISTED ON p752 NOV. ISSUE (EXCL MISC.)
"A BRILLIANT NEW ELECTRONICS COURSE"

KIT 920 . . . £29.99

ADDITIONAL PARTS – AS LISTED UNDER MISCELLANEOUS – BUT LESS RADIO MODULES, SOLENOID LOCK AND MOTOR/GEARBOX.

KIT 921 . . . £12.99

EPE PIC Tutorial V2

EPE APR/MAY/JUNE '03 and PIC RESOURCES CD

FOLLOW THIS SERIES WITH EPE PIC TOOLKIT 3

- THE LATEST TOOLKIT BOARD – 8, 18, 28 AND 40-PIN CHIPS
- MAGENTA DESIGNED P.C.B. WITH COMPONENT LAYOUT AND EXTRAS
- L.C.D. BREADBOARD AND PIC CHIP INCLUDED
- ALL TOP QUALITY COMPONENTS AND SOFTWARE SUPPLIED

KIT 880 . . . £34.99 WITH 16F84

PIC TUTOR 1

MARCH - APRIL - MAY '98 EPE SERIES 16F84

PIC TUTOR BOARD KIT

Includes: PIC16F84 Chip, TOP Quality PCB printed with Component Layout and all components* (*not ZIF Socket or Displays). Included with the Magenta Kit is a disk with Test and Demonstration routines.

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

Optional: **Power Supply – £3.99, ZIF Socket – £9.99**
LCD Display ..... **£7.99** **LED Display** **£6.99**
Reprints Mar/Apr/May 98 – **£3.00 set 3**

SUPER PIC PROGRAMMER

- READS, PROGRAMS, AND VERIFIES
- WINDOWS™ SOFTWARE
- PIC16C AND 16F – 6X, 7X, AND 8X
- USES ANY PC PARALLEL PORT
- USES STANDARD MICROCHIP • HEX FILES
- DISASSEMBLER SOFTWARE
- PCB, LEAD, ALL COMPONENTS, TURNED-PIN SOCKETS FOR 18, 28, AND 40 PIN ICs

• SEND FOR DETAILED INFORMATION – A SUPERB PRODUCT AT AN UNBEATABLE LOW PRICE.

Kit 862 £29.99

Power Supply £3.99

PIC STEPPING MOTOR DRIVER

INCLUDES PCB, PIC16F84 WITH DEMO PROGRAM, SOFTWARE DISC, INSTRUCTIONS AND MOTOR.

Kit 863 £18.99

FULL SOURCE CODE SUPPLIED
ALSO USE FOR DRIVING OTHER POWER DEVICES e.g. SOLENOIDS

Another Magenta PIC project. Drives any 4-phase unipolar motor – up to 24V and 1A. Kit includes all components and 48 step motor. Chip is pre-programmed with demo software, then write your own, and re-program the same chip! Circuit accepts inputs from switches etc and drives motor in response. Also runs standard demo sequence from memory.

MAGENTA

All prices include VAT. Add **£3.00** p&p. Next day **£6.99**

Tel: 01283 565435 **Fax: 01283 546932** **E-mail: sales@magenta2000.co.uk**

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

Prices Exclude Vat @17½%.
UK Carriage £1.50 (less than 1kg)
£3.50 greater than 1kg
Cheques / Postal orders payable to ESR Electronic Components.
PLEASE ADD CARRIAGE & VAT TO ALL ORDERS

See Next / Last Months Ad. for COMPONENT ACCESSORIES

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4012B	£0.16	74HC123	£0.33	74LS133	£0.36
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4014B	£0.30	74HC126	£0.44	74LS138	£0.33
4015B	£0.27	74HC132	£0.26	74LS139	£0.26
4016B	£0.20	74HC133	£0.34	74LS145	£0.56
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4018B	£0.26	74HC138	£0.29	74LS151	£0.29
4019B	£0.25	74HC139	£0.31	74LS153	£0.38
4020B	£0.26	74HC151	£0.33	74LS156	£0.36
4021B	£0.31	74HC153	£0.30	74LS157	£0.22
4022B	£0.32	74HC154	£0.85	74LS158	£0.21
4023B	£0.23	74HC157	£0.40	74LS160	£0.48
4024B	£0.22	74HC158	£0.23	74LS161	£0.32
4025B	£0.20	74HC160	£0.64	74LS162	£0.44
4026B	£0.70	74HC161	£0.28	74LS163	£0.32
4027B	£0.22	74HC162	£0.45	74LS164	£0.43
4028B	£0.33	74HC163	£0.26	74LS165	£0.48
4029B	£0.33	74HC164	£0.23	74LS173	£0.24
4030B	£0.17	74HC165	£0.35	74LS174	£0.24
4035B	£0.31	74HC173	£0.38	74LS175	£0.30
4040B	£0.24	74HC174	£0.27	74LS190	£0.60
4041B	£0.31	74HC175	£0.35	74LS191	£0.27
4042B	£0.22	74HC192	£0.72	74LS192	£0.60
4043B	£0.35	74HC193	£0.40	74LS193	£0.43
4044B	£0.35	74HC195	£0.32	74LS195	£0.24
4046B	£0.35	74HC240	£0.32	74LS196	£0.24
4047B	£0.32	74HC241	£0.37	74LS221	£0.41
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4049B	£0.29	74HC245	£0.34	74LS241	£0.32
4049UB	£0.24	74HC251	£0.30	74LS243	£0.30
4050B	£0.20	74HC253	£0.25	74LS244	£0.38
4051B	£0.21	74HC257	£0.25	74LS245	£0.32
4052B	£0.32	74HC259	£0.57	74LS247	£0.60
4053B	£0.22	74HC273	£0.32	74LS251	£0.24
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4072B	£0.18	74HC564	£0.48	74LS373	£0.32
4073B	£0.17	74HC573	£0.27	74LS374	£0.38
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4076B	£0.30	74HC595	£0.27	74LS390	£0.34
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4078B	£0.30	74HC4002	£0.31	74LS395	£0.26
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4538B	£0.40	74LS12	£0.25	ADEL2020A	£5.06
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40174B	£0.46	74LS38	£0.16	CA3046	£0.65
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LP339N	£0.75	78L05	£0.23
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NE565N	£2.30	LM317T	£0.31
NE567N	£0.39	LM317K	£2.48
NE592	£0.62	LM323K	£2.40
NE5532N	£0.48	LM334Z	£0.96
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OP177GP	£1.86		
OP200GP	£5.40	**Diodes**	
OP213FP	£5.70	1N914	£0.05
OP275GP	£2.57	1N916	£0.06
OP282GP	£2.27	1N4001	£0.05
OP283GP	£5.20	1N4002	£0.05
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THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

VOL. 33 No. 3 **MARCH 2004**

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL
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Phone: (01202) 873872. Fax: (01202) 874562.
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INGENIOUS

Once again it is time to choose some *Ingenuity Unlimited* prizewinners and, for this exercise, Technical Editor John and I review those published over the year, make our choices then compare notes, discuss the pros and cons of each of them and come up with a winner. We judge this on the ingenuity, practicality and usefulness of each design. What struck me when looking through those published over the last year was the diverse range of subjects covered.

We also receive entries from all around the world. Please keep them coming, but please also remember that we are looking for practical circuit ideas that have not been previously published and are a result of your own inventiveness. We do not accept projects requiring programming for *IU*, nor do we accept theoretical ideas.

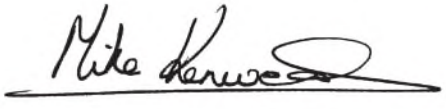
On the subject of prizes, I would like to thank Pico Technology Ltd and Peak Electronic Design Ltd, who generously sponsor our *IU* and *Readout* pages, thus further encouraging reader response to these regular items.

PIC N' MIX

When it comes to programmable ideas of the PIC variety we are planning to introduce a new *PIC N' Mix* page in the near future that will cover various aspects of PIC programming. The page is presently at the planning stage, but it is hoped that it will generate reader response both with queries and suggestions, so that it will become interactive in a similar way to *Circuit Surgery*. As they say, watch this space for further news.

NOT ONE?

Back in the January issue I wondered why so few females were interested in electronics and asked for your views on this. I was, of course, hoping to hear from some of our female readers, but so far we have had no response – any views anyone?



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PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages than can be lethal. **You should not build, test, modify or renovate any item of mains powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

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Constructional Project

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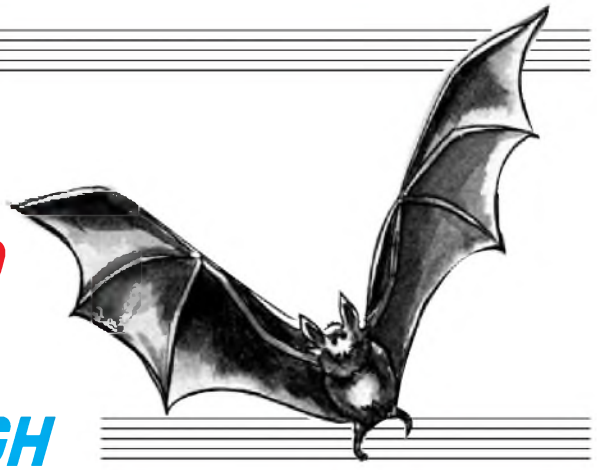


THOMAS SCARBOROUGH

Listen-in to the world of bats with this low-cost b.f.o. detector

THE author's original purpose was to design a simple Bat-Band Convertor that would "really work". The resulting Bat-Band Convertor uses just a single i.c. and a handful of components to deliver surprisingly good performance.

The circuit has been named a Bat-Band Convertor, since it not only *detects* bats, but *converts* their sounds to frequencies that fall within the range of human hearing. In so doing, it gives a reasonably faithful representation of a bat's sound.

It is well known that bats use ultrasound for navigation and the location of prey. A bat will emit rapid bursts of ultrasound – typically 10 to 200 times a second, increasing in rapidity as a bat closes on its prey. These bursts are in the region of 12kHz to 150kHz, with wide variations in frequency, depending on the species.

They are high amplitude sounds, and the first time the author used a bat detector, he was surprised at the volume that a bat emits. A typical bat will "scream its little lungs out"!

HEAR-HEAR

The Bat-Band Convertor is a highly sensitive circuit that "hears" over the range of 13·6kHz to 180kHz. The only limiting factor will be the transducer that you use.

The author settled on a standard 40kHz ultrasonic receiver transducer, and this gave good performance up to about 50kHz, with sensitivity dropping off around 60kHz. However, it was able to "hear" well above 100kHz, and the first test of the unit will be performed at 180kHz.

Constructors might wish to experiment with the transducer, and virtually any piezo device may be tried. A standard piezo sounder might well "hear" up to 50kHz, at minimal cost, and may even hear (faintly) beyond 100kHz. A crystal earpiece, too, was tried with some success.

A piezo horn tweeter was found to perform particularly well, offering better reception than a 40kHz ultrasonic transducer, and reasonable reception even up to 180kHz. It is, of course, far bulkier, and it admitted more ultrasonic noise than a 40kHz transducer – but this may in some cases be desired. The author suggests that constructors might like to try such a tweeter, and contrast its performance with a 40kHz ultrasonic transducer.

IN CONCEPT

There are two common approaches to bat detectors. The first is to compress a range of frequencies (e.g. 20kHz to 100kHz) into the range of human hearing (e.g. 2kHz to 10kHz). That is, the sounds which a bat emits are divided into lower frequencies.

The author has also used this principle to obtain a *visual* representation of a bat's sound, and this has the advantage of eliminating low frequency sounds in particular, which can be the bane of budget bat detectors.

A second approach, which is the one used here, is to use a beat frequency oscillator (b.f.o.) to obtain a beat note. As the sound of the bat is mixed with the oscillator frequency, a beat note or heterodyne is created, which represents the *difference* between the two frequencies. Hence it is sometimes called a *difference frequency*.

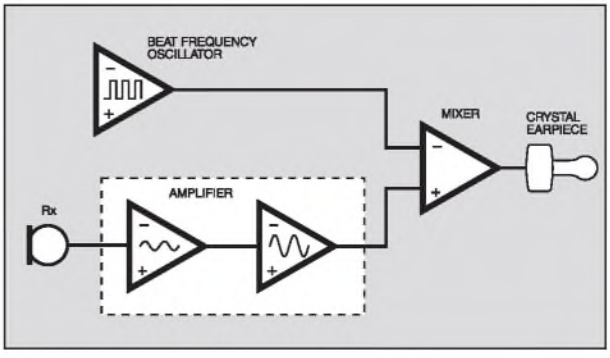


Fig.1. Block diagram for the Bat-Band Convertor.

This means that one needs to tune the circuit to within about 10kHz of a bat's sound to obtain the beat note. If the difference is greater than this, the beat note will be too high to be heard – unless one should be hearing harmonics.

This approach has the advantage of obtaining a "deeper" representation of a bat's sound (rather than a compressed one), it greatly reduces the problem of loud low frequency sounds, and it may be used to hunt for particular bats whose frequency is known. For example, Horseshoe bats use fixed frequencies of around 80kHz to 100kHz, and this easily distinguishes them from more common bats such as the Pipistrelle, which use variable frequencies of around 40kHz to 50kHz.

The block diagram in Fig.1 shows the simplicity of the concept. An amplifier, based on two j.f.e.t. op.amps, amplifies the bat's sound. A third j.f.e.t. op.amp is wired as a beat frequency oscillator. These two frequencies are mixed by a fourth j.f.e.t. op.amp, creating a beat note at the output.

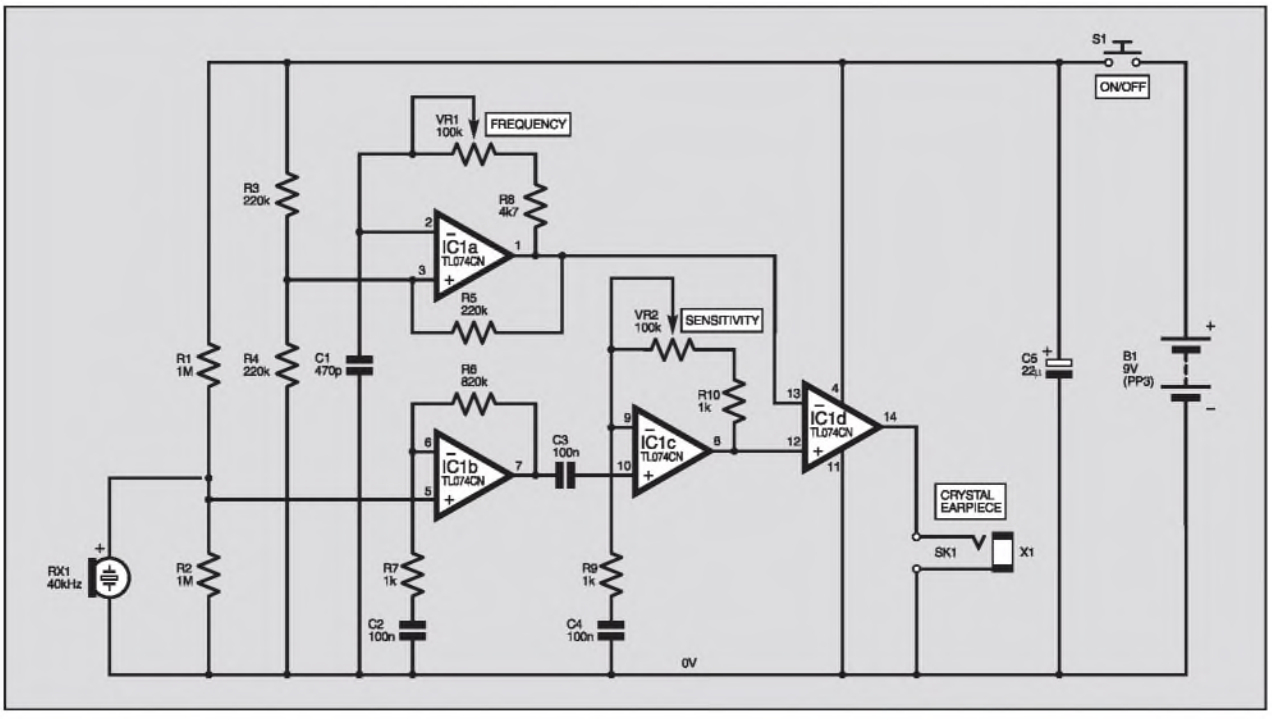


Fig.2. Complete circuit diagram for the Bat-Band Convertor. The crystal earpiece is plugged into the jack socket SK1.

CIRCUIT DETAIL

The complete circuit diagram for the Bat-Band Convertor is shown in Fig.2. IC1a represents a standard *RC* op.amp oscillator. The timing elements are capacitor C1, potentiometer VR1 and resistor R8. Depending on the setting of potentiometer VR1, IC1a oscillates between 13·6kHz and 180kHz.

As capacitor C1 charges and discharges, so IC1a's non-inverting input flips "high" and "low", causing the output to continually change its state. This serves as a so-called reference oscillator.

A simple square wave oscillator is used here, since this is the easiest op.amp oscillator to implement, while it offers a very wide frequency range. A simple Wien Bridge op.amp oscillator would produce a finer result, but this would lack the necessary flexibility. Also, alternatives would require a good many more components.

Two simple non-inverting amplifiers are made up of IC1b and IC1c. Depending on the setting of potentiometer VR2, their combined gain will lie between 820 and 82,000 times. If gain needs to be increased, increase the value of resistor R6 – and vice versa. Or, if the output should prove to be too loud, a resistor may be wired in series with the crystal earpiece X1.

The final stage, IC1d, is a simple mixer, which is essentially switched on and off by oscillator IC1a, causing the difference frequency to appear at the ouput.

Supposing that a bat emits a fixed frequency of 80kHz, and that IC1d is switched at 75kHz, this would lead to rises and falls in amplitude at a rate of 5kHz, thereby rendering the bat's sound audible. The same would apply if the reference oscillator were running faster than the frequency of the bat. Waveform Fig.3a shows the circuit's output at 40kHz when no sound is heard, and Fig.3b when ultrasound (in this case ultrasonic noise) is detected.

Two further components deserve special mention, since these are critical to the correct operation of the circuit. They are resistors R1 and R2, which provide suitable d.c. bias at IC1b input pin 5. Without these resistors, performance would be erratic.

Current consumption is about 5mA, therefore the circuit will run for about one week continuously off a 9V alkaline PP3 "matchbox" battery. It may also be run off 12V. The circuit uses a pushbutton on-off switch, S1, which prevents it from being accidentally left on.

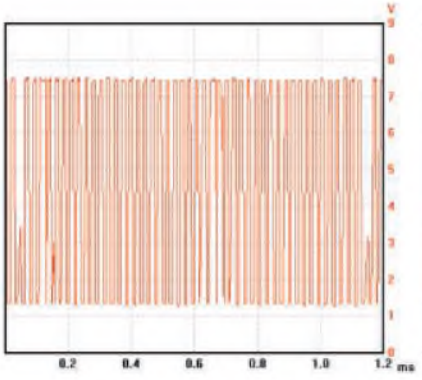


Fig.3a. Bat-Band Convertor tuned to 40kHz, no signal.

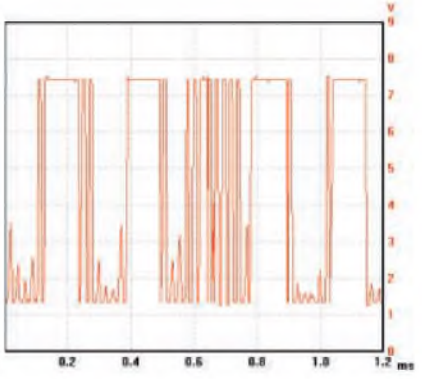


Fig.3b. Bat-Band Convertor tuned to 40kHz, ultrasonic noise.

COMPONENTS

See SHOP TALK page

Resistors

R1, R2	1M (2 off)
R3, R4, R5	220k (3 off)
R6	820k
R7, R9, R10	1k (3 off)

All 0·25W 5% carbon film

Potentiometers

VR1, VR2	100k rotary carbon, p.c.b. mounting – 5mm pin spacing, linear

Capacitors

C1	470p polyester
C2, C3, C4	100n polyester (3 off)
C5	22µ radial elect. 16V

Semiconductors

IC1	TL074CN quad low-noise j.f.e.t. op.amp

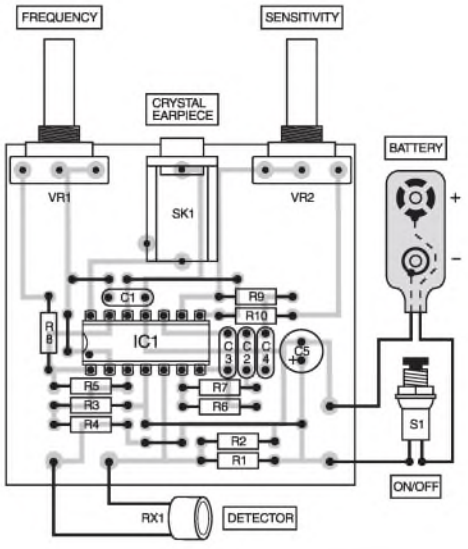
Miscellaneous

RX1	40kHz ultrasonic transducer (receiver)
X1	crystal earpiece
SK1	3·5mm p.c.b. mounting jack socket
B1	9V battery, PP3 type – see text
S1	pushbutton switch – push-to-make, release-to-break

Printed circuit board available from the *EPE PCB Service*, code 436; ABS plastic case, size 80mm x 60mm x 40mm (external); single-core link wire; multistrand connecting wire; battery clip (PP3 type); solder pins (4 off); solder etc.

Approx. Cost Guidance Only

£12 *excl. case & batt.*



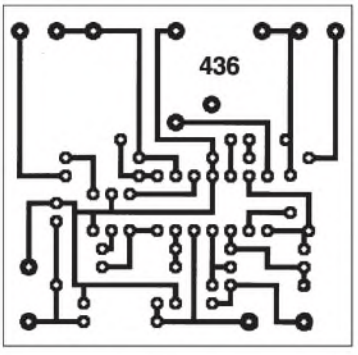


Fig.4. Printed circuit board component layout, off-board wiring details and full-size copper foil master for the Bat-Band Convertor.

CONSTRUCTION

The Bat-Band Convertor is a very sensitive circuit which operates at high frequencies, therefore it is recommended that all components be soldered *directly* to the printed circuit board (p.c.b.). The Convertor printed circuit board topside component layout, wiring and full-size underside copper foil master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 436.

Begin construction by soldering the link wires and resistors in position. Insert four solder pins, if desired, for the off-board wiring to the battery and the ultrasonic transducer RX1. Position and solder the capacitors on the p.c.b. – noting the correct orientation of C5.

Next, insert and solder in position the 3·5mm jack socket for the crystal earpiece, and the two potentiometers.

Finally, solder IC1 directly on the p.c.b. Be quick with the iron, so as not to damage IC1 – at the same time, be sure to make reliable joints.

Depending on what should prove to be more convenient, solder the battery clip, on-off pushbutton S1, and the ultrasonic receiver transducer to the p.c.b. now, or once the p.c.b. has been mounted in its case.

BOXING-UP

The circuit board is mounted in a small ABS plastic case, which measures (externally) approximately 80mm × 60mm × 40mm. Drill holes in the case for the potentiometers and the jack socket as required, and insert and secure the p.c.b. in the case.

Drill additional holes for the on-off pushbutton switch and the ultrasonic transducer, and mount these also in the case. Then attach the battery to its clip. A little padding (non-conductive) may be used to hold the battery when the case is closed.

If it should happen that the circuit has been double-checked, yet still will not work, your first suspicion should be directed at the solder joints. Although these may seem to be sound, in a circuit as sensitive as this one, they may well not be. Re-solder the joints one by one until (hopefully) the circuit comes to life.

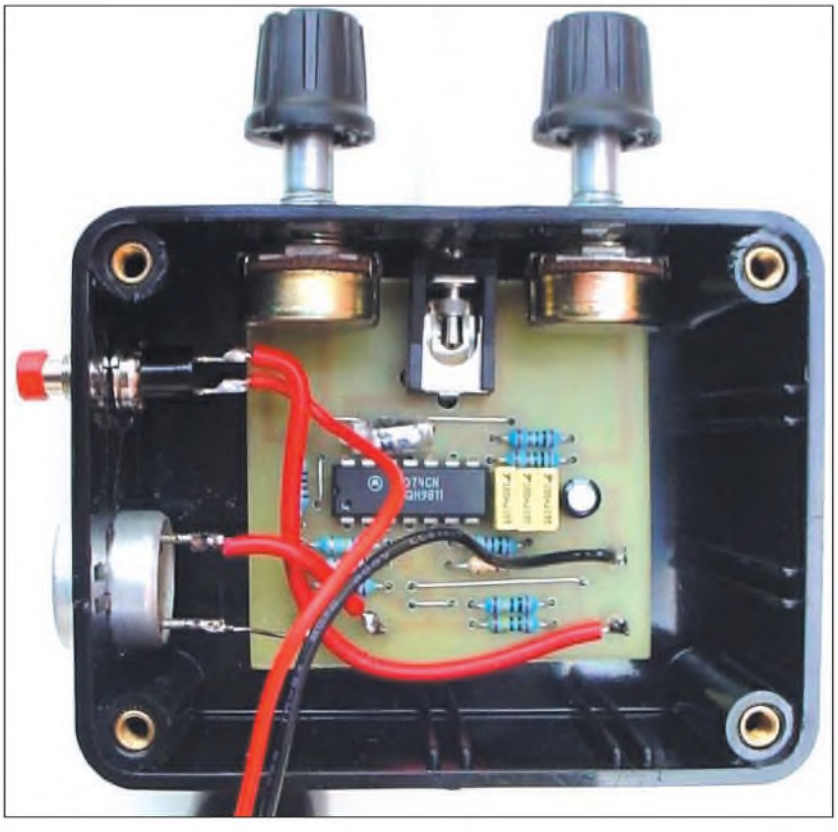
SET-UP AND USE

Sources of pure ultrasound are hard to find, although there are many sources of ultrasonic *noise* (e.g. paper tearing, hands rubbing together, keys jingling). A standard piezo sounder will respond well to such noise, as will the piezo tweeter mentioned earlier, while a 40kHz transducer will respond much better to pure frequencies.

One of the first things that the author discovered with a bat detector, many years ago, was that a cat will respond more keenly to "Puss!" than e.g. to "Marmalade!"for the reason that the "sss" in "Puss" creates a wide range of ultrasonic noise. This is the sound we shall use initially to test the Bat-Band Convertor.

Turn potentiometer VR1 fully clockwise (that is, to 180kHz), and turn sensitivity control VR2 fully back (anti-clockwise). Place the crystal earpiece in your ear, and switch on.

Now slowly turn up VR2 while gently saying "sssss" at about 10cm from the ultrasonic receiver transducer. A hiss will gradually become louder in the earpiece, until at a certain point clipping and severe distortion is likely to occur. Since this is random *noise*, it will not be as loud as a pure frequency might be (it will be louder if a piezo tweeter is used).

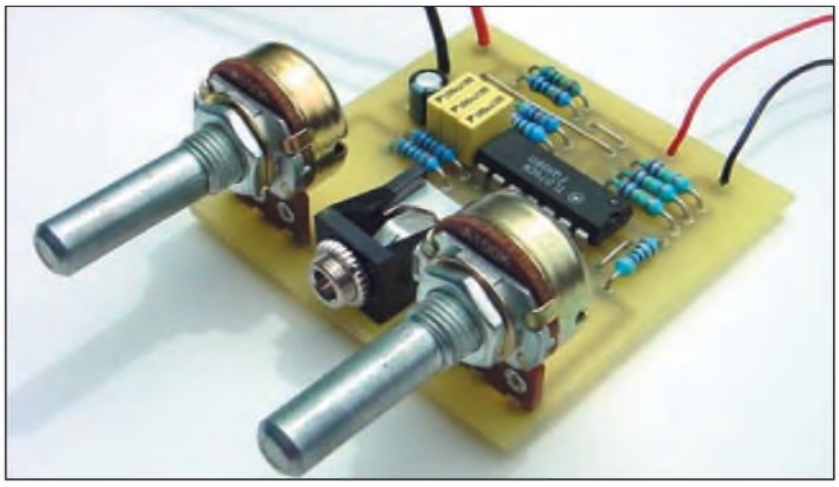


Layout of components inside the small plastic case.

As a further test, switch on your computer monitor or television set, and hold the Bat-Band Convertor near the rear of the enclosure. Turn up Sensitivity control VR2 to a suitable level (i.e. no clipping), then turn VR1 (Frequency) slowly through its entire range. You should pick up a number of pure ultrasonic frequencies.

It will be found that a pure frequency has a "null point", and that it will be heard at both sides of this point. When frequency adjustment VR1 is turned exactly to the null point (that is, silence), the Convertor is tuned exactly to the pure frequency.

When listening to bats, bear in mind that an ultrasonic transducer is highly directional, and there will be a large difference in reception depending on whether it is pointed directly at a bat or not (that is, there should be no more than about 15 degrees deviation from the source of the sound).



Completed Bat-Band Convertor circuit board.

IN CONCLUSION

A Bat-Band Convertor opens up a whole new world that is normally closed to us. Not only will it hear bats, but also many other creatures which emit ultrasound – in particular certain kinds of insect. In the author's surroundings, this includes some unusual creatures called cicada. These are so noisy they can be heard at 400 metres.

Apart from this, the Bat-Band Convertor will have a number of practical and scientific applications. It could be used as a puncture finder, since escaping air emits ultrasound. Likewise, it may be used to detect leaks in pipes. It may also be used to detect beetles or bumble-bees in wood.

It could also be used as a rough and ready "ear" for electronic experiments, or to determine the frequency response of ultrasonic transducers and piezo devices. If the frequency dial were calibrated, it could be used as a reasonably accurate frequency meter, with an accuracy better than 5%.

Finally, readers might recognise in this circuit both a v.l.f. (very low frequency) receiver and a complete digital voice transmitter.

In the case of the v.l.f. receiver, an aerial and earth are substituted for the ultrasonic transducer RX1, with a d.c. blocking capacitor being used with the aerial. A high pass filter would need to be inserted in the circuit to filter out mains interference in particular.

With regard to the digital voice transmitter, the reference oscillator would, in this case, modulate the voice for transmission.

The author was able to prove the idea, and digitally transmit and receive sound over a light beam, without any modification to the p.c.b. itself. A piezo sounder replaces the ultrasonic transducer, and a current amplifier may be added at the output to pulse an ultrabright l.e.d. A simple receiver may then feed an earpiece or headphones directly, without the need for any conversion of the received signal.

With a little further development, such a circuit should outperform similar analogue designs, since, being digital, it will transmit at full brightness all of the time. □

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News . . .

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

PENTIUM PROPOSALS PUZZLE?

Intel's new range of Pentium chips could well cause confusion in the marketplace, as Barry Fox reports.

CONFUSED? You soon will be. Intel, the company that makes the Pentium processor chips that power most Windows PCs, is now hoping to boost flagging computer sales by gunning for the audio and video market with a bewildering range of new Pentium computer chips.

"Re-inventing home entertainment" says Intel, without the encumbrance of any false modesty. "Share your digital creations – enjoy music your way by creating a digital music library while recording your favourite TV shows on your PC – edit and produce your family memories . . . experience breathtaking/realistic gaming environments online and offline".

Home Entertainment

Intel's push follows close on from the launch of Microsoft's Windows XP Media Center software, which is also supposed to turn the PC into a home entertainment centre.

Intel's briefing on the new chips was a confusion of old news, new news and news that must remain secret until launch dates that are themselves still secret. But after laborious checking with Intel, we can confidently report that the company's game plan boils down to this:

The original Pentium 4 was launched in late 2000, and it used components that are 180 nanometres apart. In January 2002 the spacing dropped to 130nm, which means there was more room for more components on a single chip, and less resistance to the current flowing between them. So less current is wasted and less heat generated. This design was code-named Northwood.

Then Intel added Hyper-Threading, which lets the computer do two things at the same time without crashing the PC. "It's anti-freeze for a PC" says Intel. Anything that really does stop PCs crashing has to be good news.

The next P4, due in February 2004, is called Prescott. This has nothing to do with the punchy British politician. Intel uses American place names as code-words for new products because they cannot infringe trademarks.

Prescott is made from "strained" silicon that has been stretched to increase electron transfer speeds. The spacing between its 125 million transistors has also been reduced to 90nm. So it uses less power. Prescott also uses Hyper-Threading. It runs at 3·4GHz and has a cache of 2MB onboard memory.

There is also a P4 Extreme Edition, also with Hyper-Threading, which will be sold as especially good for gamers.

So desktop PC makers will soon be offering a choice of boxes with P4 Extreme Edition, P4 Northwood and P4 Prescott, all with or without Hyper-Threading.

Power Considerations

Despite the close component spacing, these chips can use up to 100W of power, and on average 35W. So there must be special variants for laptop and pocket computers. These portable chips can also incorporate wireless equipment. The first of these combination chip sets, called the Mobile Centrino, was launched in March 2003. More are due later this year, called Dothan. There will be three different versions of Dothan, with different speeds, voltage and power consumption.

There are three existing Mobile Centrinos, with power consumption peaking at 24·5W for an operating voltage of 1·48V and speed of 1·7GHz, 12W for 1·18V and 1·2GHz, and 7W for 1V and 1GHz. Although the lower power consumption for the new versions of Dothan was openly given at the briefing, it was retroactively deemed secret. Suffice to say that Intel claims the average power for the new Dothans will be down to 0·5W, which puts Intel on the road to its long term design target – a laptop PC that runs for at least eight hours on a single charge.

So the PC industry can expect at least a dozen different new types of Pentium due this year.

Intel's spokesman Nick Knupffer rejects the suggestion that this will cause confusion on the shop floor and in adverts.

GO4.IT

WE have been told that a new web search engine has been launched, **www.Go4.it**. It is said to have a number of unique features, such as the business search facility, speed searching, speech enabled, travel portal, broadband and much more.

Go4.it has already attracted a large number of users over the last several months and the originators say that it has "already established itself as one of the world's top 25 search engines and is destined to break into the top 10 during 2004". It has dedicated versions running in the UK, USA, Canada, South Africa and Australia.

NANO CHIPS

BROWSING the BBC website at **http://news/bbc.co.uk/1/hi/sci/tech**, the caption "IBM hails nano chip-making method" caught our attention. BBC's Jonathan Amos was reporting that instead of the conventional technique of using light to help etch circuits onto chips, IBM are using molecules that assemble themselves into even smaller patterns.

Accessing IBM's Almaden Research Center site at **www.almaden.ibm.com**, the source story was found. IBM say the new "molecule cascade" technique has allowed working digital-logic elements to be made that are some 260,000 times smaller than those used in today's most advanced semiconductor chips.

The circuits are made by creating a precise pattern of carbon monoxide molecules on a copper surface. Moving a single molecule initiates a cascade of molecule motions, just as toppling a single domino can cause a large pattern to fall in sequence. IBM's scientists have created tiny structures that demonstrate the fundamental OR and AND logic functions, data storage and retrieval, and the "wiring" necessary to connect them into functioning computing circuitry.

The most complex circuit so far built, a 12 x 17 nanometre 3-input sorter (see photo), is so small that 190 billion could fit on top of a standard 7mm pencil-top eraser.

Farnell and Newark

FARNELL InOne, the international market and distributor of electronic products, has launched Newark InOne Direct Ship, a new service that gives direct and rapid access to around 70,000 products from its US sister company Newark InOne. For more information visit **www.farnell inone.co.uk**.

HONDA ROBOT

THE world's most advanced walking robot will make its first UK appearance at the Science Museum, London, from 16 to 22 February 2004 to demonstrate cutting edge robot technology.

Honda's ASIMO (Advanced Step in Innovative MObility) is human shaped and at 1.2 metres is as tall as a 12-year old. Four performances a day at the Science Museum will show off its ability to move like a real person, demonstrate how it can interact with people and how it can help them.

ASIMO is claimed to be the only upright robot which can climb stairs, turn corners and make predictions to adjust its motion by altering its centre of gravity. It can also react to changes in its environment. For example, if ASIMO is pushed, it responds accordingly and will not topple over. It displays intelligent behaviour, such as being able to recognise people, calculate distance, identify sounds and respond to instructions.

Heather Mayfield, deputy head of the Science Museum, said, "The Science Museum's collections bring visitors face to face with the past, present and future of human ingenuity. We're delighted to showcase ASIMO's cutting edge technology to our visitors, who I'm sure will be wowed by the robot's abilities."

Ken Keir, Managing Director of Honda UK said, "ASIMO is the result of Honda's desire to take on a unique engineering and technological challenge in the field of mobility, inspired by our commitment to innovation and the development of advanced products that will deliver real benefits to people now and in the future."

The Science Museum's website is at **www.sciencemuseum.org.uk**.

EOCS 188

NUMBER 188 is the *Electronic Organ Magazine* we have received from the Electronic Organ Constructor's Society (EOCS). Unless this news editor's calculator is wrong (and we all trust technology, don't we?!), that's about 47 years since EOCS published their first issue.

For the last 30-odd of those years we have been pleased to periodically publicise the EOCS as a worthwhile society for those interested in electronic organs and other associated electronic equipment. And, indeed, we are pleased to say that EOCS periodically publicise us too.

If you would like to find out more about this Society, contact the Hon. Secretary, Trevor Hawkins, 23 Blenheim Road, St Albans, Herts AL1 4NS. Tel: 01727 857344. Also browse: **http://eocs.org.uk**. Mention *EPE* if you get a chance!

J & N FACTORS NEWSLETTER

RECENTLY received from J & N Factors is their latest "new and more interesting" newsletter, in which they show photographs of just a small selection of their stock. The products include such diverse items as a waterproof speaker, telescopic aerial, motors, transformers, multitesters, and even a "solar gramophone kit" powered by a solar cell (only £5!). There is also a range of high quality kits offered, complete with p.c.b.s.

For more information contact J & N Factors, Dept *EPE*, Pilgrim Works, Stairbridge Lane, Bolney, W.Sussex RH17 5PA. Tel: 01444 881965. Email: jnfactors@aol.com.

PICS AND CORECHART

SOUTH Australian company eLabtronics tell us that they have been winning awards and acclaim for their innovative CoreChart Graphical Assembler software for PICs. They have now released a professional PIC16Cxxx Family Library CD for use with it.

Included on the CD are additional projects, more advanced subroutine modules, direct support for an expanded set of chip configurations, as well as valuable technical data. The new library now supports 82 chips, with the ability to import subroutines to any chip and export new subroutines to expand the library. For more information go to **www.elabtronics.com/products_cat_CoreChart.htm**.

YOU WON'T GET YOUR FINGERS BURNT

It may surprise you but buying an Antex soldering iron costs less than you think in the long run. British made to exacting standards, they last significantly longer than imported brands. And with a wide range of thermally balanced soldering irons, you can pick up a "fixed temperature" or "in-handle" temperature model that will suit your needs perfectly.
None of which will burn a hole in your pocket.

If your hobby demands the best iron for the job but you don't want to get your fingers burnt by the cost, visit our website or your electronics retailer for the coolest models around.

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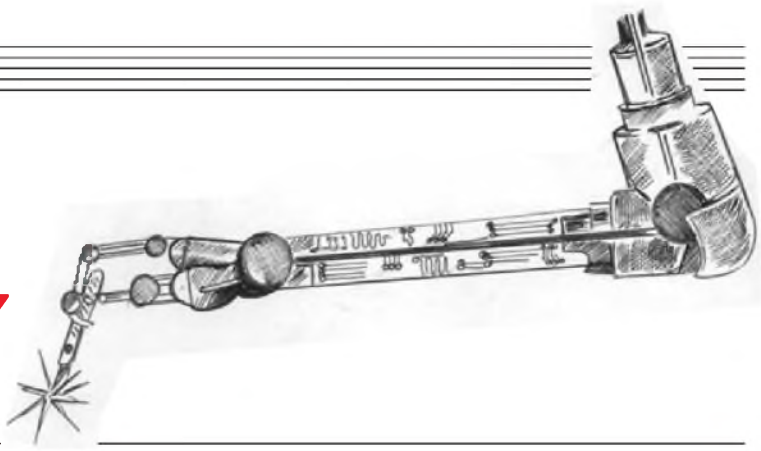


ALAN WINSTANLEY and IAN BELL

Our monthly column of readers' queries introduces the diac and triac, suggests the best way of placing voltage regulators in parallel and includes a* Please Take Note *for last month's MOSFET Basics.

WE have received a request from reader *Alan Brown* for an explanation of the operation of triacs. Triacs are a member of a family of devices that also includes diacs, silicon controlled rectifiers (SCRs), and various more exotic components such as MOS thyristors. The circuit diagram symbols for an SCR, Diac and Triac are shown in Fig.1.

All these devices are **bistable**, that is they have two states of operation, with different levels of conductivity between the devices' two main terminals in the two states.

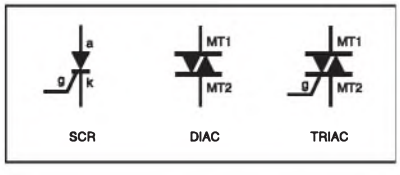


Fig.1. Circuit symbols for an SCR, Diac and Triac.

In the "*on*" state they have a low impedance, which is maintained as long as the current through the main terminals remains *above* a certain limit known as the **holding current**. In the "*off*" state they have very high impedance, which is maintained as long as the applied voltage is *below* a certain limit known as the forward **breakover voltage**.

Some of these devices, such as SCRs, conduct in one direction (as described above) and behave as reverse biased diodes in the other direction, for these devices the main terminals are designated **anode** (a) and **cathode** (k). Other devices, such as diacs and triacs, conduct in both directions, as described above. Here the main terminals are simply called **main terminal 1** (MT1) and **main terminal 2** (MT2).

Through the Gate

Some of these device, such as the SCR and Triac, have a third terminal known as a **gate** (g). The higher the current into the gate the smaller the forward breakover voltage becomes. Thus, applying a sufficient pulse of current to the gate will switch the device into the on state. Once in the on state the gate current is not required to be maintained due to the bistable action mentioned earlier. The device remains on until the main current falls below the holding current.

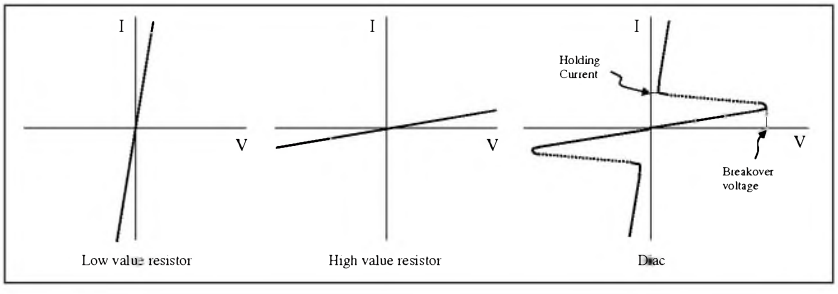


Fig.2. Plots of current against voltage for low value resistor, high value resistor and diac.

The bistable action of these devices means that plots of current against voltage look a little odd. A graph of current against voltage for a diac is shown in Fig.2. For comparison the plots of a low-value and a high-value resistor are also shown. Notice how the diac switches from high resistance to low resistance when the breakover voltage is reached.

All these devices are based on at least four alternating layers of *p* and *n* silicon with at least three diode junctions. The structure of an SCR, see Fig.3, is constructed from four layers of silicon of alternating type (i.e. *pnpn* (*p* and *n* type semiconductor)).

Compare this with a bipolar junction transistor (b.j.t.) which is three-layer – either *pnp* or *npn*. The SCR is like two overlapping transistors – the *np* of a *pnp* transistor overlapping the *np* of an *npn* type, as indicated by the dashed boxes in Fig.3a. This leads to the transistor equivalent circuit in Fig.3b.

A Turn On

We can understand this behaviour by looking at the equivalent circuit of the SCR in Fig.3b. The "trigger" gate current turns on transistor TR1. The collector (c) current of TR1 provides a base (b) current for TR2, turning it on too. In a similar manner the collector current of TR2 provides more base current for TR1, turning it on even more. This is a positive feedback effect that quickly ensures that both transistors are on.

Once this condition has been triggered by the gate it is self-sustaining, so gate current is no longer needed. If the voltage between anode and cathode is increased to the breakover point the currents within the device are sufficient to switch it on without any additional current from the gate.

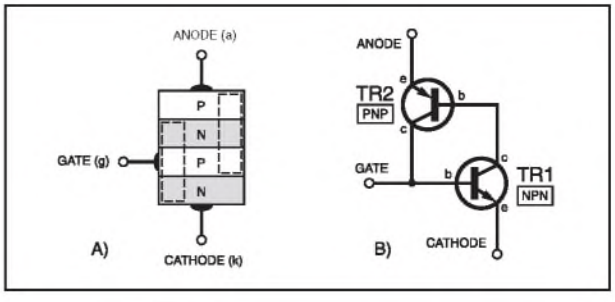


Fig.3. SCR structure and equivalent circuit

The triac is like two back-to-back SCRs. It conducts in both directions and can be switched on by a gate current of either polarity.

The diac is like a triac without the gate connection. It is switched on by applying a voltage above the breakover voltage in either direction. The bidirectional nature of the diac and triac operation means that they can be used to switch a.c., whereas SCRs can only be used for d.c. or one half of an a.c. waveform. Triacs are often used for a.c. mains power control and switching.

Lamp Dimmer

One of the best known applications of triacs and diacs is in dimmer circuits for incandescent lamps. The triac is switched on part way through each half cycle of the mains waveform and hence supplies power to the lamp.

The triac will switch off as the waveform crosses through 0V because the current in the device will fall below the holding current. Thus, the earlier in each half cycle the triac is switched on the greater the proportion of time the lamp will be on and hence the brighter it will shine.

An outline of a dimmer circuit is shown in Fig.4. During each half cycle of the mains waveform the capacitor, C, charges up at a rate set by the variable resistor, VR. When the voltage on the capacitor reaches the breakover voltage of the diac it will switch on sending a pulse of current into the triac. The triac and hence the lamp, LP, will switch on and remain on until the mains waveform crosses through 0V again.

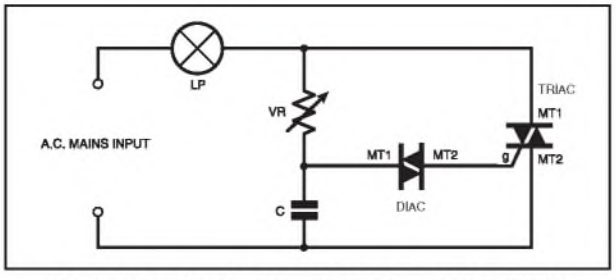


Fig.4. Lamp dimmer concept (not a practical circuit)

The triac's breakover voltage will be higher than the peak mains voltage (a typical value would be 500V) so it will not switch on by this mechanism, only by the gate current via the diac. The diac's breakover voltage will be much lower than the mains peak voltage, a typical value would be around 30V.

This circuit is for illustration only as it lacks important features such as r.f. suppression, diac current limiting, and snubbing, and has relatively poor control particularly at low power levels. Additional circuitry is needed for an acceptable performance. *I.M.B.*

Parallel Regulators

The *EPE Chat Zone* Message Board (**www.epemag.wimborne.co.uk**) is busier than ever before, with many users from around the world joining in to share hints and tips, help out with electronics problems and generally put the hobby electronics world to rights!

Regular Chat Zoner ***Jim Byrne*** asks: *Just a quick question! How can I parallel some 78-series regulators to get a higher current? Will mismatches cause any problems?*

When a number of regulators are placed in parallel to boost the current level, during normal operation a certain voltage will appear "across" each regulator, which may be say 2V to 3V or so minimum. Since different devices adopt a slightly different input-output voltage (V_{IO}) from the others, the danger is that the regulator with the lowest V_{IO} will shunt or "hog" current that should be shared by all the others, and it will therefore handle more than its fair share of the load. This can cause excessive power dissipation in the device that hogs the most current.

The recommendation is to use a low value resistor (sometimes called a ballast resistor) in series with each regulator. The resistor allows for an "error" voltage to be created as any small voltage differences will be seen across the ballast resistor.

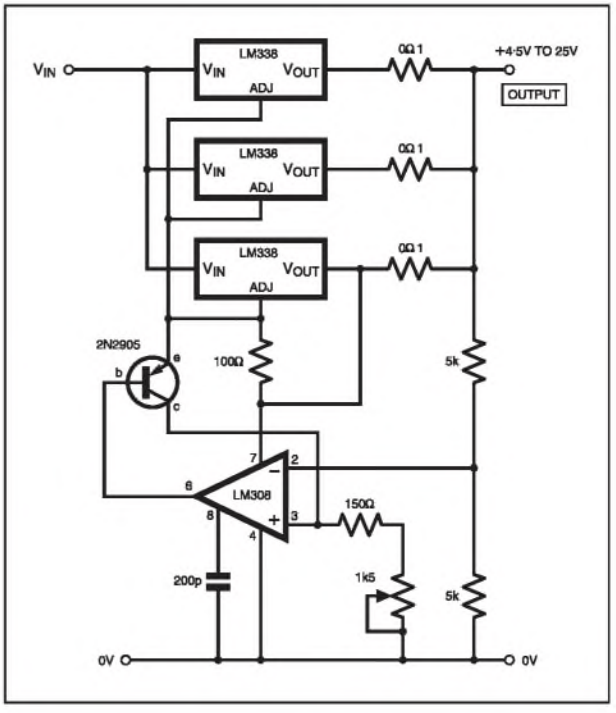


Fig.5. A suggested 15A adjustable regulator using three LM338s in parallel each with series ballast resistors (courtesy National Semiconductor).

To give you the idea, Fig.5 shows an adjustable 15A regulator circuit (courtesy of National Semiconductor) using three LM338 devices in parallel, with a 0·1 ohm series resistor used (the circuit has not been proven by us). The resistor value is not critical but it should be a low value high power type, perhaps home-made from suitable resistance or copper wire: values of 100 to 200 milliohms are mentioned in data sheets.

It is worth checking manufacturers' web sites, notably National Semiconductor (**www.nsc.com**) for application notes and data sheets. *ARW.*

You can contact the authors or email your general electronics-related questions to **alan@epemag.demon.co.uk**. The writers regret that a personal reply cannot always be guaranteed but we publish a selection of replies every month.

PLEASE TAKE NOTE

MOSFET Amplifier Design *(C/S Feb '04)*

In the Feb '04 column we outlined the basic design process for a simple single stage MOSFET amplifier. Unfortunately, a gremlin crept into our text concerning the drain-source current that resulted in subsequent calculations being incorrect; the current value we intended to use was **1mA** not 10mA. A corrected version is published below with revisions to values highlighted in bold. We are sorry for any confusion caused: our thanks to reader ***Dave Shephard***, who first brought this to our attention.

(*Page 114 3rd column*) . . . For example if we have a MOSFET for which V_T=0·7V and K=2·5mA/V^2 and we choose a quiescent drain-source current of **1mA** we require a gate source voltage of **0·7+√(1·0/2·5)=1·3V . . . .** The above example has a transconductance of about 3·2mA/V at I_{DS}=1mA.

(*Page 115*) . . . If we choose 500 ohms for R4 we get 0·5V at the source from the 1mA bias current. This means the R1/R2 potential divider must give 0·5+**1·3=1·8V**, so we could use R1=**850** kilohms and R2=**150** kilohms.

The value of R3 influences the voltage gain and output swing. The drain voltage should not fall below the gate voltage by more than V_T (0·7V in our example), so the minimum drain voltage is **1·1V**. The maximum drain voltage is the supply voltage (12V), so we have a maximum swing of **10·9V** or **±5·45V** centred on **6·55V**. For a drain voltage of **6·55V** with no signal we need **R3=(12–6·55)/1mA=5·45k**.

The voltage gain of the circuit (Fig.2 page 114) is given by $-g_mR_3/(1+g_mR_4)$.

In our example the gain is about **6·7**. The stabilising resistor reduces the gain, but this can be overcome by bypassing it with a capacitor.

Disruptive Technologies

What's bad news for some is good news for others, as Andy Emmerson explains.

CHANCES are that you won't have heard the expression "disruptive" applied to technologies, but you'll certainly have encountered it.

Do you know anyone who still uses a radio pager? Me neither. Yet there was a time not so long ago when a pager and a £5 phonecard was the supreme form of low-cost mobile communication. People paged you with their number, then you headed for the nearest cardphone to find out what the panic was.

These days cardphones are as much an endangered species as pagers, whilst texting and the plummeting cost of mobile phones mean that firms that made their business from radiopaging alone have long since shut up shop.

Texting, or SMS messaging to give it its proper title, is a classic example of a disruptive technology, one that took users and suppliers alike by surprise. SMS was a technical afterthought, one that its designers never dreamed would be as popular as it became.

CHEAP AS CHIPS?

DVDs are another. In a period of economic downturn, nobody expected that DVDs would supplant video tapes as rapidly as they did, and far less that DVD players would be churned out in such quantities that they could retail for as little as £39.

Texting and DVDs are both examples of disruptive technologies – new products and processes that can knock industry predictions for six, ruining some suppliers and making the fortunes of others. Interestingly though, disruptive technologies can also increase overall market size and not cause substitution.

Television did not kill the radio and cheap mobiles have not made people abandon their fixed line telephones, at least not most people. Remarkably too, incumbent market players frequently discard new technologies when their customers show no interest. But new players then introduce these products to fresh customers and develop the market to a point where customers are motivated to buy them – from the new supplier.

Unforeseen events are not always disastrous for a business either; they can be highly beneficial as well. With foresight you can know how to handle all eventualities, which is why most major companies employ tame forecasters to track all new trends and technologies that could affect their business.

VITAL ROLE

Comms giant British Telecom is one company that employs skilled teams taking a keen interest not just in future customer demand but also in new technologies and social trends. According to BT's Paul Armstrong, traditional forecasting activities still play a vital role in planning new investment, but careful observation of social factors is also very important.

Says Paul: "You ignore value perceptions at your peril, since these have as profound an influence on customer take-up as costs. Looking at new developments in mobile communication this explains why WAP-style Internet access has not been a hit, and why with upwards of a billion text messages sent each month, SMS has been a resounding success."

Tracking technology trends is equally vital, as colleague Dave Brown explains. "A critical part of my team's activity is spotting disruptive new technologies with the potential to undermine the business before they affect us, and then redirecting its plans. Input on how people use technology in daily life comes from the *Digital Living* project and from a number of collaborative activities undertaken between BT, universities and other companies."

BUGS

One of the latter is the international Giga Information Group, whose research fellow Will Capelli argues the case for investment in research of this kind. "Much perception can be gathered by understanding the past better," he declares. "Scenarios repeat themselves, demonstrating that a measured approach to investing in new technologies frequently works best. By postponing heavy investment as long as possible, you let the early adopters take the risk and are not precluded from exploring other opportunities. You gain the fullest information possible and end up paying less for a technology with the bugs knocked out."

All the same, you can never eliminate uncertainty, which has the power to wreck well-honed business plans (as the events of 11th September did for the air travel industry). Unpredictable events can also bring blessings, as Paul Armstrong affirms, "All too often the winners are not those who forecast the most accurately but those who can manage uncertainty the best. You cannot plan for unpredictability but you can align your business process to recognise it and then react positively. The trick is to allow for uncertainty without descending into anarchy, so you can turn uncertainty to your commercial advantage."

RING TONES

Another insight from the experts is that forecasting is never 100 per cent accurate when you are dealing with human reactions. Purchases are made on whim as well as from rational need – just look at musical ring-tones for mobiles.

Comparative analysis of alternative scenarios can nonetheless identify the factors that are uncertain but important. It's also easy to over-estimate the amount of change that can happen in two years, but underestimate what can occur in ten. Customer perception takes time to adjust, which is why new technologies are frequently oversold initially and fail to reach commercial expectations, even though the trend was observed correctly.

But what's the next disruptive technology likely to change our lives, or at least lives of techies like you and me? Surprisingly it's one that this magazine covered last June, when I as good as wrote off the chances of powerline communications. Unloved and unregarded, the idea has been reborn in the USA and now goes under the sexier name of BPL (broadband-over-powerline). Mention the word *broadband* and you have everyone listening, from Tony Blair downwards.

LEAKY FEEDERS

Twenty years ago nobody expected the country would go overboard on skateboards, ZX-81 computers or citizens' band radio, and yet it did.

And this sudden uptake phenomenon could happen all over again, if Brian Seedle, chairman of Fylde Micro Ltd, is right. At a recent radio industry conference he took the audience entirely by surprise by suggesting that broadband-over-powerline had the potential to cause serious havoc to business radio operators and other radio users. Not by taking away their business but by interference "leaking" from electricity supply mains delivering wideband Internet service using a radio carrier frequency.

The fact that this technique radiated like mad and had been widely condemned by all manner of bodies was irrelevant, he argued. The reality was that broadband was starting to take off as a mass-market commodity and mains-borne broadband could reach the parts that BT and the cable companies couldn't reach.

With electricity supply companies sniffing big money to be made, a powerful consumer-led lobby could easily steamroller all opposition to BPL, leaving radio users with a spectrum polluted by leakage and harmonic products. Past performance of supine governments indicates that with sufficient impetus from "citizen consumers", the weight of numbers would overrule (remember how Citizens' Band radio displaced the legitimate users of 27MHz without a murmur?).

Only time will tell.

Review

THE AMATEUR SCIENTIST

CLIVE (MAX) MAXFIELD

Review of the Amateur Scientist 2.0 Science Fair Edition CDs, every Amateur Scientist column ever published is presented on one CD!

ONE of most respected magazines for providing insights into science and technology, *Scientific American* (**www.ScientificAmerican.com**) was the brainchild of the artist, musician, teacher, and inventor Rufus Porter (May 1, 1792 to August 13, 1884). A prolific inventor, Porter has been described as "A 20th century man who was born in the 18th century and lived in the 19th century!"

From its 1845 origins as a weekly broadsheet, *Scientific American* has been informing its readers about the latest developments in science and technology for more than 150 years, making it the oldest continuously published magazine in America!

As for myself, I've been a devoted reader of the magazine for more years than I care to remember. I particularly like the fact that each issue offers insights into a wide range of disciplines, from chemistry and biology to physics, electronics, and . . . the list goes on.

Like many readers, I have my favorite nooks and corners of the magazine. For example, I always enjoyed running across the *Amateur Scientist* column, which provided the perfect "how to" resource for citizen scientists. In addition to providing a starting point for hundreds of thousands of high-school science fair projects, this column provided the seeds that launched many a career in science and technology.

A DISTINGUISHED HISTORY

The *Amateur Scientist* traces its history to 1928, when the famous astronomer Albert Ingalls instigated a column called *The Back Yard Astronomer*. By means of these articles, Ingalls told his readers how to grind their own lenses, construct professional-quality instruments, and make cutting-edge astronomical observations. The name of the column mutated a number of times before finally settling on *The Amateur Scientist,* which was selected because Ingalls wished to widen the scope of his articles to embrace all fields of science and technology.

Ingalls continued to write the column for 26 years until his demise in 1954, at which time the publisher selected C. L. Stong to pick up the baton. An electrical engineer at Westinghouse, Stong was a brilliant tinkerer who peppered the column with cunning and sophisticated projects like atom smashers and home-made lasers.

Stong continued to write *The Amateur Scientist* for the next 23 years until he passed away in 1977. After searching far and wide for a new host, the publisher offered the column to Jearl Walker in 1978. Under his stewardship over the next 12 years, Walker presented fewer "how-to" articles and instead concentrated on explaining the physics underlying common phenomena. Due to his unique ability to explain the physics underlying the everyday world, Walker's columns are still consulted by educators and students to this day.

When Walker stepped down, it proved difficult to find a single individual with the breadth of knowledge and the professional credentials needed to recapture the energy and popularity of the original column. Thus, following three articles by Forrest Mims III – the renowned writer of books on do-it-yourself electronics projects – individual columns from a wide variety of professionals were published under the *The Amateur Scientist* umbrella. In fact, it wasn't until 1995 that the editorial staff at *Scientific American* discovered The Society for Amateur Scientists (**www.sas.org**). The society's founder – Dr. Shawn Carlson – was subsequently persuaded to take over the column until its last appearance in 2001.

THE END OF AN ERA

Sad to relate, *The Amateur Scientist* column is no more. The last time the column appeared in print was in the March 2001 issue of the magazine. And the very last column of all appeared in the e-bulletin board associated with the November 2001 copy. At that time it was intended to keep the electronic version alive, but lack of time and resources prevented it from going forwards.

Strange as it seems to me now, like many readers I didn't really notice the column's passing. It was only recently when I was chatting to the guys and gals at the Tinkers Guild (**www.tinkersguild.com**) that I realized that I hadn't seen its familiar banner for quite some time. And of course, as soon as I realised that *The Amateur Scientist* was no longer with us I started to miss it dreadfully (isn't that always the way of things?).

NO TIME FOR TEARS

But turn that frown upside down into a smile, because I am the bearer of glad tidings. The folks at the Tinkers Guild have recently released *The Amateur Scientist 2.0 Science Fair Edition*, which contains two jolly interesting CDs. The first contains every *Amateur Scientist* column ever published. That's over 1,100 articles and projects in all, covering every major field of science!

This CD – which runs on Macintosh, Windows, and Linux platforms (I love that) – supports multiple techniques for finding articles of interest. For example, the CD's self-contained Java search engine allows you to search the contents by keywords (on a whim I first searched for "fish" and was soon engrossed in articles that delighted me for hours).

Alternatively, you may decide to browse by subject. You can start by selecting from Archeology, Astronomy, Biology, Chemistry, Earth Science, Mathematics, and Physics (Technical Notes and Tools & Techniques are also options here) and then rooting through the ensuing topics. Last but not least, if you simply wish to be exposed to a wide variety of "stuff," then all you have to do is select the "Browse By Decade" option by clicking one of the 1920s, 1930s, 1940s . . . 2000s buttons and then scan through the associated topic summaries.

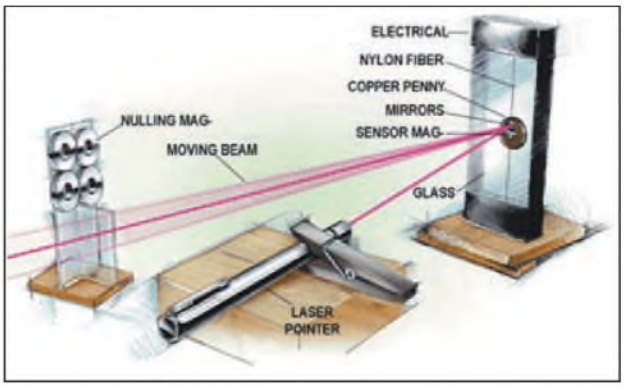
A PLETHORA OF TOPICS

The great thing about *The Amateur Scientist* is that there's something for everyone. For example, I have an abiding interest in all things to do with digital

electronics, which made the August 1962 article by C. L. Stong, entitled *How Streams of Water Can Be Used to Create Analogues of Electronic Tubes and Circuits* a must-read.

Truth to tell, it would be well nigh impossible to write this review without regaling you with at least a smattering of the columns you'll find on the CD, for example:

- March 1960: *Concerning Homemade Vacuum Pumps and Some of the Things That Can Be Done with Them* (. . . the mind boggles!. . .)
- February 1964: *How to Photograph Air Currents in Color and Build an Accurate Foucault Pendulum*
- October 1966: *How to Build a Wind Tunnel That Achieves Supersonic Speeds with a Vacuum System*
- February 1966: *How to Record and Listen to the Electrical Signals Produced By Microscopic Animals*
- October 1967: *How to 'Sputter' Thin Films of Metal Onto Glass and Experiment with Them*
- April 1967: *Little Pendulums That Oscillate Like Big Ones*
- February 1967: *How to Make Holograms and Experiment with Them*
- June 1968: *A Plan for an Analogue Computer That Can Be Built for about $40* (that's original dollars in the title, but this project has an adjusted cost range of 0 to $100).
- May 1969: *How to Blow Soap Bubbles That Last for Months or Even Years*
- February 1969: *How to Construct an Argon Gas Laser with Outputs At Several Wavelengths*
- September 1970: *Curious Oscillators That Involve Salt Water, Flame and Hot Wire*
- January 1970: *Experiments in Generating the Constituents of Living Matter From Inorganic Substances*
- April 1974: *Curious Bubbles in Which a Gas Encloses a Liquid Instead of the Other Way Around*
- November 1979: *Flames in Which Air Is Introduced into a Flammable Gas Rather Than Vice Versa*
- April 1988: *How to Map Electrically Charged Patches with Parsley, Sage, Rosemary and Thyme*



Taking the Earth's magnetic pulse – Jan. 1999.

- August 1989: *How to Analyze the Shock Waves That Sweep Through Expressway Traffic*
- . . . and the list goes on, and on, and . . .

As you can see, these articles cover an incredibly diverse range of do-it-yourself projects and interesting topics sufficient to keep you drooling for days. Some are downright serious, while others are of a more philosophical bent. As an example of the latter, one need look no further than the April 1989 offering entitled *How to Build a Plank-Mass Accelerator in Your Solar System.*

In addition to being linked to extensive supplementary resources, each project has an associated difficulty level from 1 to 5, a danger level ranging from 1 (no hazards), through 4 (POSSIBLY LETHAL!), and an associated cost in terms of today's monetary values. Of course, costing these projects is somewhat tricky – not the least that "stuff found around the house" tends to be a major component of many of them – so the values provided are (very) rough estimates.

THE SCIENCE SOFTWARE LIBRARY

Accompanying the main CD is a *Science Software Library CD* that contains a library of demo programs, shareware, freeware, and other items that may be of use to amateur scientists. These offerings are categorized by topics that include Astronomy, Biology, Chemistry, Physics, Earth Science, Mathematics, Computer Science, General Tools and Utilities, and Teaching Aids.

In the case of electronics, for example, one item that caught my eye was the *CRO Tutor,* which is a computer program that simulates a single-channel cathode ray oscilloscope. I've seen these sorts of programs before and they can be incredibly useful, but they can also be quite expensive, so it's great to be able to play with one here. The CRO Tutor offers a variety of basic controls such as the Timebase, Horizontal Shift, and Level. Also available are more complicated controls such as Coupling and Trigger-level Adjustment, but these are added in stages so as not to frighten the unwary too soon.

I must admit that I was a little like a kid in a sweet shop running from one delight to another. Under the Astronomy category, for example, I discovered the NEWT program, which can be used to design Newtonian telescopes. This was of particular interest to me, because I recall one of my uncles grinding his own telescope mirrors (it took months of effort, but it kept him from getting under my aunt's feet).

IN CONCLUSION

Personally, I think that *The Amateur Scientist 2.0 Science Fair Edition* is a must-have for just about anyone who is interested in knowing more about "stuff" (it's certainly a valued item in my collection). Even if you don't end up constructing any of the apparatus or performing any of the experiments yourself, it's strangely reassuring to know that one has the ability to fabricate something like an electromagnetic gun that can fire nails at the speed of sound in the comfort of one's own front room, should one so desire. (Not that I'm saying such a project exists on the CD you understand, but it certainly wouldn't surprise me . . . in fact I think I'll take another stroll through the projects as soon as I've finished penning this article.)

Considering the amount of effort that has gone into pulling all of the *Amateur Scientist* columns together and creating this CD – not to mention the hours of fun to be found while playing with the applications on the *Science Software Library CD* – I think this is a real good value at £19.95 including UK postage and VAT. It is available from the *EPE Direct Book Service.* □

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Constructional Project

EMERGENCY STAND-BY LIGHT

TERRY de VAUX-BALBIRNIE

A home emergency light – don't be caught in the dark! Use 12V battery power to drive a low-energy mains light bulb

THIS circuit will operate a mains low-energy light bulb of up to 24W rating from a 12V d.c. supply. As well as being useful for home emergency lighting, it could be made part of a solar or wind-charging system for use in areas where a mains supply does not exist.

A 60Ah lead-acid battery ("leisure battery") makes an excellent power source and will operate a 24W low-energy bulb for some 24 hours before the need to re-charge. For lighter loads, a smaller sealed lead-acid unit is recommended. For example, a 12Ah battery could operate an 11W lamp for around eight hours.

HIGH EFFICIENCY

For an equivalent light output, low-energy lamps consume 80 per cent less energy than the tungsten filament type. A 24W low-energy bulb will therefore provide more illumination than a standard 100-watt bulb.

Low energy bulbs are handier than the tubular fluorescent type. They have a more convenient shape and fit a standard light fitting. Also, they give a quality of illumination similar to a tungsten filament lamp.

The efficiency of this circuit approaches 80 per cent when delivering full power. However, it falls with decreasing load. When operating a 24W lamp, the current drawn by the prototype is 2·5A with a "base" value of 550mA. That is, 550mA is needed even in the absence of a load.

This "base" current is the reason for the efficiency reducing with load. An 11W lamp requires some 1·5A giving an efficiency of 63 per cent.

The Emergency Stand-by Light circuit has been designed with *Philips Ecotone* lamps in mind. The manufacturer was helpful in supplying certain technical details needed for the design. However, successful tests were made using other energy-saving bulbs. ***Note that it is not suitable for tungsten filament lamps or any other appliances.***

Low-energy lamps are, of course, normally operated from the a.c. supply mains. However, they may be powered from a d.c. (direct current) source. They will operate at full brightness using 230 volts and with an absolute maximum of 350 volts. Below 160V, they fail to conduct and do not work at all.

STRIKING EXAMPLE

As well as the need to supply current at a sufficiently high voltage, a "striking pulse" needs to be delivered at switch-on. The manufacturer suggests that this may be as much as 25A for 250µs (microseconds). However, all the lamps tested "struck" using a much lower current. It seems that a smaller current is needed when the lamp is already warm.

SAFETY NOTE

This system uses a high voltage direct current (d.c.) output of between 220V and 300V approximately, depending on the load. It could therefore be dangerous if not constructed and used with due care and attention regarding electrical safety.

It must be regarded as a "mains type" circuit and should not be attempted by anyone who does not have the necessary knowledge and skill. Note also that it is suitable for dry indoor use only.

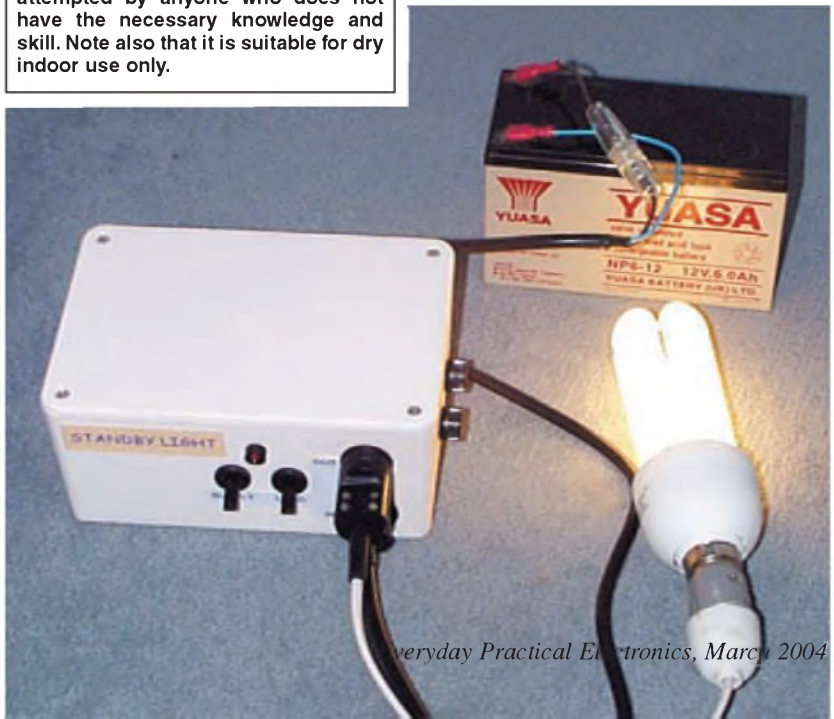
The fact that a low-energy lamp will work over a wide voltage range means that there is no need for the supply to have particularly good voltage stability. A filament lamp, by contrast, must be operated close to its nominal value. A small increase would lead to a serious reduction in service life. Operating it at a slightly lower voltage would result in a significant decrease in light output.

HOW IT WORKS

The circuit presented here is a form of *voltage converter*. It thus accepts a d.c. input at one voltage and changes it into a d.c. output at a different voltage. The complete circuit diagram for the Emergency Stand-by Light is shown in Fig.1.

Ignore for the moment the section containing IC1, a CMOS micropower voltage detector. This is the under-voltage sensing part which sounds a signal when the battery falls to its low-point. This will be explained later.

The main section of the circuit is based on IC2, a 555 timer i.c. configured as an astable. It thus produces a stream of on-off pulses at its output, pin 3.



Current is supplied from the 12V battery via external in-line fuse FS4, input plug and socket PL1/SK1, switch S1 (Supply), fuse FS2, thermal fuse FS1 and diode D1.

Diode D1, in conjunction with capacitor C1, provide a smooth local supply and isolate the astable (IC2) from the sudden high current changes which occur later in the circuit. These would cause "dips" in the supply voltage and could result in erratic operation.

The operating frequency of IC2 is related to the values of fixed resistors R4 and R5, preset potentiometer VR2 and capacitor C2. With the values specified, it will be in the range 40Hz to 100Hz depending on VR2 adjustment and will have more-or-less an equal mark/space ratio (equal *on* and *off* times).

The frequency has a large effect on the operating efficiency and will be adjusted at the end for best effect. Capacitor C3 is necessary for the stable operation of the bipolar timer i.c. used.

The signal from IC2 output, at pin 3, follows two paths. One is direct to the gate (g) of MOSFET TR2. The other is via resistor R6 to the base of transistor TR1. Resistor R7 is the load resistor for the latter transistor and the gate of TR3 is fed from its collector. The purpose of TR1 is to invert the pulses so that those appearing at its collector are high when the IC2 output is low and vice versa.

OPEN THE GATE

MOSFETs are switched using a *voltage* applied to the gate (g) unlike a conventional bipolar transistor which requires a finite current flowing into its base. A MOSFET requires a negligible gate *current* to operate it. Transistors TR2 and TR3 therefore operate alternately as their gate voltage is switched on and off.

While *on*, the appropriate MOSFET develops a very low resistance between its drain (d) and source (s). Current can then flow from supply positive through one half of the primary winding of transformer T1 (that is, the secondary winding if it were used as a conventional mains transformer). It then returns to 0V via the MSOFET drain and source circuit. As each MOSFET conducts, it gives a "push-pull" effect with current flowing in one direction through one half-winding then in the opposite direction via the other one.

When current is flowing in one half-winding, there is an "auto transformer" action with the other one. This effectively doubles the voltage at the drain of the *off* transistor. In fact, the voltage overshoots this value.

The off MOSFET needs to tolerate this higher voltage and the specified type appears to work well in this respect. If the pulse were to be bypassed using a diode, energy would be removed from the system and the circuit would be less efficient.

SQUARE WAVES

Since transformer T1 is used in reverse, that is, the primary (as originally intended) is now the secondary and the secondary is the primary, there is a voltage *stepping-up* rather than a stepping-down effect. This appears as a high-voltage "square" wave at the secondary winding (see Fig. 2). One MOSFET is responsible for the positive half-cycles and the other, the negative ones.

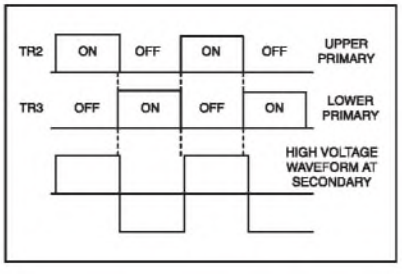


Fig.2. High voltage waveform.

In fact, the wave is far from square since, due to the inductance, the magnetisation of the transformer core takes a certain time to reach maximum and fall again to zero. Once it levels off, the primary current simply wastes energy by heating up the transformer.

It would be best, therefore, if there was only sufficient time allowed for the magnetisation to reach maximum and fall to zero before reversal took place (that is, the other MOSFET took over). This is done by adjusting the astable operating frequency. At the optimum value, the efficiency is highest (maximum output power for a given input power).

A HOT POINT

In operation, the MOSFETs do not normally produce much heat. However, over time they do become warm and a heatsink is needed. Also, if the astable (IC2) stopped with its output either high or low, one of the MOSFETs would be switched on continuously and a very large current would flow through the associated

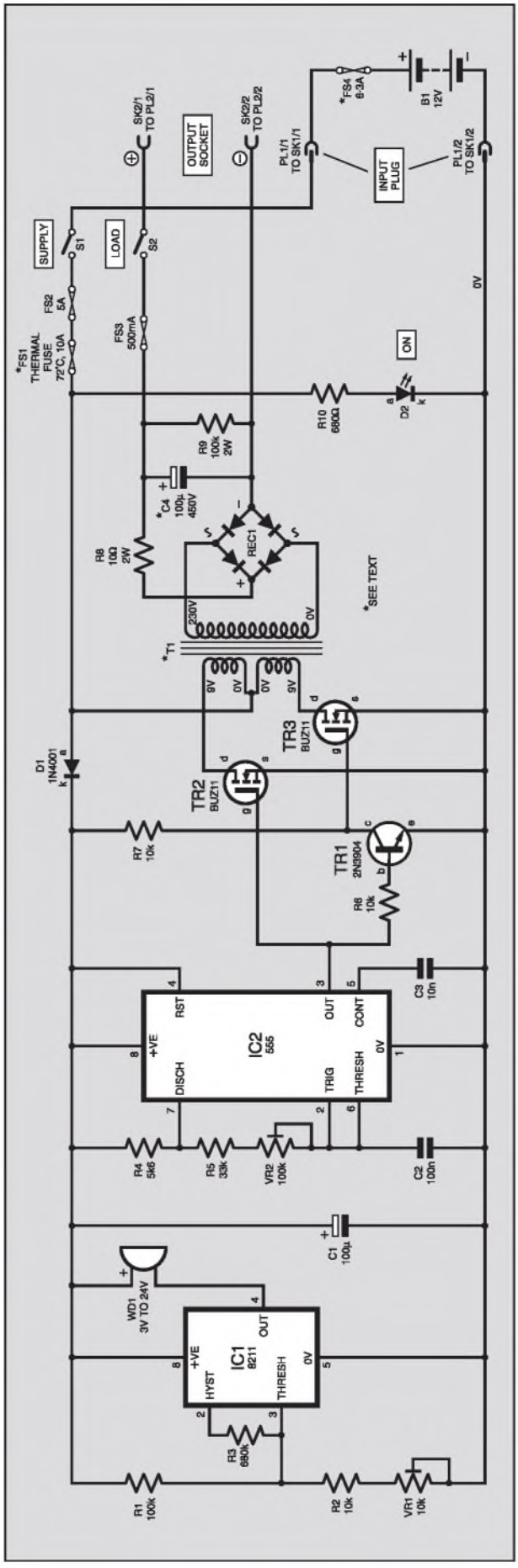


Fig.1. Full circuit diagram for the Emergency Stand-by Light.

primary half-winding. This would also happen if a MOSFET were to fail with a closed circuit between its source and drain.

Excessive current could cause the wiring and heatsink to become very hot. To prevent this happening, fuse FS2 or possibly FS4 will blow and cut off the supply.

FINAL PROTECTION

As a further means of protection, the heatsink is fitted with a *thermal fuse*, FS1. This device, unlike a standard fuse, cuts off the current flowing through it when the material inside it melts due to *externally applied* heat.

Like a normal fuse, this is a "one shot" device which ***must*** be replaced if it fails. If, for any reason, the heatsink exceeds 72°C, the fuse will blow. As well as circuit failure, this could be due to the temperature inside the case rising excessively. ***Do not omit the thermal fuse!***

In the prototype, IC2 was removed (so switching on TR3) to check operation and FS2 blew quickly with no other damage. *There is no need for the constructor to try this!*

OUTPUT CIRCUIT

The high-voltage output is rectified using bridge rectifier REC1 and smoothed using capacitor C4. The current flowing initially into the capacitor is limited by resistor R8. The result then appears at output socket SK2, via fuse FS3 and Load switch S2.

The specified value of capacitor C4 is sufficiently high to allow for a suitable striking pulse to be delivered to the lamp. However, in most cases it will not be working at full capacity. It was even found that the lamp often "struck" with no capacitor at all!

However, if this is done, the lamp would be operating from a very unsmooth supply and there is no guarantee that it would survive for very long under those conditions. To allow the capacitor to charge up, Supply switch S1 needs to be operated a short time *before* switching on Load switch S2.

Resistor R9, connected in parallel with capacitor C4, will discharge it to near zero over a period of some 60 seconds (six time constants). **Without R9, and with the load and supply removed, the output terminals could maintain a dangerously high voltage for many hours.**

LOW POINT DETECTOR

Returning now to the under-voltage detection section, based on voltage detector IC1. This helps to avoid discharging the battery excessively by sounding warning buzzer WD1 when some preset low point is reached. It is very important to avoid discharging a lead-acid battery too far or it is likely to result in permanent damage.

If the voltage applied to the threshold input (pin 3) of IC1 falls below an internal reference value (1·15V), the output (pin 4) goes low and can "sink" current from the positive supply rail. The audible warning device (solid-state buzzer) WD1 then sounds.

Resistor R1 forms the upper arm of a potential divider while fixed resistor R2 connected in series with preset potentiometer VR1 is the lower one. The whole arrangement is connected across the supply.

Preset VR1 is adjusted so that, when the battery is at the required low point, the voltage applied to pin 3 will fall below the threshold value. Note that the voltage sensed by pin 3 will be 0·7V less than the threshold value due to the forward voltage drop of diode D1.

Positive feedback is applied to IC1 pin 2 (hysteresis), through resistor R3, so that the "on" triggering point is a little higher than the "off" one. This prevents excessive on-off switching near the critical value.

COMPONENTS

Approx. Cost Guidance Only **£30** excl. batt., case & lamp

See SHOP TALK page

Resistors

R1	100k
R2, R6, R7	10k (3 off)
R3	680k
R4	5k6
R5	33k
R8	10Ω 2W
R9	100k 2W
R10	680Ω

All 0·25W 5% metal film, unless otherwise stated.

Potentiometers

VR1	10k multiturn preset, top adjust
VR2	100k multiturn preset, top adjust

Capacitors

C1	100µ min. radial elect. 25V
C2	100n polyester 5mm pitch 5% tolerance
C3	10n polyester 5mm pitch
C4	100µ radial elect. 450V (minimum rating)

Semiconductors

D1	1N4001 50V 1A rect. diode
D2	5mm red l.e.d. indicator (panel mounting)
REC1	1·5A 800V bridge rectifier
TR1	2N3904 *npn* transistor
TR2, TR3	BUZ11 power MOSFET (2 off)
IC1	MAX8211, CMOS micropower voltage detector
IC2	555 timer

Miscellaneous

T1	50VA (minimum) mains transformer, with 230V primary and twin 9V secondary windings
WD1	Solid-state buzzer d.c. operation 3V to 24V operation at 10mA maximum
S1, S2	Toggle or rocker switch, 5A d.c. rating (2 off)
FS1	thermal fuse (14mm x 4mm diameter) 10A current rating. 72°C operating temperature
FS2	5A 20mm fuse
FS3	500mA 20mm slow-blow (time delay) fuse
FS4	6·3A 31mm fuse or to suit line fuseholder
PL1/SK1	panel input plug and line socket (3A rating minimum)
SK2/PL2	panel output socket and line plug (mains rated)

Printed circuit board available from the *EPE PCB Service*, code 438; ABS impact resistant box, size 177mm x 120mm x 83mm; 8-pin d.i.l. i.c. socket (2 off); 2-way p.c.b. screw terminal block, 5mm pitch; 4-way p.c.b. screw terminal block, 5mm pitch (2 off); TO220 mounting kit (2 off); 20mm panel fuseholder (2 off); line fuseholder; material for transformer insulating shield, see text; plastic insulating boots for output socket and fuse FS3; self-adhesive plastic or rubber feet (4 off); 6A stranded wire; 3A mains-type wire; nylon screw terminal block 5A rating (2 pieces required); battery connectors; nylon fixings; solder, etc.

CONSTRUCTION

This unit is best regarded as Class 2 equipment since there is no "earth" provided by the supply wiring. The circuit ***must*** *be built in a high-impact ABS plastic (insulating) box. A metal box* ***must not*** *be used. This is because, in the event of a fault, it could become "live" (by touching one of the output connections).*

This, in itself, would not cause an electric shock if the user touched it since no earth loop exists. However, there would be a danger of shock if someone touched the other output wire by accident while making contact with the box. For this reason, there must be no metal parts (such as bolt heads) that can be touched from outside the case.

Construction of the Emergency Standby Light is based on a single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service,* code 438. The topside component layout and full-size copper foil master pattern are shown in Fig.3.

Begin construction by drilling the p.c.b. mounting holes and then solder in position the single link wire at IC2 pin 3. Add the i.c. sockets, sections of terminal block (TB1 to TB3) and all resistors (including the presets) and capacitors, taking care over the polarity of C1 and C4.

Follow with the other polarity-sensitive components: diode D1, transistors TR1 to TR3 (see below), buzzer WD1 and bridge rectifier REC1. You will need to spread the end leads of REC1 and the transistors to fit the p.c.b. holes. Solder pieces of light duty stranded connecting wire, about 10cm long, to the l.e.d. (D2) copper pads.

The MOSFETS are static sensitive devices. It would, therefore, be wise to remove any charge from your body by touching something which is "earthed" (such as a metal water tap) before touching TR2 and TR3 pins.

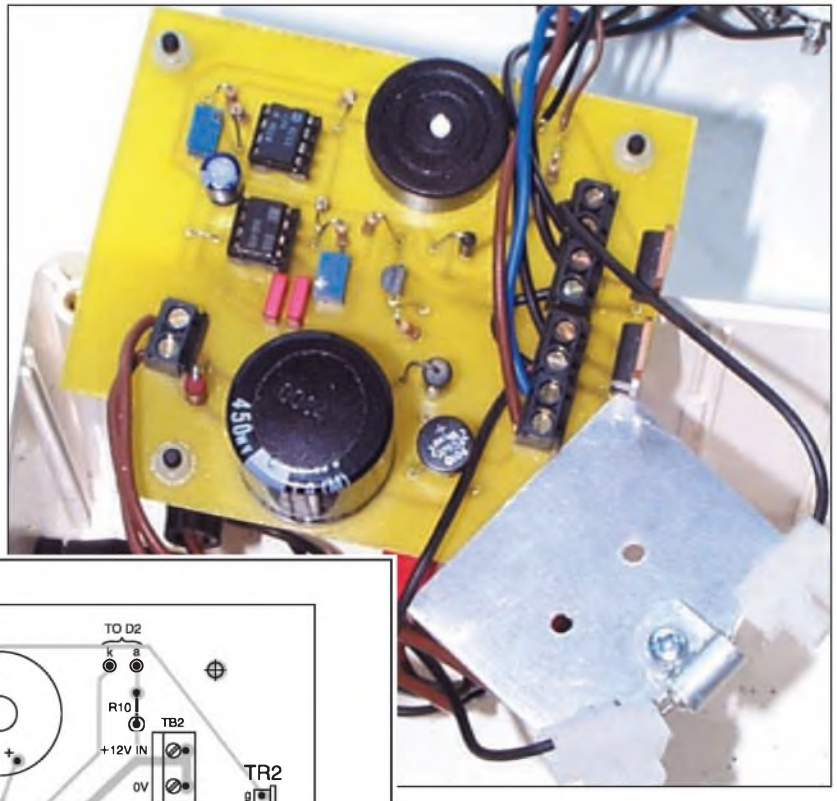
Insert the i.c.s in their sockets observing the anti-static precautions above with IC1 (not necessary for IC2). Adjust presets VR1 and VR2 to approximately mid-track position (by counting the number of turns between the clicks that are made at the extremes of travel).

HEATSINK

The heatsink is made using a piece of sheet aluminium size 50mm × 40mm although these dimensions are not too critical. Both TR2 and TR3 are attached to this as well as the clip which holds the thermal fuse (FS1).

Prepare the heatsink by drilling holes for the MOSFET tabs and for the thermal fuse clip. In the prototype, the clip was made using a piece of thin aluminium, size 10mm × 30mm. This was bent around the shank of a drill bit having a slightly smaller diameter than the fuse itself. *It is essential that the fuse makes good thermal contact with the heatsink.* Fit the thermal fuse in its clip, attach it in position and check that it is secure.

Mount the heatsink on TR2 and TR3's tabs. *It is essential that the tabs are electrically isolated from one another, from the heatsink and from everything else.* TO220 mounting kits (consisting of a plastic bush and insulating washer) ***must***, therefore, be used on both devices. *It is easy to fit these incorrectly so check using a multitester. When correctly fitted, there will be an infinite resistance between the heatsink and each MOSFET tab.*



Completed circuit board and close-up of the thermal fuse mounted on the aluminium heatsink. Use a TO220 insulating kit for mounting the heatsink on the transistor tabs.

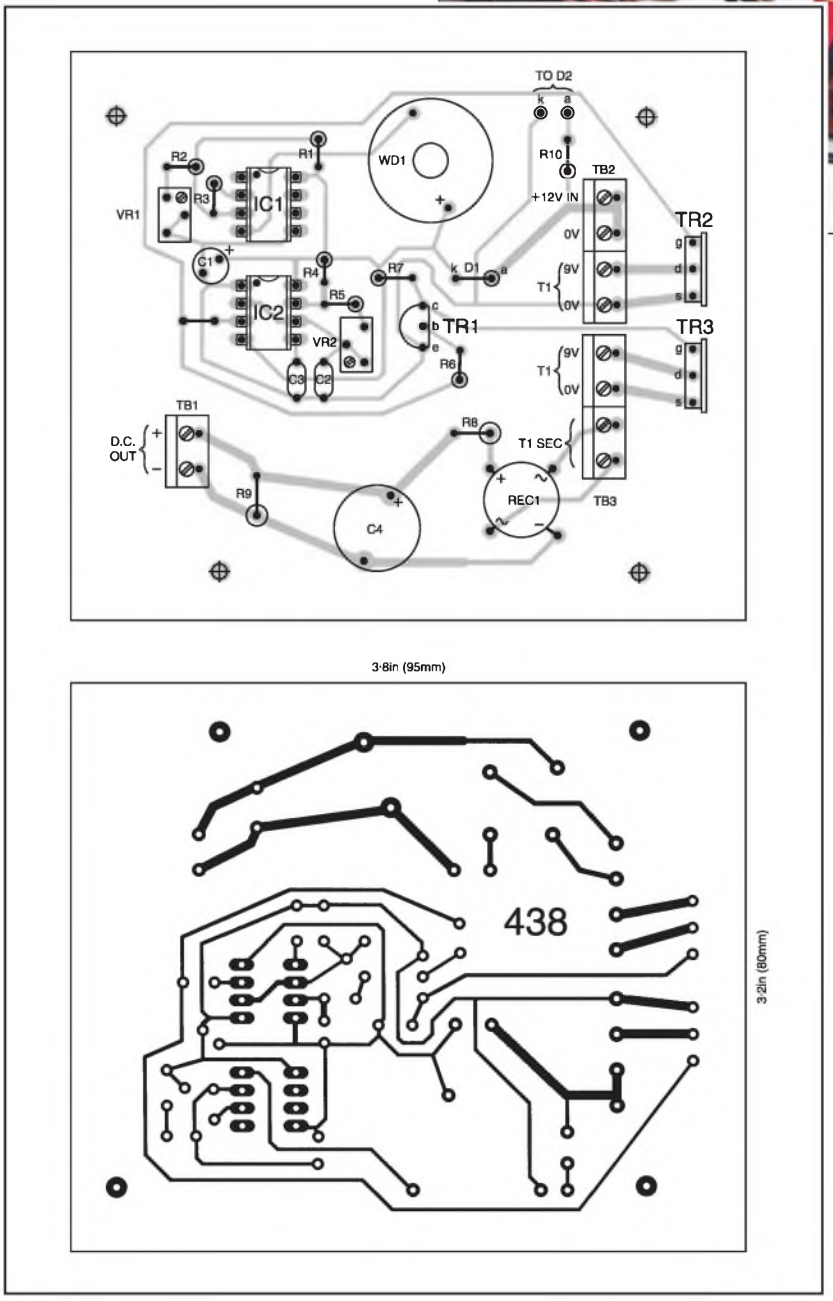


Fig.3. Printed circuit board component layout and full-size copper foil master for the Emergency Stand-by Light.

BOXING UP

The plastic box must be large enough to accommodate all parts with a clear space around them (see photograph). This will allow heat from the transformer (especially) and the heatsink to escape harmlessly. The tag side of the transformer should be placed nearer to the side of the case as shown in the photograph.

Mark the position of the p.c.b. mounting holes, also those for the transformer, fuseholders FS2/FS3, on-off switches, l.e.d. on indicator and the input and output sockets. A polarised panel-mounting plug (PL1) of 3A rating *minimum* should be used for the battery input connection.

The output must be made to a *socket* (SK1) so that it is impossible to touch the pins and this should be of a high-voltage (mains-rated) type different from the national mains type. This will prevent other devices from being plugged into it by mistake. It does not need to be polarised because the connecting plug may be inserted in either sense. If it is of the three-pin type, only two of them are used.

Remove all the parts and drill the holes. Mount the p.c.b. on 10mm high plastic stand-off insulators. Use nylon (non-metallic) fixings to attach the p.c.b., input/output connectors (if of this type) and the transformer. Fit the l.e.d. indicator.

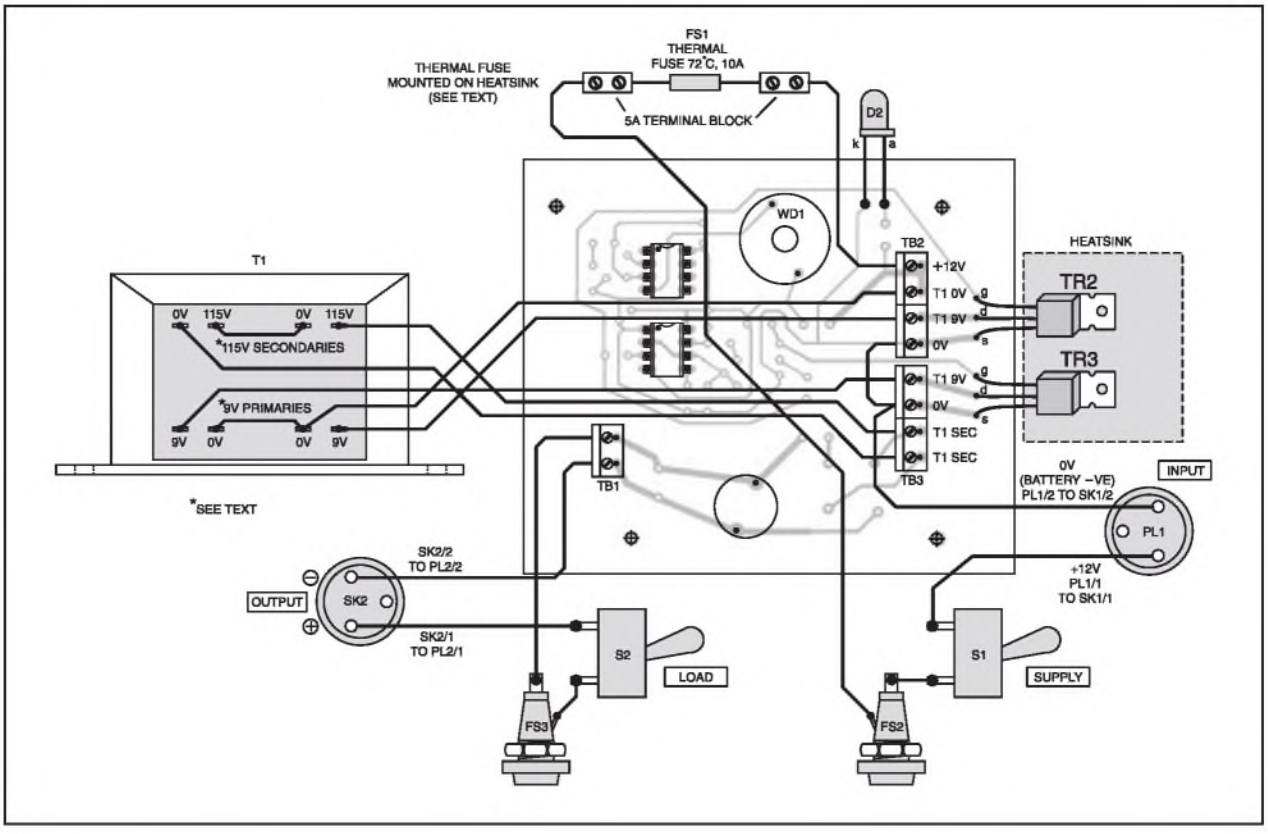


Fig.4. Details of interwiring from the p.c.b. and between off-board components. Not shown in this diagram is the mounting of the thermal fuse and transistors TR2, TR3 (using insulating mounting kits) on an aluminium heatsink. Also not included is the line-fuse FS4 in the positive lead from the battery.

WIRING UP

Referring to Fig.4, complete the internal wiring. For the low-voltage connections, including the links between the transformer's 9V primaries and the two "0V" connections on the screw terminal block (TB2/4 and TB3/2), use 3A stranded wire.

The connections to the thermal fuse leads must *not* be made by soldering. The heat conducting along the end leads would blow it! Instead, use two single pieces of screw terminal block which are resistant to 100°C – nylon is suitable. Make sure the end leads cannot touch the heatsink and use heat-resistant sleeving to prevent this happening if necessary. Connect the l.e.d. D2 indicator taking care over the polarity and sleeve the bare wires and joints to prevent them touching.

Mains-type wire of 3A rating should be used for all high-voltage connections. If the transformer has twin 115V windings (rather than a single 230V one), connect these in series as shown. The photograph shows an interior view of the prototype unit with the transformer secondary shield (see later) removed.

GETTING READY

You will need a multitester suitable for making measurements up to 400V d.c. *minimum.*

Prepare the battery connecting lead using twin flexible wire of 6A rating minimum. Mains-type, 13A flexible wire would be ideal. This should not be more than, say, two metres long to avoid excessive voltage drops.

Fit a line fuseholder containing the specified quick-blow fuse (FS4) in the positive wire close to the battery terminal. Use proper battery connectors – makeshift methods are **not satisfactory**. Wire the line socket (SK1) to the other end of the wire taking care that the polarity will be correct when it is connected to the circuit.

SAFETY FIRST

For safety reasons, fit insulating rubber boots over the terminals of the output socket and fuseholder FS3. Fit an insulating shield over the transformer secondary output tags (this must not interfere with the free flow of air around the transformer).

Tape a temporary cardboard cover over the p.c.b. in the region of REC1, R8, C4 and R9 so that no high-voltage components can be touched while making adjustments to presets VR1/VR2. You can't be too careful!

General layout of components inside the **plastic** *case. The mains transformer tags must be covered and positioned close to the sidewall of the case.*

While making adjustments, work with one hand in your pocket! Remember, lead-acid batteries can deliver a very large current in the event of a short circuit. This is why fuse FS4 is essential.

Fit self-adhesive plastic feet to the bottom of the box. These will allow a circulation of air underneath and promote cooling. The bottom of the unit will become quite warm in operation so, to prevent damage, do not place it on a heat-sensitive surface.

TESTING

Start with a fully-charged battery. Switch S1 (Supply) off then plug in the battery lead. Switch on the supply and note that the l.e.d. indicator D2 lights. You should also hear a gentle buzzing sound from the transformer. If a fuse blows or if there are any unusual sounds or smells or smoke, ***switch off immediately*** and investigate the cause.

If the "low battery" warning sounds, ignore it. Note that the audible warning device is modulated to some extent at the astable frequency and makes a distinctive "buzzing" sound.

Taking great care, apply the multitester probes to the output socket or, if this is not possible, *direct* to the output terminals of TB1. The meter should record a value of around 270V to 300V d.c.

Switch off the supply and check the voltage again after one minute. It should have fallen to near zero. *Before any adjustments are made, the battery must be disconnected, capacitor C4 allowed to discharge for one minute minimum and the voltage checked before proceeding.*

TAKING THE LEAD

Assuming all is well, prepare the lamp by making a connecting lead using *mains-type* (double-insulated) two-core wire of 3A rating. This may be of any reasonable length. Fit an *unswitched* plastic lamp holder on the end.

Switch off the battery and output switches, then plug in the lamp. Switch on the battery then, after a second or two, the output Load switch S2. This procedure allows capacitor C4 to charge up and provide the starting pulse. The lamp should "strike" and reach full brightness in a short time.

MOST EFFICIENT

The best way to attain maximum efficiency is to minimise the on-load current drawn from the battery while maintaining maximum output voltage. Since the actual value of the current does not matter, a good method is to measure the millivoltage "drop" across a section of wire carrying the battery current. The 0V ("negative") wire leading from the battery terminal to the corresponding terminal at the input plug would be sufficient.

Adjust the multitester to a low "volts d.c." range. Apply the multitester between these points. Adjust preset VR2 to obtain a minimum "drop" without the output voltage falling significantly. In the prototype, the voltage drop was 50mV approximately with 230V maintained. Of course, if you have a suitable ammeter, you could measure the current *direct*.

Fit the lid of the case and allow the circuit to continue to operate under full load. Check at intervals that the case is not too hot. After one hour, disconnect the supply and allow capacitor C4 to discharge.

Feel the transformer and heatsink. In the prototype, after this time the case felt slightly warm on the outside (especially underneath in the region of the transformer). The transformer itself was quite hot but the heatsink only slightly warm. The temperatures soon stabilise and do not rise any further.

Completed stand-by unit.

A good quality transformer should not require additional ventilation. If it turns out that this is required, small holes may be drilled in the case to allow the warm air to escape. If this must be done, *do it with great thought and care.* The greatest danger is that metallic objects could fall or be pushed inside and touch high-voltage components. Make sure this cannot happen.

LOW-POINT VOLTAGE

When the battery low-point is reached (check at intervals), remove the lid of the case and carefully adjust preset VR1 so that the audible warning device just sounds. As stated previously, this makes a distinctive "buzzing" noise. A suitable low point for a large unit is 11V but a smaller one may be set to 10·5V. It only remains to re-attach the lid and label the switches and sockets.

When cold, the low-energy lamp will strike easily by waiting for a second or two before switching on the Load switch. A cold lamp might strike without doing this but it may be slow to operate. A warm lamp will strike easily anyway.

After use, always switch off the supply – never just the load. This avoids the unnecessary off-load drain. In use, take care to avoid covering over the unit which might result in overheating. □

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SHOP TALK with David Barrington

Emergency Stand-by Light

Safety must be the byword when selecting components for the *Emergency Stand-by Light* project and you should use nylon fixing nuts and bolts, and cover any exposed "mains potential" connections with some form of protective insulation, such as heatshrink sleeving. Note also that capacitor C4 *must* have a *minimum* working voltage of 450V d.c. or better.

The 50VA mains transformer, with twin 0V-9V at 2·78A secondary windings, used in the model came from **Farnell** (☎ ***0870 1200 200*** or ***www.farnellinone.co.uk***) code 696-640. They also supplied the axial type 72°C 10A thermal fuse, code 476-560, and the bridge rectifier (code 330-7943). Comparing the main spec. for the bridge rectifier you could probably use one from the WO series, namely the WO8.

The thermal fuse is also listed by **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***), code 740-150. You must ***NOT*** omit this fuse from the unit.

Some readers may have difficulty locating the MAX8211 CMOS micropower voltage detector. This was purchased from **RS Components**, code 427-506. It can be ordered through any *bona-fide* RS stockist or direct (credit card only) on ☎ ***01536 444079*** or ***rswww.com***. A post and handling charge will be made.

The output must be taken to a socket in which it is impossible to touch the pins, be of a high voltage (mains-rated) type and be different from the national mains type. This will prevent other devices from being plugged into it by mistake. An ideal combination would be one of the well-known Bulgin range, such as SA2404 3-pin chassis socket and SA2403 3-pin line plug with shielded pins. Another alternative would be a "European style" mains outlet chassis socket and line plug.

The printed circuit board is available from the *EPE PCB Service*, code 438 (see page 221). For a suitable lead-acid battery, readers should scan the advertising pages as some run "bargain offers" from time to time. Try **Bull Electrical** (☎ ***0870 7707520*** or ***www.bullnet.co.uk***).

Finally, please pay heed to the safety panel and other safety pointers throughout the article. Note also that this unit is *NOT* suitable for tungsten filament lamps or any other appliances. For the real "McCoy" you could do no better than invest in one of the power inverters listed in the **BK** ad. on page 192.

MIDI Health Check

Indications are that a number of parts called for in the *MIDI Health Check* project may prove to be elusive to track down locally.

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 4050 hex buffer i.c. should be generally available.

Quite a number of our advertisers now stock 2-line 16-characters per line alphanumeric l.c.d. modules and sourcing should not be a problem. However, you should check you have the relevant pinout information when purchasing so that you are able to "hardwire" it to the p.c.b.

As used in the prototypes, the 3-terminal, s.p.d.t. 0·5A 50V d.c., push-button switches appear to be only listed by **Farnell** (☎ ***0870 1200 200*** or ***www.farnellinone.co.uk***) codes 147-405 black and 147-406 red. You could substitute with miniature "biased" toggle switches.

The printed circuit board (p.c.b.) has been designed to accept components for either the Transmitter or Receiver. Likewise, the software to drive either unit is programmed into a single PIC. This means, of course, you will require two p.c.b.s and two programmed PICs.

For those readers unable to program their own PICs, a ready-programmed PIC16F628 microcontroller (two needed) can be purchased directly from the author for the sum of £8.00 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*, and *only* in £ sterling and drawn on a British bank, UK postal orders are also accepted.

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 221). It is also available *Free* via the Downloads click-link option on the home page when you enter our main web site at **www.epemag.wimborne.co.uk**, then enter the PIC Microcontroller source codes folder and select **PIC MIDI Health Check**.

The printed circuit board is available from the *EPE PCB Service*, code 437 pair (see page 221).

PIC Mixer for RC Planes

We have been unable to find a UK source for the Fairchild KA336-2·5 device (D1) on the circuit diagram. To keep within the author's specified components for the *PIC Mixer for RC Planes*, we have only found the LM336-2·5 version of the programmable shunt regulator or voltage reference device listed by **RS Components**, code 411-668. You can order direct (credit card only) from RS on ☎ ***01536 444079*** or ***rswww.com***. A post and packing fee will be added. Looking at the main spec. for the above voltage reference, the TL431 device seems to be a possible substitute but has not been tried in this circuit.

A preprogrammed PIC16F84 microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £5.90 each (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 221). 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**, then enter the PIC Microcontroller source codes folder and select **PIC Vplane**.

Bat-Band Convertor

Readers should not experience any real problems when sourcing components for the *Bat-Band Convertor* project. The only minor hiccup is that some suppliers only sell the 40kHz ultrasonic transducer as a matched transmitter and receiver pair. However, the current **Squires** (☎ ***01243 842424*** or ***www.squirestools.com***) catalogue list the transducers as separate items and the Receiver is coded 800-274.

The author strongly advises that the i.c. be soldered *directly* to the circuit board, but warns against excessive heat during this operation. If any reader is a bit wary about this, you could try an i.c. socket here.

The small printed circuit board is obtainable from the *EPE PCB Service*, code 436 (see page 221).

Teach-In '04 Part 5

If Teach-In '04 readers wish to experiment/build the PIC-based controller circuit of Fig.5.17, a preprogrammed PIC microcontroller chip 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 5. 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 221 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: Tech-Supplies, Dept. EPE, 4 Old Dairy Business Centre, Melcombe Road, Bath BA2 3LR. The telephone number of Revolution Education is 01225 340563, and their web-site is at **www.rev-ed.co.uk**.

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03/04

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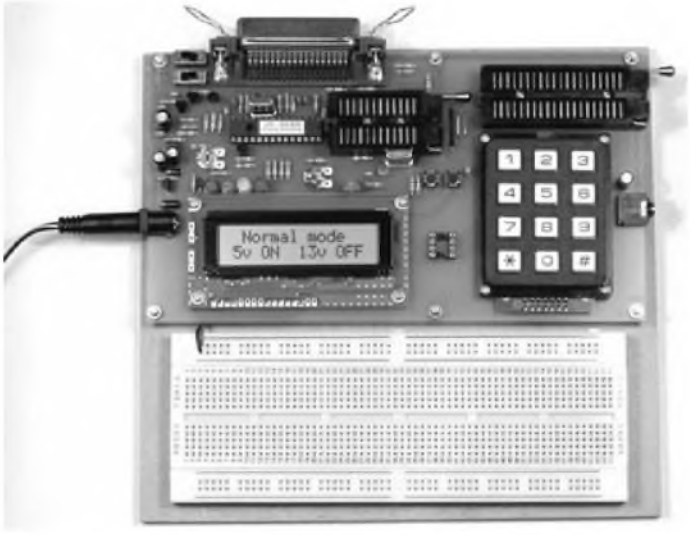

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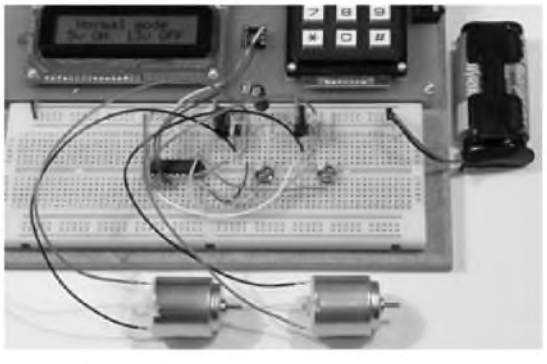

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The PIC16F627 is then introduced as a low cost PIC16F84. We use the PIC16F627 as a step up switching regulator, and to control the speed of a DC motor with maximum torque still available. We study how to use a PIC to switch mains power using an optoisolated 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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New Technology Update

Poor soldering is the cause of circuit failures even for professionals. Ian Poole reports.

SOLDERING and solder technology are at the very heart of electronics technology. Without solder, electronics manufacturing would be very different to the way we know it today. Printed circuit boards are by far the most widely used form of construction, and every joint made on these boards uses solder.

However, solder hardly seems to be a high tech material. It has been around since the very earliest days of radio and electronics, and although improvements have been made, it appears to be essentially the same.

Many improvements have occurred as a result of the advances made in the technology of electronics circuitry construction and packaging. Surface mount technology has come to the fore in the last fifteen years and has placed many new requirements on soldered joints. With the number of joints rising as circuits become more complicated, very careful control of the soldering process is required because these joints are the major source of faults in new equipment.

New Formulations

New solder formulations have been created and better methods for applying the right amount of solder in the right places have been developed. For mass production, solder masks are generated from the same information as the circuit board layout data. These masks ensure that solder is only applied to the required areas of the board, and in the correct amounts. The solder in the form of a paste is added, and then the components are placed onto the boards using specialised pick and place machines. Once everything is in place, the board is run through a heater, generally an infra-red heater, to melt the solder and create the soldered joints.

Automatic Optical Inspection (AOI) machines are then used to check the boards. These machines optically examine the boards and compare the results with known good examples in a "database" of previous examples of the board. The machines are very good at detecting poor joints, and if this check is completed immediately after soldering, it is possible to quickly remedy problems to ensure that further boards do not have the same faults.

Solder Developments

Apart from the manufacturing process developments that have been occurring, solder itself has been undergoing development. This has been brought about, at least in part, by the miniaturisation of many of the packages that are used. There is an increasing use of Ball Grid Arrays (BGAs).

These chips use small mounds or balls of solder under the chip to connect to pads on the board. There has to be a very high degree of certainty that the joints are correct before the boards are passed on to the next stage of manufacture. Problems are very difficult to locate unless X-ray inspection techniques are used.

In addition to this, the size of many of the board/chip connections is such that the areas for the connections themselves are becoming smaller and very high current densities are commonly found. It is not unknown for densities of 106A/cm^2 to be seen!

Reliability

Furthermore, long term reliability is an issue. Customers expect electronic equipment to be very reliable despite the greatly increased complexity. This places a new set of requirements on solder technology. These may also be more difficult to test, because by their very nature they will take months, or even years to test, although there are methods in the laboratory of accelerating the testing to some degree.

Problems associated with soldering and modern assembly technology are being actively addressed by the Electronic Packaging Laboratory at the University at Buffalo School of Engineering and Applied Sciences in the USA. In particular they are looking at critical problems that are confronting the electronics industry as the challenges facing them increase.

In many areas it is the packaging technology that is limiting the development of the integrated circuits themselves. As a result Intel are working with the University at Buffalo to develop the packaging technology for their next generation Pentium processor.

One of the major areas of work is centred around investigations with lead free solder. One researcher said that solder joints are the biggest bottleneck and source of failure in microelectronics. It is not the chips that fail, instead it is the area where they interface to the printed circuit board where the failures occur. By improving this area, the overall reliability of a system can be considerably enhanced.

Investigating Failures

One of the major approaches is to investigate how the failures occur. It appears that very little work has been undertaken into the study of the nature and reasons for failures. In a typical production environment it is found that in most cases where a failure occurs the i.c. itself is replaced and the failure is attributed to the i.c. rather than the joint. Unfortunately the evidence of the cause of the failure is destroyed by the very act of the removal of the i.c. and as a result there is comparatively little data available.

To overcome this the University at Buffalo has been looking at the degradation of solder joints. In their investigation they have looked at a number of elements of the joint. One area is the strain field in the joint resulting from the very high current densities.

In addressing this area it has been necessary to be able to measure the stress. This has been achieved using a process known as Moiré Interferometry. The technique uses laser beams to measure the displacement field of the solder material.

The technique has enabled the research team to measure displacements down to distances of only 27nm. This has highlighted a number of factors, including the fact that electro-migration occurs with the solder material gradually moving downwards towards the board. This creates voids within the solder, forcing the current to flow through an even smaller cross sectional area. This effect then creates even more strain on the solder joint causing further degradation. As can be imagined, this process accelerates as the area through which the current can flow reduces, ultimately causing a failure.

Further investigation of the mechanisms around the migration show that one of the more mobile constituents of the solder is lead. Apart from the moves to reduce the levels of lead in solder for green considerations, this new research places even further emphasis on the electronics industry to move towards the use of lead-free solder.

Computer Simulation

The practical investigations have been proceeding alongside computer simulations of the behaviour of the solder joints. These have now been refined to the point where they agree accurately with the measurements that have been made.

This now opens the gate to being able to refine the technology behind solder techniques more accurately and also more rapidly. In this way it should be possible to accelerate the research into the degradation of solder joints, thereby opening the way to even more reliable electronics equipment, and also removing the block which chip manufacturers are finding with the interconnect technology.

Constructional Project

MIDI HEALTH CHECK

DAVID CLARK

Check out your MIDI home studio with this transmitter-receiver pair!

THE author is an enthusiastic user of the kind of music technology that employs the MIDI (Musical Instrument Digital Interface) protocol to communicate between keyboards, sound modules and computers in order to create and record sounds and music.

When originally starting to use this type of equipment, the author often found that the system did not work the first time. Lack of experience made it unclear whether something was faulty, devices were connected up wrongly, or simply that a particular setting had not been chosen correctly.

What was needed was a simple device that would transmit and detect single messages in a way that clearly demonstrated the presence or absence of meaningful code signals. This would be a great improvement over basically having to guess at what might be happening from the flood of data that an oscilloscope showed to be streaming constantly from the keyboard, even when no-one was touching it!

HOME STUDIO

The growth in the use of computers in the music recording field, coupled with the accompanying reduction in cost of the associated software, has brought about the possibility of producing, in a studio in a spare bedroom, music of a quality high enough for commercial release. With suitable software, in fact, this can be done using only a computer with a suitable sound card and a MIDI master (piano-style) keyboard.

A MIDI master keyboard merely outputs MIDI codes, and need have no sound producing facilities whatsoever. Even the keyboard could be done away with, though composing music on a computer simply using the computer mouse would probably be far too frustrating and time-consuming to be worthwhile.

Neither might a sound card be necessary if the computer motherboard is equipped with audio facilities, as most are now. Nevertheless, a sound card should give a far better quality sound output, and will probably incorporate a MIDI interface, allowing the computer to be linked to a MIDI sound module, which should give even greater sound quality.

MINIMUM REQUIREMENTS

Minimum requirements for a reasonable home recording studio set-up are: a PC, some sequencing software (which can be bought off-the-shelf inexpensively) and preferably a MIDI sound module.

But although using MIDI equipment is fairly straightforward, especially once some experience has been acquired, it can be confusing at first. Modes, channels, local on/off, synchronisation, mixer settings, mute; these are some of the settings that need to be made correctly for a system to work properly.

Without "tweaking" some settings on the keyboard, the computer hardware, the sequencing software and the MIDI sound module, the first sound to come out of a new set-up is likely to be a deafening silence (or even worse, a deafening 50Hz hum – but that's a different issue).

So, is the keyboard faulty? Or is the computer set up incorrectly? Is the sound module receiving any data? Is a cable faulty? How do you find out? One answer of course is to try a second keyboard/computer/sound module. Most home studio users, however, probably would not have that luxury. Enter the MIDI Health-Check system!

INTERFACE

The MIDI protocol is essentially a serial interface system that has been specified for a specialised use. (Details of the MIDI system will not be included in this article as it is assumed that anyone wanting to construct this project will already be familiar with the basic principle, if not the detail.)

Prior to the advent of PIC microcontrollers, designing such a serial interface usually meant using a dedicated device such as the 6402 UART (Universal Asynchronous Receiver/Transmitter). In fact, the author first thought of designing this project by attempting to combine a 6402 "cannibalised" from a previous project (a MIDI interface for a Sinclair ZX Spectrum!) with a PIC16F84.

The 6402 is looking a little "creaky" nowadays, though. It is also relatively

expensive, currently retailing for around £12. Since a microcontroller was going to be used anyway, it made much more sense to use the PIC16F628, as this device has its own USART (Universal Synchro nous/Asynchronous Receiver/Transmitter). This greatly simplified the design.

CONCEPT

The PIC16F628's USART can be set up via software to operate as both a transmitter and a receiver, so a design was first considered for a single unit that could be operated as either. It was soon realised how much more useful and flexible the system would be if the transmitter and receiver were separate units.

The units could be operated some distance apart, to test a cable for example. Separate units can, of course, also test each other, proving without a doubt whether signals are actually available. It simplified programming too, and furthermore, since only a limited amount of information can be displayed at any one time on a 16 × 2 liquid crystal display (l.c.d.), the units are easier to use and the displayed information more intuitive if each unit has a dedicated function.

SIGNALS

With most technology, ease of use conceals some very complex operations. The basic idea behind MIDI communication is simple: send a signal to turn a note on, wait a bit, and then send a signal to turn it off.

Even at first glance, this is a huge over-simplification. A computer sequencer with a MIDI interface can control individually 16 different instruments even in a very basic system. Each instrument can usually output several notes at once, often with different timbres. But there's far more going on than that, invisible to the user.

Timing signals might be transmitted constantly between pitch and channel data, and messages that communicate information for a particular make of instrument only are sometimes encountered. In the case of recording equipment, signals that start and stop recording or playback, or indicate where in a particular song the recording equipment is, are usually present too. It can be very confusing when things happen (or don't happen) contrary to expectations.

PROBLEM SOLVING

This MIDI Health-Check system should simplify problem solving greatly. The transmitter will transmit one message byte only, followed by the appropriate number of data bytes for that particular message.

Each appropriate data byte has a fixed and different value, so that by hearing, or observing, what happens when connected to a synthesiser or other equipment, it should be clear whether or not a particular message has been received correctly. (A software sequencer display can be particularly instructive as this can usually display a list of the codes recorded, assuming of course that it is not the sequencer that is causing the problem.)

The receiver can be set to detect and display all of the message bytes. It can also be set so that all system messages, or only clock messages if preferred, can be filtered out. So again it should be possible to detect exactly what (if anything) a synthesiser, keyboard controller or other equipment is transmitting.

TRANSMITTER CIRCUIT

The full circuit diagram for the MIDI Code Transmitter is shown in Fig.1.

The circuitry is straightforward, being based around the PIC16F628, IC3. The PIC is operated at 4MHz, as set by crystal X1 in conjunction with capacitors C3 and C4. The l.c.d. module, X2, is driven in 4-bit mode.

The MIDI interface is defined in the protocol as a 5mA loop, optically linked at the receiver end only. This is a current value that the I/O (input/output) pins of the PIC are more than capable of providing, and so no further drive circuitry is necessary. The output from the transmitter at PIC pin RB2 is via a 180° 5-pin DIN socket, as specified by the MIDI protocol.

COMPONENTS

MIDI Code Transmitter

See SHOP TALK page

Resistors

R1	1k
R2, R3	220Ω (2 off)
R4	10k

All 0·25W 5% carbon film or better.

Potentiometer

VR1	10k skeleton preset, horiz.

Capacitors

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

Semiconductors

IC1	78L05 5V 100mA voltage regulator,
IC2	74HC4050 hex buffer
IC3	PIC16F628 microcontroller, preprogrammed (see text)

Miscellaneous

S1	min. s.p.s.t. toggle switch
S2, S3	min. s.p.d.t. pushbutton switch, momentary action (2 off)
SK1	5-pin 180° DIN socket, panel mounting
X1	4MHz crystal
X2	2-line 16-character (per line) alphanumeric l.c.d.

Printed circuit board, available from the *EPE PCB Service*, code 437; plastic case, 150mm x 100mm x 60mm; 16-pin d.i.l. socket; 18-pin d.i.l. socket; 9V battery (PP3 type), with clip; 1mm terminal pins; connecting wire; solder, etc.

Approx. Cost Guidance Only

£20 *excl. case & batt.*

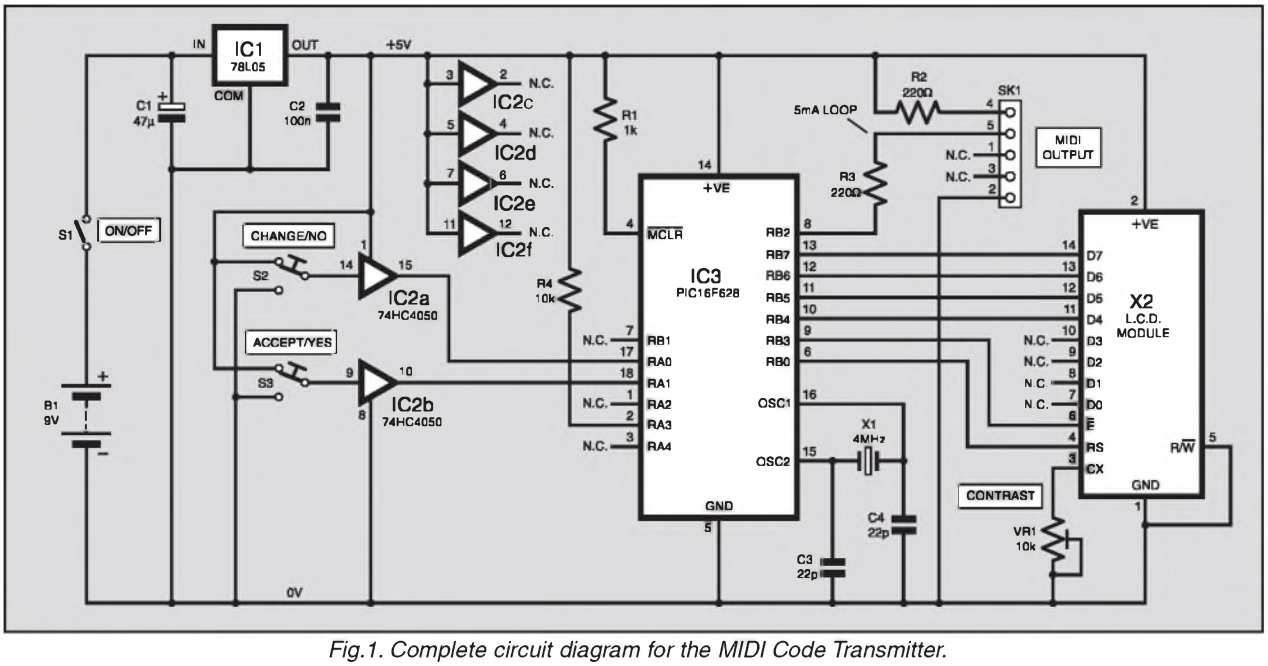


Fig.1. Complete circuit diagram for the MIDI Code Transmitter.

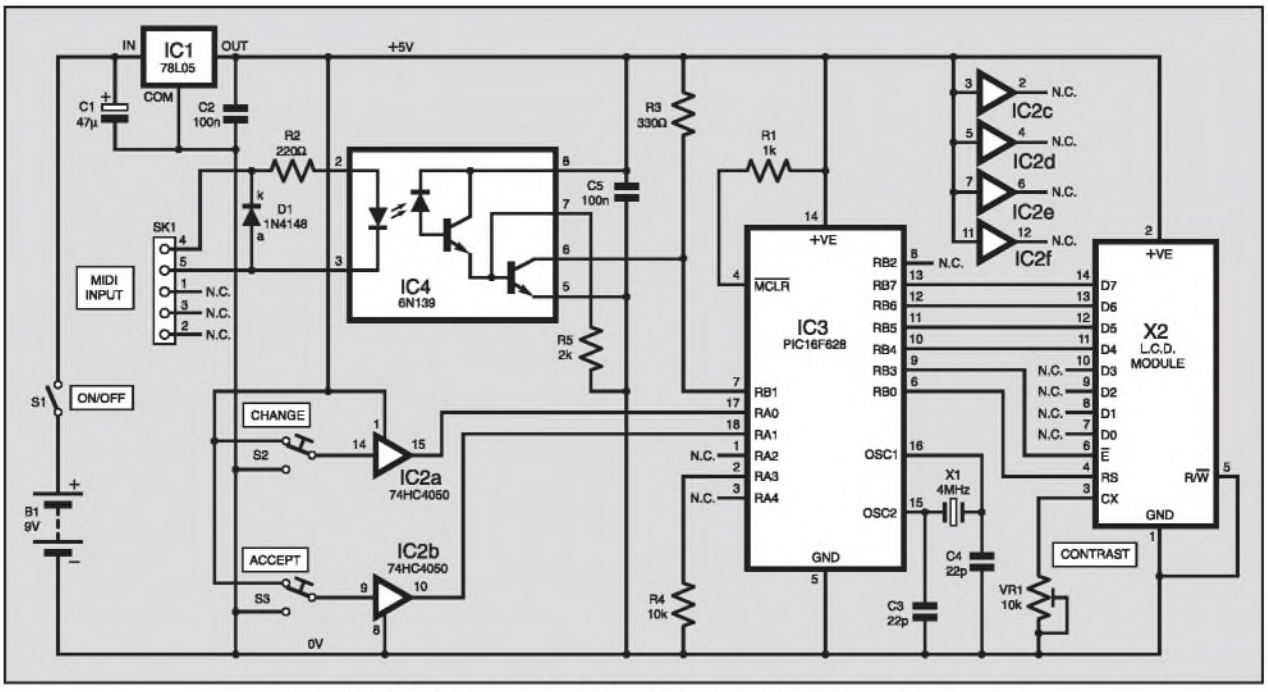


Fig.2. Full circuit diagram, with optoisolator input, for the MIDI Code Receiver.

Switches S2 and S3 are buffered by inverters IC2a and IC2b as a cure to switch-bouncing problems. The circuit is powered by a 9V PP3 battery, with IC1 regulating the voltage down to 5V.

RECEIVER CIRCUIT

The full circuit diagram for the MIDI Code Receiver is shown in Fig.2.

As with the Transmitter, the Receiver has a standard interfacing to the l.c.d. display, the switches are debounced and the power supply regulated in the same way.

The main difference in the circuit is that an optoisolator, IC4, is needed on the input to comply with the requirements of the MIDI protocol. The output from IC4 pin 6 is fed to PIC pin RB1.

TRANSMITTER CONSTRUCTION

The printed circuit board (p.c.b.) has been designed to accommodate the components for either the Transmitter or the Receiver as required. The component layout for the transmitter circuit is shown in Fig.3, along with the full-size master track layout pattern. This board is available from the *EPE PCB Service*, code 437. You need two copies of this board, the second being for the Receiver.

Assemble the board by starting with the wire links, and then the i.c. sockets. Then assemble in ascending order of component size, correctly observing the orientation of the voltage regulator, electrolytic capacitor and i.c.s, although you should not insert the latter, or connect the l.c.d., until the correctness of the power supply has been proved.

Note that the order of the TB1 terminal pins matches the order of the pins on the l.c.d. module. Particular care needs to be taken when wiring switches S2 and S3, which have three terminals. Use a multimeter to check which are which. Care also needs to be taken over the pin numbering on the 5-pin DIN connector, SK1.

RECEIVER CONSTRUCTION

The component layout for the Receiver circuit board is shown in Fig.4. As said, its track layout is the same as for the transmitter, as in Fig.3.

Construction of the receiver circuit is very similar to that of the transmitter, and a similar assembly order should be followed. The only significant differences are the additional components associated with the optoisolator and the wiring of socket SK1.

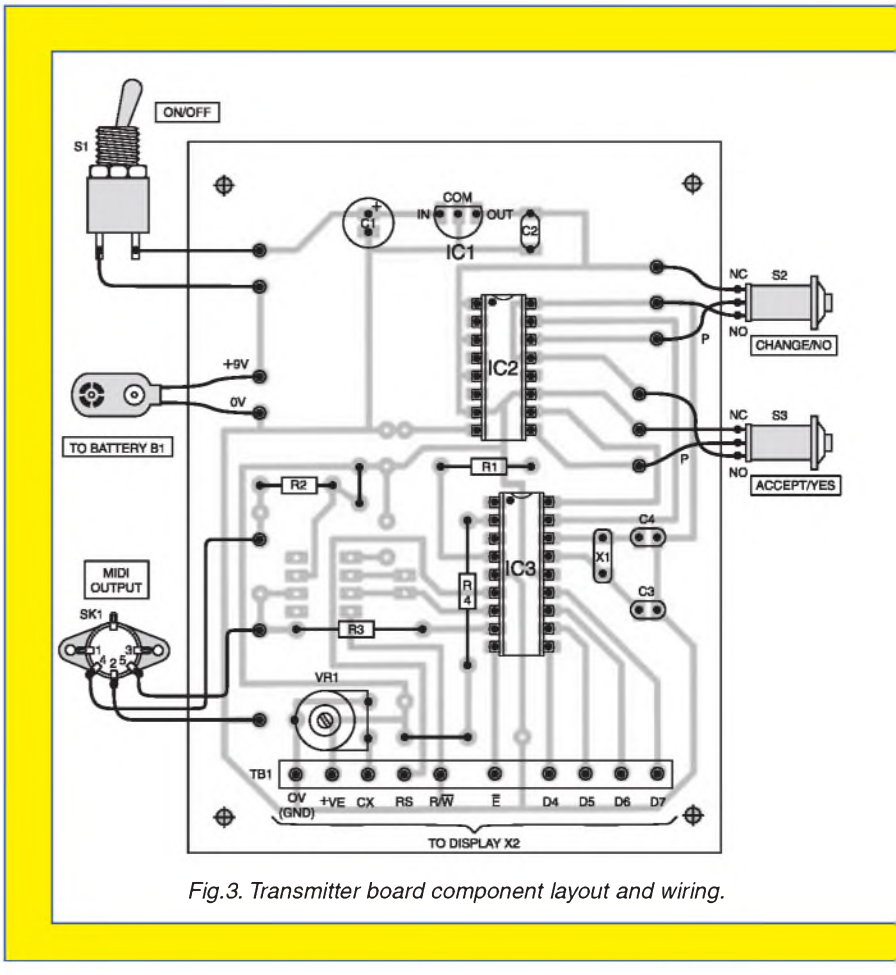


Fig.3. Transmitter board component layout and wiring.

COMPONENTS

Approx. Cost Guidance Only **£21** excl. case & batt.

MIDI Code Receiver

See SHOP TALK page

Resistors

R1	1k
R2	220Ω
R3	330Ω
R4	10k
R5	2k

All 0·25W 5% carbon film or better.

Potentiometer

VR1	10k skeleton preset horiz.

Capacitors

C1	47μ, radial elect. 16V
C2, C5	100n ceramic disc, 5mm pitch (2 off)
C3, C4	22p ceramic disc, 2.5mm pitch (2 off)

Semiconductors

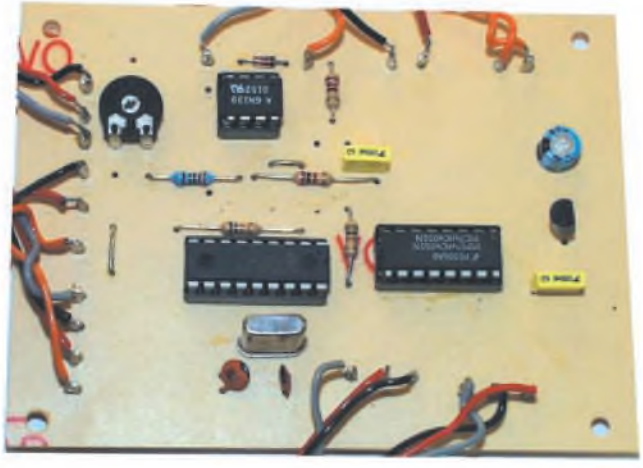
D1	1N4148 signal diode
IC1	78L05 5V 100mA voltage regulator,
IC2	74HC4050 hex buffer
IC3	PIC16F628 microcontroller, preprogrammed (see text)
IC4	6N139 optoisolator

Miscellaneous

SK1	5-pin 180° DIN socket, panel mounting
S1	min. s.p.s.t. toggle switch
S2, S3	min. s.p.d.t. pushbutton switch, momentary action (2 off)
X1	4MHz crystal
X2	2-line 16-character (per line) alphanumeric l.c.d.

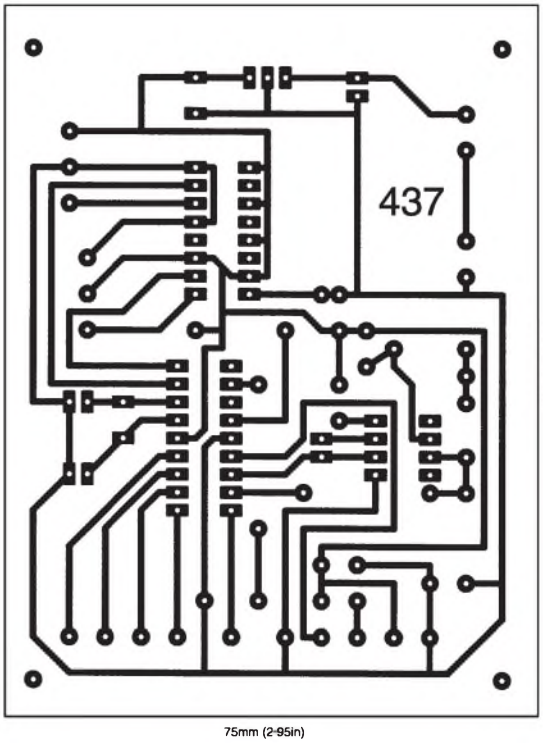
Printed circuit board, available from the *EPE PCB Service*, code 437; plastic case, 150mm x 100mm x 60mm; 8-pin d.i.l. socket; 16-pin d.i.l. socket; 18-pin d.i.l. socket; 9V battery (PP3 type), with clip; 1mm terminal pins; connecting wire; solder, etc.

Note also that the link near resistor R2 on the transmitter is not needed for the receiver. This link allows the PIC software to recognise with which board it is being used – both PICs use the same program, jumping to the appropriate routines



Receiver components mounted on the p.c.b.

P.C.B. MASTER



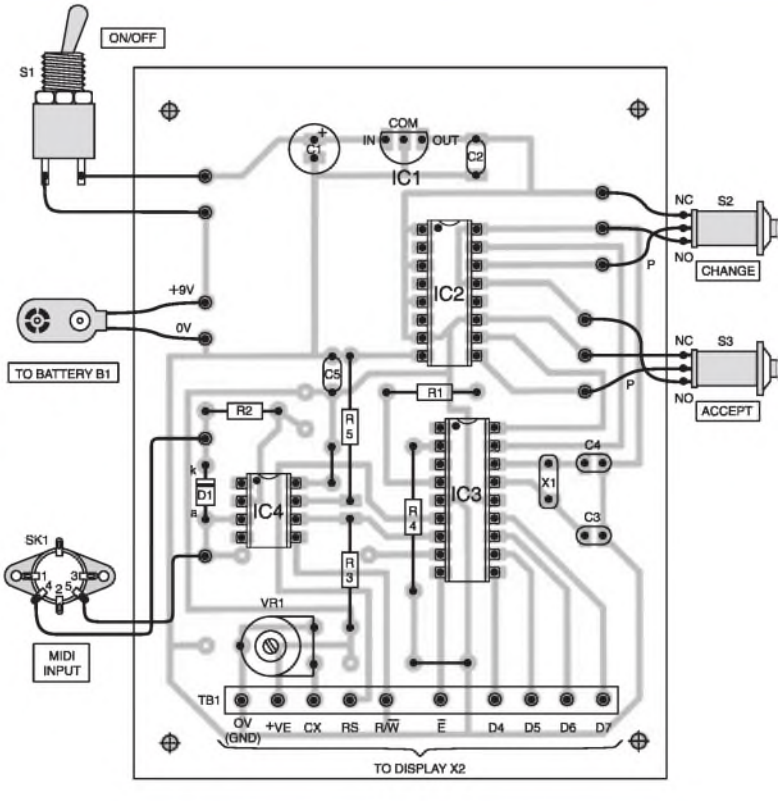


Fig.4. Receiver board component layout and wiring.

depending on which board the software detects.

ENCLOSURES

Both units should be housed in an enclosure suitable for use in a practical situation. The cases used for the prototype basically measure 150mm × 100mm × 60mm, although they taper slightly from the top downwards.

A viewing slot for the l.c.d. needs to be cut out, and holes drilled for the switches (see photograph) and the socket, which was mounted at the rear of each case.

The p.c.b.s should be fixed in position inside the housing with mounting pillars (self-adhesive types are ideal). The battery too should be fixed to prevent damage through it moving around inside the case – a cable tie and a self-adhesive cable-tie base are a straightforward solution to this.

TRANSMITTER USE

The MIDI Code Transmitter is used to detect whether a seemingly non-functioning piece of equipment is receiving correctly. The transmitter's output at socket SK1 should be connected to the "IN" socket of the receiving equipment, using a suitable MIDI cable; the existing connection needs to be removed, of course.

The transmitter will transmit singly the codes shown in Table 1. These options are presented sequentially via the l.c.d. module, with the opportunity to accept or change the option via the two pushbutton switches, notated Change/No (S2) and Accept/Yes (S3), before transmitting the message.

Pressing S3 causes the message to be transmitted, which is confirmed by the l.c.d. briefly displaying the word "Transmitting". The screen then invites the user to repeat the transmission or to change to another option if required.

The message "Note On" is probably the most useful to use at first. Then, if the receiving equipment sounds middle C, it is working correctly, and there is something amiss with the rest of the set-up. The note should keep sounding until a "Note Off" message is sent.

If the receiving equipment does not respond correctly, its settings can be adjusted one by one and a "Note On" transmission repeated until the correct setting causes middle C to sound. Or, having exhausted all possible settings, it is concluded that the receiving instrument is faulty.

A faulty receiving instrument can be confirmed as such by disconnecting it and using the MIDI Code Receiver in its place, replacing the MIDI Code Transmitter with the original instrument.

Operating the transmitting instrument should cause the MIDI Code Receiver to indicate that it has received the signal to which the other equipment failed to respond. If a note does sound, it is likely that all the facilities of the receiving equipment are operating correctly. To make sure, or if a more subtle fault is suspected, other messages could be transmitted, "Program Change" for example, and their reception checked for individually.

RECEIVER USE

On switching on the MIDI Code Receiver the user is invited to choose, by pressing "Accept" switch S3, one of three options as shown in Table 2. They are presented sequentially by pressing "Change" switch S2.

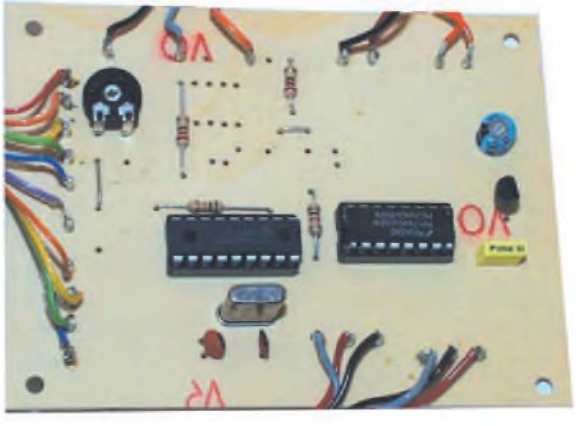
The option that should be chosen depends on what is being checked. Details of the type of test that might be done and the appropriate setting necessary are described later. The text for the option that has been chosen is displayed on l.c.d. line 2, and the last message received at the input DIN socket is shown on line 1. The latter will naturally be blank at first.

The text for the message that has been received is shown in Table 3. Note that all the messages transmitted and received by the MIDI Health-Check system are on MIDI Channel 1, except System Reset, which is not associated with a particular channel, so there can be no confusion about whether an incorrect channel setting is the cause of a non-function.

Rear of the case lid showing the l.c.d. module and wiring to the three switches.

Table 1. Messages sent by the MIDI Code Transmitter

Message Sent	*Value*	*Display*
Note On	C3 (middle C)	Note On (C3)
Poly Key Pressure	64	P-Key Press (64)
Control Change	controller 7, main volume, 127	Ctrl Chg (7-127)
Program Change	99 transmitted, corresponds to program 100	Prog Ch (99)
Overall Pressure	90	Ovrl Press (90)
Pitch Wheel	msb/lsb 95/85	Pitch W (95-85)
System Reset	all channels	System Reset
Note Off	C3 (middle C)	Note Off (C3)



Component layout on the Transmitter board. Note the unused holes on the master p.c.b.

This means, of course, that the equipment being monitored must be set to appropriately receive or send signals on this channel. This should be the first thing to be checked if a system is not working, and the novice is helped here by the fact that MIDI equipment almost invariably defaults to Channel 1 on power-up.

To detect whether or not a piece of equipment is transmitting correctly, the MIDI Code Receiver should be connected to the transmitting instrument's "OUT" connector, the existing connection having been removed.

Table 2. Receiver modes

L.C.D. Screen	*Messages Displayed Function*
All message	Channel, Clock and System
No Clk; Show Sys	Channel and System only
No Sys or Clk	Channel only

Table 3. The text displayed by the MIDI Code Receiver for received message codes

LCD Message Display
Note On
Note Off
Poly Key Pressure (16 characters only)
Control Change
Program Change
Overall Pressure
Pitch Wheel
Clock Signal
System Message

The MIDI Code Receiver *could* be connected to the "THRU" connector of any of the other pieces of equipment in the system, thus making it unnecessary to disconnect the system from the transmitting instrument being checked. However, this would add a further level of uncertainty as to where a fault exists, and so is not recommended.

The receiver mode is then selected as required. The setting that should be chosen depends on two things – what is being looked for, and what is present, and these are also dependent on the type of equipment being checked.

The possibilities are – channel messages, system messages and clock messages. In fact, clock messages are a type of system message, but it is helpful to treat them as a separate category. Channel messages are those most directly concerned with producing sound, and will be output by master keyboards and sequencers that are playing back pre-recorded music. These will be the messages of most interest for problems that will have a simple solution, for example an incorrect channel or program setting.

Clock messages will be present in the case of keyboards that have some form of tempo setting, usually those that have an arpeggio and/or sequencer function. Clock messages are also usually present in the output from computer sequencers, though one of the options usually available in sequencers is to switch off this form of synchronisation.

System messages are unlikely to be sent by keyboards unless the user chooses to send them deliberately. Sequencers and other recording and playback equipment will send out system messages associated with starting and stopping. Song position pointers and clock signals are usually associated with this. The choice, therefore, really depends on the situation; it's up to you!

EXPECTED RESULTS

To perform a check, the transmitting instrument is operated according to whatever is appropriate for the check. It is likely to be a straightforward decision – if a keyboard is being checked it might simply be a matter of operating the control of interest. This could be a program change button or simply a note key.

If a sequencer is being checked it would probably be appropriate to set up a pre-recorded sequence (there is usually a "demo" sequence included with such equipment that can be used if it is the first time the sequencer is being operated). The sequencer would be started and stopped as appropriate.

If the MIDI Code Receiver displays the message expected, then the transmitting equipment should be operating correctly and the system fault lies elsewhere. If not, once again the settings on the transmitting equipment can be altered until the system operates as required, or until it is concluded that the transmitting equipment must be faulty.

As with testing receiving instruments, this can be checked by connecting the MIDI Code Transmitter into the system in the place of the suspected faulty equipment, and replacing the MIDI Code Receiver with the original receiving instrument. Sending the appropriate message should confirm that the receiving equipment now receives messages correctly.

CAUTIONARY NOTE

Readers should be aware that the MIDI Code Transmitter and Receiver system is primarily intended to check channel messages – the transmitter cannot transmit clock signals or system messages other than "System Reset".

Nevertheless, the MIDI Code Transmitter and Receiver should prove extremely useful for checking a MIDI-based home studio system, and be of value not only to newcomers to this area with perhaps a modest amount of equipment, but also to those with more extensive set-ups.

RESOURCES

The software for the MIDI Health-Check is available from the *EPE* Editorial office on 3.5in disk, for which a nominal handling charge applies – see *EPE PCB Service* page. It is also available for *free* download via the *EPE* homepage at **www.epemag.wimborne.co.uk**. Select the Downloads click-link, and then enter the PIC's folder.

The author can supply preprogrammed PICs, see this month's *ShopTalk* page, which also gives advice about component buying. □

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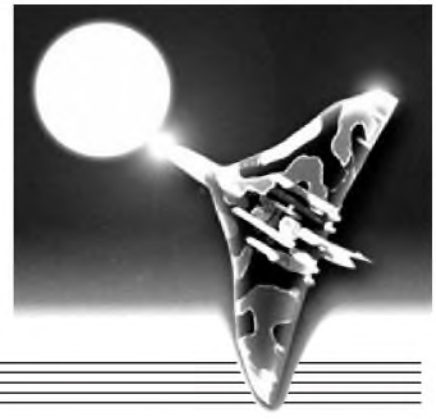
Constructional Project

PIC MIXER FOR RC PLANES



MARIUS BENSCH

A flight command mixer for delta or V-tail radio-controlled model planes

EXACTLY what made the author start out on this PIC-based project is unknown to him, since he has the good fortune of owning a radio-controlled (RC) transceiver with a programmable mixer. He thinks it was probably because he was just looking for something to program and tinker around with!

CHALLENGING

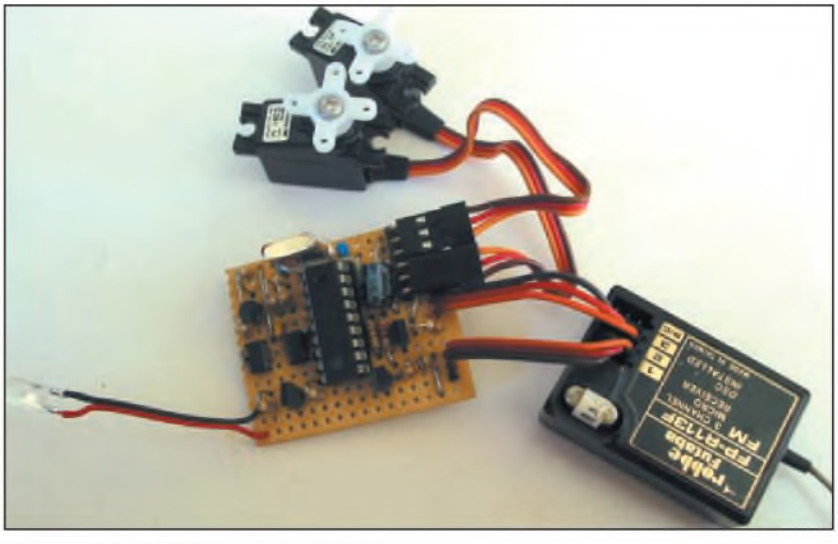
There were one or two challenges on the way which he thought were insurmountable (having only limited programming knowledge). These applied mainly to the resolution of the acquired input pulses and the generation of the mixed output pulses.

The challenge was to achieve a resolution of one microsecond, giving a thousand steps over the servo's range – the resolution which top-notch RC radio sets offer.

With the PIC running at 4MHz, this means a resolution of *one* program instruction cycle. PIC programs run at the oscillator rate divided by four, $f_{osc}/4$, over a range of ten bits. This 10-bit requirement ruled out the use of the PIC's TMR0 timer, which only has an 8-bit capability.

The function of the mixer is just to cross-mix two channels for delta or V-tail configurations. In such a configuration, one servo operates one control surface. However, taking elevator/aileron mixing as an example, each of the servos must respond to both aileron and elevator commands for the required action to be performed.

Twiddling the elevator at the transmitter, for example, affects only the Channel 2 output at the receiver, but both servos must receive the signal to move the flaps in the right way. The mixer thus takes the signals as they come from the receiver, does the calculations, and generates new signals to move the servos correctly.



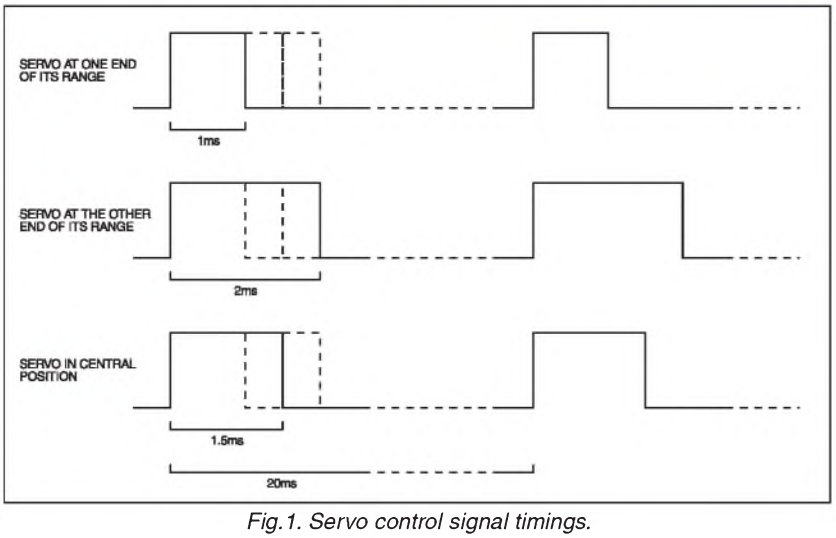


Fig.1. Servo control signal timings.

SIGNALS, SIGNALS

The receiver generates positive pulses at a frequency of 50Hz (see Fig.1). The duration of a pulse depends on the position that the servo is meant to have. The shortest pulse that the receiver will generate is one millisecond and the longest is two milliseconds.

Electronics inside the servo convert the pulse lengths to a specific position of the servo output disk, using a feedback potentiometer that is mechanically connected to the disk to supply information about its current position. The shortest and longest pulse lengths will cause the servo disk to travel to its opposite limits; 1·5ms pulses will centralise it and so on.

CIRCUIT DESCRIPTION

Aside from the PIC there is, as usual for this kind of circuit, not much else required.

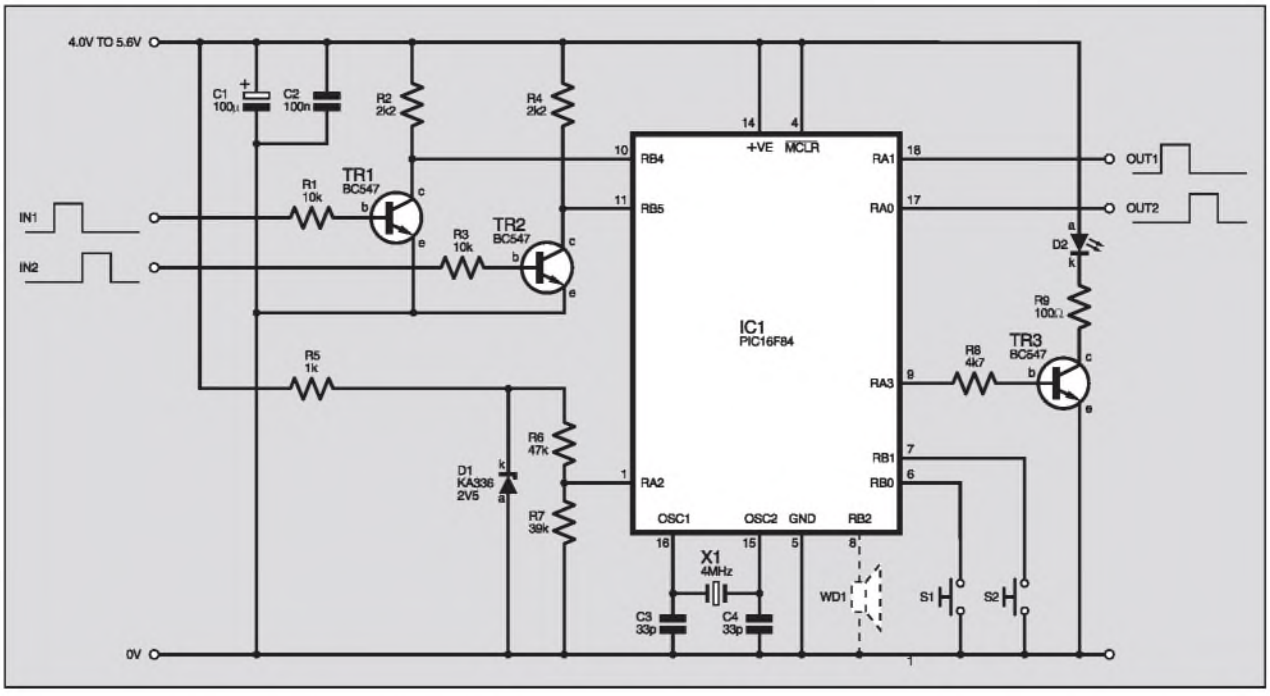


Fig.2. Complete circuit diagram for the PIC Mixer For RC Planes.

The full circuit diagram for the PIC Mixer For RC Planes is shown in Fig.2.

Many receivers produce output pulses that have a sufficiently high voltage to switch a transistor in the servo's electronics, but the pulses are not necessarily rail-to-rail. The input stage, based on transistors TR1 and TR2, ensures that the pulses received by the PIC on pins RB4 and RB5 swing fully between the power line voltages. At the same time, of course, the pulses are inverted, but this does not matter to the PIC.

The software processes the information coming from RB4 and RB5, and then outputs suitable control signals to the plane's servos via pins RA0 and RA1.

Switches S1 and S2 are used for setting the mark-space ratio of the output pulses. Bias resistors are not needed with the switches since Port B is used with its internal pull-ups turned on.

PIC pin RB2 is intended for the optional use of a buzzer. The pin goes high when no pulses are being received via RB4 and RB5, i.e. when the transmitter is switched off. (Note that this does not apply to PCM receivers, since such receivers already have a mixer within them.)

A buzzer is useful if slope soaring in an area with high grass or bushes, and you have to land and are left with no clue as to where your plane is (a common situation)! The buzzer should be of the active type, which has its own oscillator built in. It should draw no more than 20mA.

The section around programmable shunt regulator D1 is for low-battery detection. The diode is in series with current-limiting resistor R5 and drops the voltage to 2·5V. The potential divider formed by resistors R6 and R7 provides a reference of just over 1V to PIC pin RA2.

The PIC reads an input high from about 25% of its supply voltage, thus as the battery voltage sinks, the PIC's input threshold voltage point also sinks, although the reference voltage at R6/R7 remains the same. When the PIC's threshold sinks below the reference voltage for more than 2·5 seconds, the software sets l.e.d. D2 flashing as a warning that it's time to land!

The exact value of the PIC's RA2 threshold is, of course, quite undefined and probably slightly different from PIC to PIC, and also somewhat temperature dependent.

If preferred, a 100kΩ preset potentiometer could be substituted for resistors R6 and R7. A high brightness l.e.d. should be used for D2.

The duty cycle of the l.e.d. driving pulses is set within the software to about 10 per cent. This is not much, but it serves to conserve power when the battery is on its last stretch of service.

SOFTWARE FUNCTIONING

When power is first switched on, the PIC's software goes through a basic initialising routine, and then the value of the mixing factor (MULFAC) is recalled from the PIC's internal EEPROM (electrically erasable read-only memory).

Next, the program waits for the Channel 2 receiver input to go low. The input pulses are recognized by using Port B's interrupt-on-change facility. On receipt of a pulse, the main program loop is entered. This consists of four sections: getting the pulse lengths, doing the calculations, outputting the calculated pulses, and finally checking the switches and the battery.

The tricky bit about finding the input pulse values was that the PIC's TMR0 timer is only eight bits wide, but the range between the minimum and maximum pulse lengths is just over 10 bits (taking into account the additional range of the pulse lengths due to the precise settings of the transmitter's trimmers – from about 0·95ms to 2·05ms).

This problem was resolved by also using a counter. While the program waits in a loop for the pulse lengths of both channels to be received, the counter is incremented.

COMPONENTS

See SHOP TALK page

Resistors

R1, R3	10k (2 off)
R2, R4	2k2 (2 off)
R5	1k
R6	47k
R7	39k
R8	4k7
R9	100Ω

All 0·25W 5% carbon film.

Capacitors

C1	100µ radial elect. 16V
C2	100n ceramic disc
C3, C4	33p ceramic disc (2 off)

Semiconductors

D1	KA336-2·5 or LM336-2·5 or LM236-2·5 programmable shunt regulator
D2	red l.e.d., high brightness
TR1 to TR3	BC547 *npn* transistor (3 off)
IC1	PIC16F84 microcontroller, pre-programmed (see text)

Miscellaneous

S1, S2	s.p. push-to-make switch, p.c.b. mounting (2 off)
WD1	active piezo buzzer, optional (see text)
X1	4MHz crystal (see text)

Stripboard, 14 rows x 16 holes; 6-pin connector strip, right-angled; 3-pin servo connectors to suit (2 off); 18-pin d.i.l. socket; wire; solder, etc.

Approx. Cost Guidance Only **£9.50** *excl. batt.*

When the pulses are evaluated, the counter and TMR0 values are both used to reconstruct the exact value of the pulse lengths, which may be up to 11 bits long.

Next, the calculations to find the values of the output pulses are done, yielding the results for MULFAC. The pulse lengths are then checked to see whether they fall within the acceptable range, and if not, they are replaced with the minimum or maximum value as appropriate.

So far as is known, the pulse lengths are standardised between different RC transceivers. However, readers with PIC programming facilities may change the pulse lengths, and the duty cycle for the flashing l.e.d., through the program's EQU statements if they wish.

CONSTRUCTION

The circuit is built on stripboard, whose assembly and track cutting details are shown in Fig.3.

The board has been kept as small as possible due to the sometimes very limited space inside an RC plane.

Start assembly by making the track cuts and then inserting the link wires. Note that in some cases *two* wires or component leads use the same hole. Use a drill to enlarge the hole if necessary. There are three links to be made on the *rear* of the board.

Continue assembly in order of component size. Capacitor C1 should be mounted on its side to minimise its height. A socket *must* be used for the PIC (IC1). It is preferable (but not essential) to use a low-profile crystal (X1).

Switches S1 and S2 are also mounted on their sides, to prevent accidental operation (to press them a small screwdriver should be used). This means that a wire connection needs to be soldered between the switch contacts and the board. Gluing the switches to the board helps their stability.

It is suggested that a cable tie is used around the board to prevent the PIC dislodging on a hard landing!

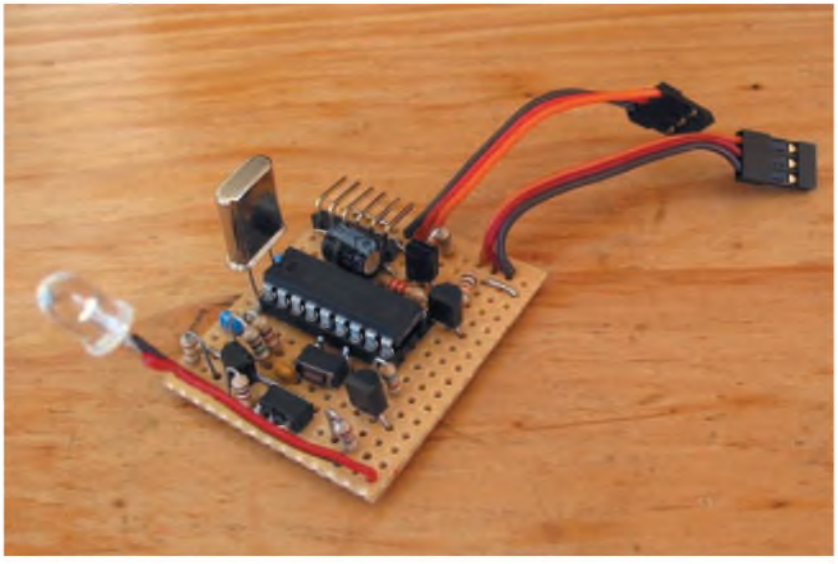
Users with "don't plug me in the wrong way" servo leads may have their safety tabs interfering a little with each other due to the proximity of the plugs, but this was not found to be a problem. Also note that the plug for Channel 1 has its negative connection at the top, whereas Channel 2 has its negative connection at the bottom.

The PIC will operate at between 2.0V and 6·0V. **On no account should the upper limit be exceeded**. The module is intended for use with a 4-cell battery pack.

IN USE

Use of the assembled module is basically "plug and fly". The l.e.d. lights up briefly when power is applied, going off when a pulse from Channel 2 is detected.

Switches S1 and S2 increase and decrease, respectively, the mixing ratio in 5% steps from 50% to 100%. If the ratio is 50%, a full-up elevator command will only make the servo travel half its full way, leaving the other half for the aileron command.



The completed stripboard assembly.

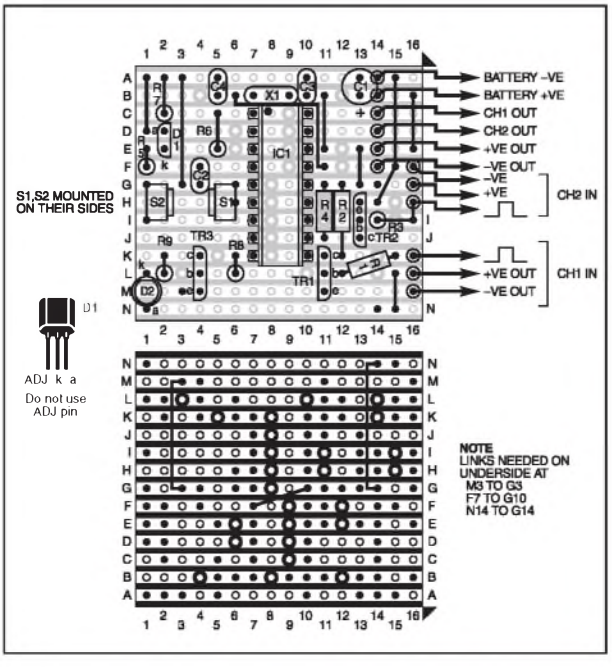


Fig.3. Assembly and track cutting details.

If the ratio is 100%, a full-up elevator command will make the servo travel its full way, but then there is no travel left for an aileron command on the up-going flap, only on the down-going flap. The ratio that you fly at is a matter of preference. The author flys his aircraft at 80%.

Happy mixed flying!

RESOURCES

The software for this design 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/Vplane**).

Read this month's *Shoptalk* page for information on component buying for this project, including details of purchasing pre-programmed PICs. □

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Beat Balance Metal Detector – Matter of Balance

THE circuit diagram shown in Fig.1 may well represent an entirely new concept, being a hybrid between beat frequency operation (b.f.o.) and induction balance (i.b.) metal detectors. Its performance also lies between the two. If it were a b.f.o. design, its performance would be unusually good. If it were i.b., its performance would be modest.

The advantages of the design are its simplicity and low cost, its easy set-up and adjustment, its relative immunity to temperature and voltage variations, and its ability to auto-adjust to ground conditions through its two coils, which balance each other out.

IC1a and IC1b each represent a simple CMOS single-gate Colpitts oscillator which oscillates at just over 80kHz. The frequency of each of these oscillators shifts at the presence of metal near L1 or L2.

When the two search coils, L1 and L2, are in balance, mutual induction modifies the frequencies of the two oscillators so that they oscillate at close to the same frequency. These two frequencies are mixed through mixer IC2, thereby producing a clear beat note in piezo sounder WD1. Potentiometer VR1 is used to adjust the beat note after the coils have been fixed on the search head.

Searching

The author used seventy turns of 30s.w.g. (0·315mm) enamelled copper wire on a 120mm diameter former for both search coils. Faraday shields may be added to the coils if desired, and these are connected to 0V. These would serve to minimise ground effect and capacitive coupling.

To set up the Beat Balance Metal Detector, turn "beat note" control VR1 to its mid-position. Place the two coils on top of one another, and switch on. Now slowly move the coils apart until a low tone is heard in the piezo sounder WD1. At this point, the coils should be fixed on the search head and VR1 is used for further adjustment. For noisy conditions, a crystal earpiece may be used in place of the piezo sounder.

Thomas Scarborough,
Fresnaye
South Africa

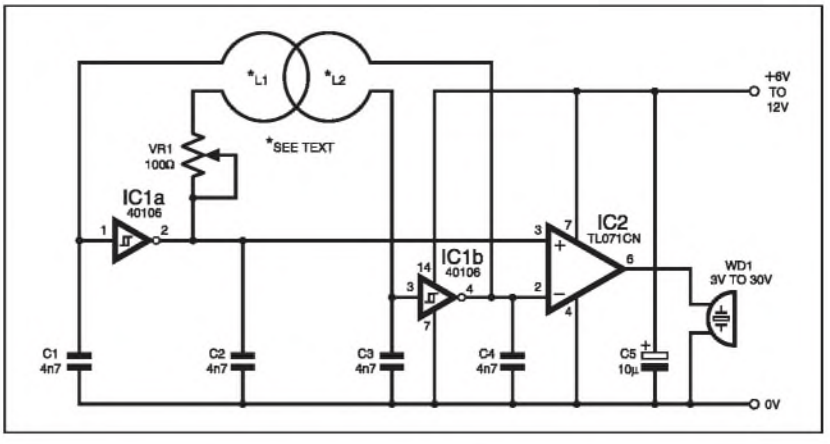


Fig.1. Circuit diagram for the Beat Balance Metal Detector.

Simple Signal Injector – Got It Taped

WANTING a cheap and cheerful audio oscillator to help when working on audio amplifiers, and after considering multivibrators and the like, the circuit diagram shown in Fig.2 was finally selected. Its beauty is its simplicity.

The frequency determining elements are the tape playback head and capacitors C1 and C2 – the only other components being the amplifying transistor TR1, its collector load resistor R1, and capacitor C3 which d.c. blocks the output.

The oscillator is inherently short circuit proof, though both the frequency and the collector a.c. voltage fall a little under such conditions. As the average collector voltage is only around 0·6V (the same as the base voltage), it's pointless powering the circuit with more than 1·5 volts.

A great beauty of the circuit is that the tape head itself provides another output. The magnetic field produced at the tape head gap can be used to induce an audio current in an insulated wire or in a p.c.b. track etc., though the induced current is small, and is useful only around amplifier input circuitry.

The circuit oscillates at around 2kHz, with a peak-to-peak a.c. collector voltage of about 0·8V, though the output is not very sinusoidal. It takes about 2mA from the battery, and continues to oscillate down to about 0·7V, so there's no excessive drain on the battery.

The tape playback head used was salvaged from an old Walkman-type cassette player with both left and right channel heads wired in parallel. If you use an erase head in the circuit, it will oscillate at around 10kHz to 20kHz.

P. A. Tomlinson,
Hull, East Yorkshire

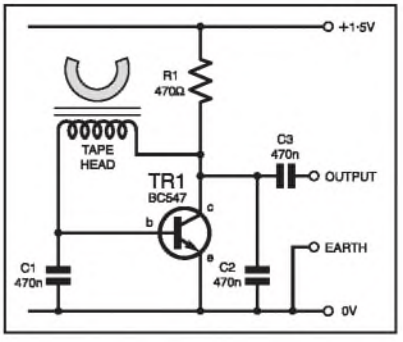


Fig.2. Simple Signal Injector circuit.

Easy Sinewaves – Sine Of The Times

GOOD quality sinewaves can be obtained from standard components, using the Wien bridge circuit shown in Fig.3. The filter produces a phase lead, followed by a phase lag, and the circuit oscillates at the frequency where lead and lag cancel.

The output is 1V peak-to-peak, with a frequency of 200Hz to 2kHz, depending on the setting of the potentiometer VR1. If capacitors C2 and C3 are replaced by 0·01μF types then coverage is 2kHz to 20kHz. But the higher range is severely truncated if an op.amp is used for the amplifier.

To obtain good quality output it is essential to control the amplifier gain automatically, to prevent the output voltage from bumping into the supply rails. This is usually done with an f.e.t., but their parameters do vary greatly. In this circuit diodes Dl and D2 effect the necessary regulation.

When the output exceeds 1V p-p, current pulses are delivered by transistor TR1 and smoothed by C1 to yield a steady 70μA or so. As a result, diodes D1 and D2 offer a low resistance to the small superimposed a.c. signals from the filter. If a diode is passing I (mA) its a.c. resistance is 25/I ohms, so each of these diodes will offer about 360 ohms. They shunt the current from the filter to ground, attenuating the loop gain and preventing further growth of output voltage.

The amplifier has a gain of 100, and with the output limited to 1V p-p its a.c. input voltage must settle at 5mV peak. But diode D2 has an exponential characteristic, and a 5mV rise at A will increase its current by 20%. According to the above formula its a.c. resistance will fall by the same amount, curtailing the upper crest of the waveform.

This is where diode D1 comes in. The same 5mV rise at A which increases D2 current by 20% also reduces D1 current by 20%, raising its a.c. resistance to cancel the reduction at D2.

Attenuation remains almost constant throughout the signal cycle, and distortion on the output is very low. The same technique will standardise the output from a microphone.

Michael McLoughlin,
St Albans

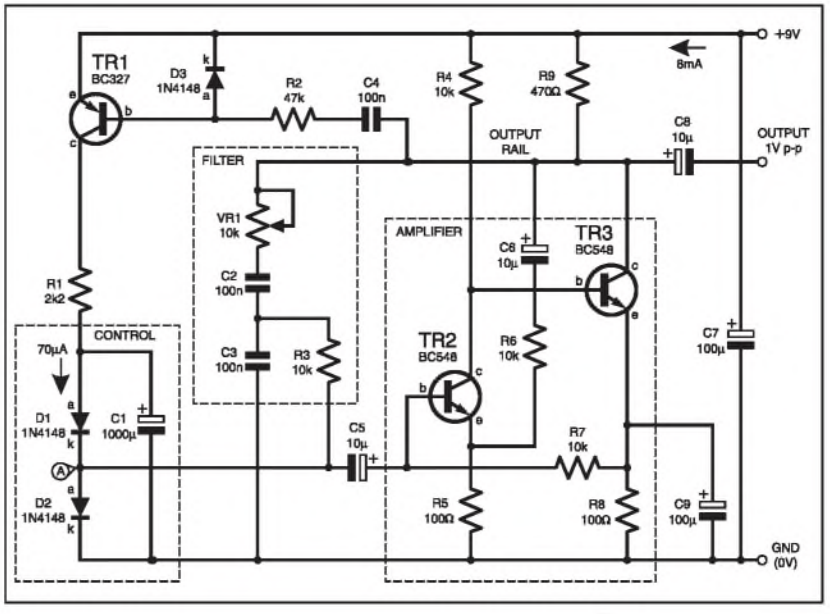


Fig.3. Circuit diagram for an "easy" Sinewave Generator.

Sonic Control for Toys – A Sound Response

THE purpose of the circuit diagram shown in Fig.4 is to provide a form of "wire-free" control for a small toy. The prototype circuit was for a toy car which, before conversion, would travel forwards until it reached an obstacle and would then flip right over and carry on in the opposite direction.

With the addition of the sonic control receiver circuit it allows the toy to respond to a hand-clap which, depending on the choice of relay, can be wired to give start and stop or forward and reverse. The idea of sonic control has the advantage that the transmitter is simply a person's hands.

A crystal microphone, X1, is used as the input transducer, which is actually an uncased piezoelectric transducer glued into place behind a small aperture in the top of the model (held in place by the rim only, as sensitivity is degraded otherwise). An LM380 audio amplifier (IC1) is used as a voltage amplifier which is an excellent match for X1 as it was made to be connected to a crystal record player pick-up.

The amplified audio transient waveform of the hand-clap is now passed from output pin 8 of IC1 to diode D1, which rectifies the signal to leave just the negative swing. Resistors R1 and R2 provide the d.c. bias to prevent the diode's voltage drop causing a loss of sensitivity.

The resulting output signal is now applied to a negative-edge-triggered D-type bistable-multivibrator (TR1/TR2), which changes state each time a strong enough transient comes through. The relay coil RLA forms one of the bistable's collector loads and avoids needing an extra stage to drive it.

An extra idea, linked with the change of direction option, was to wire a resistor in series with a pair of l.e.d.s across the motor terminals as "reversing-lights". A usable range of over a metre was achieved with a fresh PP3 battery.

M. Robertson and M. Bashir,
Chasetown

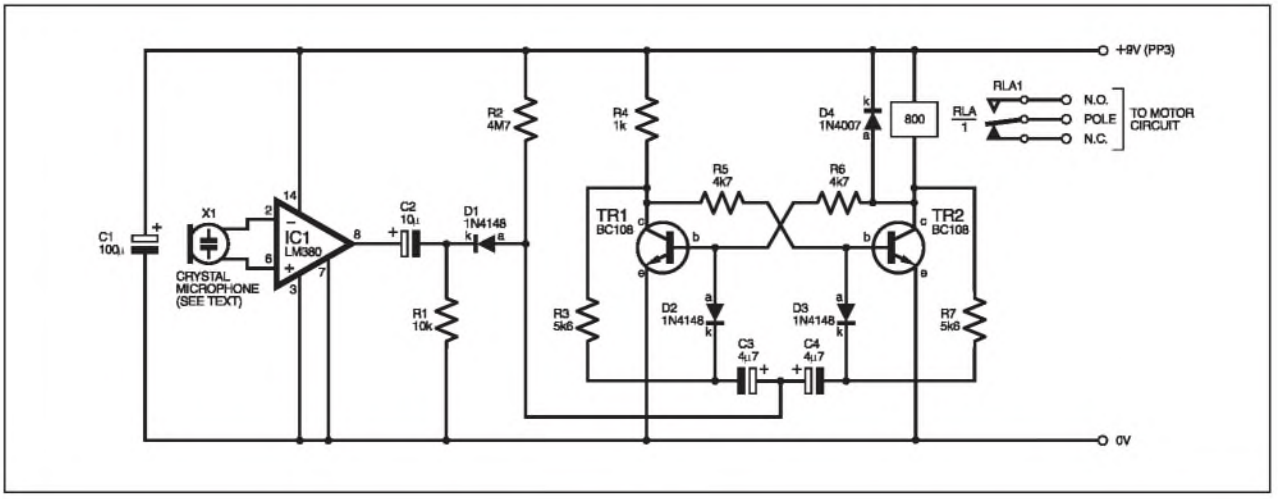


Fig.4. Circuit diagram for the Sonic Control Receiver for toys.

Camera Power – On Your Bike

YOU'VE been there: clutching your digital camera, blending with the furnishings, avoiding Aunt Vera as she rounds up mingling relatives for the family photograph.

"We may never be together like this again," she cries (myriad eyes flicker to ancient Uncle George) as cousin Tom is frogmarched from his beer.

Cats corralled, eyes drift toward you. Auntie gives you the nod. You ease camera and tripod into position, and notice the battery-low symbol flashing on the status display. Sphincter muscles quiver.

Fortunately, you are prepared – this time. After your performance at young Toby's first birthday party, you built an adaptor to power your Kodak DC4800 from your 6V re-chargeable bicycle-lamp batteries (or in desperation, your 12V car battery).

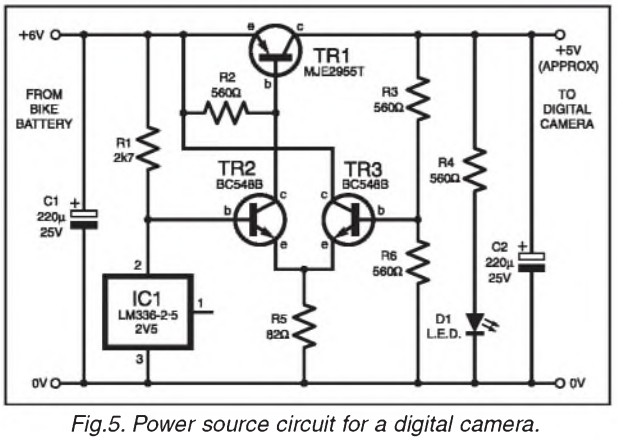


Fig.5. Power source circuit for a digital camera.

Feigning control, you ease a bike battery from your tote bag, suspend it from the tripod, plug the adaptor between it and the camera, and exhale very slowly as the battery symbol stabilizes. You huddle behind the viewfinder to compose yourself and the photograph, press the shutter button, and give thanks that all eyes are on the self-timer light as you slink to your reservation in the assemblage.

A flash, one more shot "while we're all together", and it's over — till next year.

The Kodak DC4800 digital camera can be charged or operated from an external d.c. supply – the nominal voltage is 5V, but the test camera functioned reliably from 4·8V to 5·4V. The current drain on this external supply can reach about 300mA during charging, and 1·2A during operation – depending on the state of charge of the lithium-ion battery, and the functions used on the camera.

Adaptor Circuit

The adaptor interfaces bike battery with camera, as shown in the circuit diagram Fig.5. The circuit is a series voltage regulator, constructed from discrete components to achieve a dropout voltage around 0·5V – this is needed for the adaptor to maintain 5V output when the bike battery voltage drops to 5·5V.

Reference diode IC1 establishes a constant voltage of 2·5V on the base of transistor TR2. Resistive divider R3 and R6 feeds half of the adaptor output voltage back to the base of transistor TR3. If the adaptor output voltage deviates from 5V (due to a change in load resistance), the difference amplifier, TR2/TR3, responds by varying the base current to series-pass transistor TR1 – the collector of which varies the current to the load, restoring the output voltage to 5V (nominal).

The maximum current that transistor TR2 can deliver to the base of TR1 is about 20mA (1·8V across resistor R5), so the maximum collector current available from TR1 is at worst 400mA, and at best 2A (the specified d.c. current-gain range of the MJE2955T is 20-100). This meets most current requirements of the camera.

The prototype adaptor produces an output voltage of 5·1V unloaded, decreasing to 4·9V at a load current of 1A. This meets the voltage requirement of the camera.

The dropout voltage of the prototype varies from 0·5V at 300mA to 1·2V at 1A. Consequently, when a bike battery nears exhaustion at 5·5V, the adaptor will only maintain 5V output for up to 300mA of load current – still adequate for charging the camera.

Two 6V bicycle-lamp batteries have been used with the adaptor – one employing 4·5Ah nickel-cadmium cells, and the other, 4·2Ah sealed lead-acid cells. Both batteries can deliver several amps continuously, and exhibit working voltage ranges from 7V (charged) to 5·5V (discharged).

When the adaptor is used with a 6V bike battery, the maximum power dissipation in transistor TR1 is about 2·5W, requiring minimal heat sinking. If the adaptor is used with a 12V car battery, however, the maximum power dissipation could exceed 10W, requiring additional heat sinking.

Nigel Stone, Fulham, Australia

PICO PRIZE WINNERS

It's time to decide the lucky winners of superb PC-based Oscilloscopes, generously donated to *Everyday Practical Electronics* by Pico Technology, to whom we extend our appreciation for sponsoring the column once again. There is more information about Pico's range of PC-based test equipment by visiting their web site at **http://www.picotech.com**, or see their advertisement elsewhere in this issue.

EPE Editor Mike Kenward and Technical Editor John Becker considered all *Ingenuity Unlimited* entries published over the last twelve months, and the lucky prizewinners were finalised as follows:

Winner – receives a superb Pico ADC200-100 Digital Storage Oscilloscope worth £586.
Bio-Feedback Tension Monitor by Tony Lee, Old Reynella, Australia (*EPE* December 2003).

Runner-Up – a Pico DrDAQ Data Logger/Scope worth £69.
Fully Automatic Egg Timer by M. A. Jones, Harrogate, N. Yorkshire (*EPE* May 2003).

Yes-No Indicator – Decidedly Decisive

THE circuit of Fig.6 produces a random "Yes" or "No" with a single button-press, which is displayed through a red or green l.e.d. The design has a number of advantages over similar circuits.

Firstly, it does not use an on-off switch, so that it requires just a single pushbutton switch. When switch S1 is pressed, an oscillator within IC1 oscillates at around 15kHz, as set by components C1, R4 and R5. This frequency is divided by 16 within IC1 and is output at pin 7, Q4.

At the same time, C2 charges through R3, so that IC1's clock input (pin 11) is disabled as TR1's gate (g) goes "high", thus stopping the clock. The delay at TR1's gate is about one tenth of a second, therefore nearly a thousand oscillations take place at output pin 7 before the clock is stopped.

Secondly, the circuit has a high degree of randomness. This is because it takes advantage of a near-perfect 50:50 duty cycle at output Q4. This pin is buffered internally, so that the duty cycle remains equal despite slightly unequal loading by the l.e.d.s. Besides this, variations in charge on C1 and C2, voltage and temperature variations, and the unpredictability of when the pushbutton will be pressed, mean that randomness is assured. On first testing the circuit, the Yes-No Indicator scored 51 Yes, 49 No.

Standby current is zero. Therefore, if a miniature 12V (e.g. MN21) battery is used to power the circuit, it could be used thousands of times over before the battery would run flat.

Thomas Scarborough, South Africa

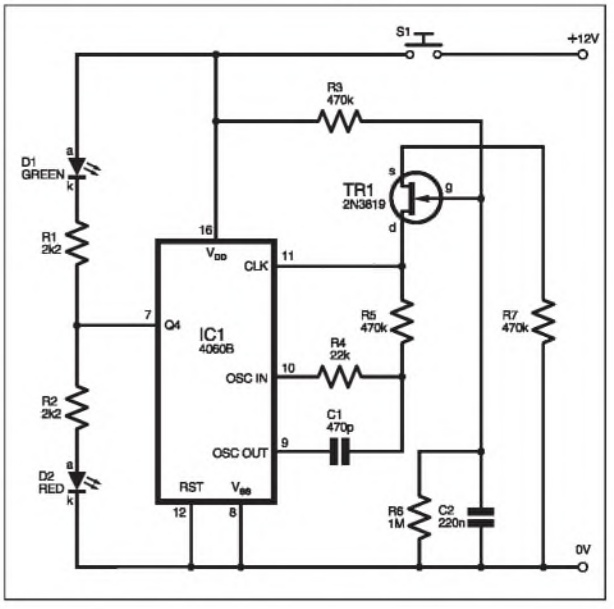


Fig.6. Circuit diagram for a Yes-No Indicator

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

WITH the possible exceptions of a few specialist projects and retro designs, modern projects are nearly all based on a printed circuit board of some kind. Construction is more straightforward using a custom board, but the general principles are much the same using stripboard.

In theory, there should be no difficulty in producing a circuit board once you have learned to solder reasonably proficiently. In practice, there will be a few minor problems to sort out when building even the most simple of boards.

Getting Physical

The component layouts in *EPE* have physical representations of the components rather than circuit symbols. Layout diagrams are component-side views, but the copper tracks on the other side of the board are also shown in "see-through" faint print. With this method it is easy to see where every component fits on the board, and (where appropriate) which way round it goes. The inclusion of the tracks can be helpful when faultfinding, but if you work slowly and carefully this should only be of academic importance.

No system is totally foolproof, but the diagrams are clear enough to largely eliminate confusion. However, before you start building any project it is essential to check that you have correctly identified every component. Be especially careful with components that have the values marked using colour coding. Always check that you have the right component *before* soldering it to the board, and also check that it is being fitted in the right place. In general, it is easier to solder components to the board than it is to remove them.

Most circuit boards can be built with the components fitted in any order, and there is not, strictly speaking, a right order. On the other hand, some orders will make the job easy while others will make it relatively difficult.

Life is generally easier if the small components are fitted first, gradually working up to the largest, which are fitted last. The reason for this is simply that large components tend to get in the way when trying to fit the smaller ones, but the smaller components are not troublesome when fitting the larger components. It therefore makes sense to fit the smaller components first.

If the layout requires any link-wires, these will be the smallest components. The trimmings from resistor leadout wires are ideal for short links, but some 24 s.w.g. (0·56mm diameter) tinned copper wire is needed for links more than about 20mm long. It is advisable to insulate the longer links using p.v.c. sleeving. It might also be worthwhile insulating the shorter wires where two or more run side-by-side.

A piece of insulation of the right length can be produced by placing the sleeving in place between the appropriate two points on the board and then marking the cutting point or just trimming it straight away using small wire cutters. Thread the sleeving onto the wire and then cut the wire to leave about five millimetres protruding from each end of the sleeving. The link-wire can then be formed and fitted onto the board much like any other horizontally mounted component.

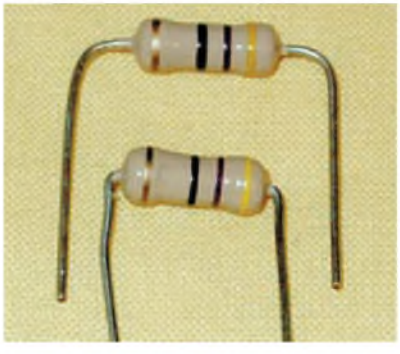


Fig.1. The leads are normally formed a millimetre or two from the body (top) and not right next to it (bottom).

Holes Apart

With custom printed circuit boards (p.c.b.s) the hole-spacing for resistors and other axial lead components is usually designed to suit each component. The hole-spacing is generally made several millimetres more than the length of the component's body. This means that the leadout wires are not bent at 90 degrees right next to its body. You should aim for something like the upper resistor in Fig.1 rather than the one below.

On the face of it, bending the wire right next to the body is easier than placing the bend a few millimetres further down the lead. This is indeed the case, but bending the wire next to the body can result in damage to a component. Glass-bodied diodes are very vulnerable to this problem.

Stripboard construction usually results in the designer having to accept a few compromises, and it might sometimes be necessary to squeeze a component into the available space by bending the leads as close as possible to its body. The same problem can arise if the component you have is somewhat bigger than the one the designer had in mind when producing the layout. Going carefully reduces the risk of damage occurring, but to minimise the risk it is best to support the lead next to the component's body using the tip of some long nose pliers and then bending the lead using your other hand.

With stripboard construction it is quite common for components having axial leads to be used with longer than normal lead spacing. This makes construction slightly more awkward but helps to keep the boards compact and reduces the number of link-wires needed. With experience it is possible to gauge the positions of the bends in the link-wires quite accurately even when the hole-spacing is quite large. In the meantime, it is better to place each component in position over the holes in the board and mark the positions of the bends on the leadout wires using a soft pencil or a felt-tip pen. This is quicker than using a lot of trial and error. It also saves possible damage to the component

Flat-out

Ideally, components should always be mounted so that they are right against the circuit board with no gap in between, as with the left-hand capacitor of Fig.2. This is not just a matter of neatness, as any gap between the board and the component significantly weakens the assembly. The problem is that any downward pressure on a component tends to rip the underside joint away from the board.

Sometimes this results in the track being broken away from the joint. In other cases the track lifts away from the board and maintains the connection, but this is still something that needs to be "avoided like the plague".

The problem is easily corrected if you find that a component is mounted like the centre and right-hand components in Fig.2. With the bit of the iron applied to a joint, the solder will soon melt so that the relevant end of the component can be pressed down into place.

Mounting axial lead components vertically, as in Fig.3, is not considered to be a good idea, because it also leaves the finished board prone to problems with pressure on the top surface ripping the joints and tracks away from the

Fig.2. Components should be mounted flush with the surface of the board (left) and not with a gap underneath (centre and right).

underside of the board. Sideways pressure is, if anything, even worse.

Vertical mounting is a compromise that is sometimes used with stripboard, and it can even be used with custom boards where compactness is of great importance. Use the "kid gloves" approach with boards that have axial lead components mounted vertically.

With the links and the small radial components in place it is time to move on to the larger components, or perhaps more accurately, to those that protrude well above the surface of the board. Most modern capacitors are designed for vertical mounting, and even though they are not particularly large they often extend well above the surface of the board. Accordingly, it is better to mount the axial components first, then the vertical or "radial" mounting types, and finally the semiconductors and any genuinely large components.

Fig.3. Mounting axial components vertically is best avoided but is called for by some component layouts. As usual, mount the components with the bodies as close to the board as possible.

Short Lead

Components that are intended for vertical mounting (radial types) can be fitted tight against the board and will not introduce the physical weaknesses associated with axial components mounted vertically. Vertical mounting electrolytic capacitors (also known as PC or printed circuit mounting capacitors) usually have quite long leads and can accommodate practically any lead spacing. The same is not true for most non-electrolytic types as these almost invariably have very short leads that are actually more like the pins of integrated circuits than normal leadout wires.

Consequently, these capacitors are usually designed to fit a specific lead spacing, and it is essential to make sure that you buy ones designed for the correct spacing. Capacitors that have plastic cases are quite tough, but some have open construction and are relatively brittle and they can easily part company with one of their leads.

Axial electrolytic capacitors normally have the positive (+) lead indicated by an indentation around the relevant end of the body, with "+" and "–" marks included as well. The indentation method is not always applicable to radial electrolytic capacitors because they have both leads at the same end of the component. The "+" and (or) "–" labels should be present though, and there is usually a black or white bar down the side of the body next to the negative leadout wire.

Fitting electrolytic capacitors with the wrong polarity can occasionally have dire consequences, so always double check that the polarity is correct before soldering one of these components in place.

Semiconductors

With only one or two very rare exceptions, semiconductors have to be fitted the right way round. The layout diagram should make the correct orientation "crystal clear". Again, there can be dire consequences if you get it wrong, so always double-check the orientation before actually soldering any semiconductors to the board. There will sometimes be leadout identification diagrams for the transistors. Note that these are nearly always base views and that they show the components looking onto the leadout wires.

These days most of the semiconductors used in projects are d.i.l. (dual-in-line) integrated circuits (i.c.s) that are fitted to the board via holders. A selection of d.i.l. holders appears in Fig.4. Do not be tempted to save money by fitting integrated circuits direct to the board unless the article specifically requests this. Modern semiconductors are reasonably tolerant of heat, but are still far more vulnerable to heat damage than most other components.

Also, a substantial proportion of semiconductors are vulnerable to damage from small static electricity charges. Using holders greatly reduces the chances of static charges causing damage. Always strictly observe any anti-static handling precautions detailed in the text of the article.

Another advantage of using sockets is that it is easy to correct a mistake if you should accidentally fit an i.c. the wrong way round. It can be carefully prised out of its socket using the blade of a small screwdriver, lifting one end and then the other until it comes free, and then it is simply plugged in the right way round.

There will usually be some hard wiring running from the circuit board to controls, sockets, or whatever. Connecting the hard wiring directly to the board is not a good idea because any twisting of the wires can result in the joints breaking away from the copper tracks. The better way is to fit solder-pins to the board and then connect the hard wiring to these pins. It is mostly single-sided pins that are used, and these are inserted from the copper side of the board and then soldered in place. Connections are then made via the pins on the component side of the board.

Double-sided pins protrude on both sides of the board, and are only needed where it will be necessary to make the connections on the copper side of the board.

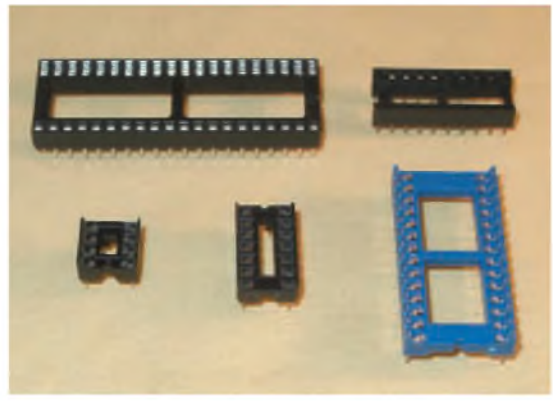


Fig.4. A selection of d.i.l. sockets having from eight to 40 pins. Do not be tempted to save money by connecting integrated circuits directly to the board.

Look, No Hands

When fitting most components onto a printed circuit board there is the minor problem of finding a third hand! Ideally you need one hand to hold the component in place on the board, a second to hold the soldering iron, and a third to feed the solder into the joint.

The "proper" way of doing things is to use a printed circuit assembly frame. These vary somewhat in points of detail, but the general setup is to have an adjustable metal frame to hold the board against a thick piece of soft foam material. The board is held with the component side pressed well into the foam so that the components are firmly held in place against the board. The leadout wires are then trimmed to length, the joints are soldered, and the finished board is released from the frame.

It is not usually possible to do the whole board in one go if it contains a mixture of large and small components, because the larger components prevent the small ones from being held in place properly. The small components are fitted and soldered into place first, and then the large components are added separately. Even so, it is usually possible to complete quite large boards very quickly with the aid of an assembly frame. The drawback of this method is that the cheapest assembly frames are still fairly expensive.

There are simple and cheap alternatives, and some Bostik Blu Tack or plasticine probably represents the cheapest and simplest. Fit a few components onto the board using Blu Tack or plasticine and then place the board component side down on the worktop. The Blu Tack or plasticine will temporarily stick the assembly to the worktop if a little pressure is applied. The leadout wires are then trimmed and the joints are completed.

Next the board is removed from the worktop, the Blu Tack or plasticine is removed, the next batch of components is added, and so on until the board has been completed. For beginners it is probably best to take things relatively slowly and carefully.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

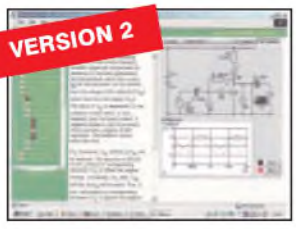
Logic Probe testing

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

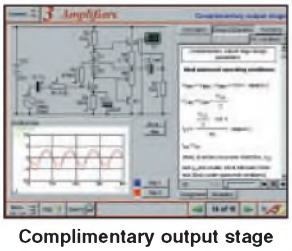
VERSION 2



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



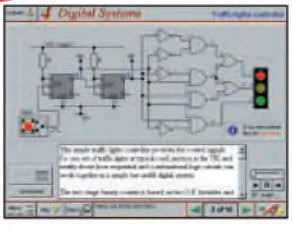
Complimentary output stage

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

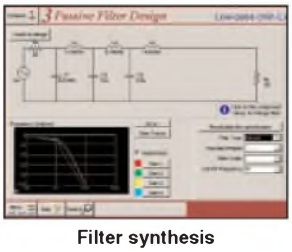


Virtual laboratory – Traffic Lights

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.

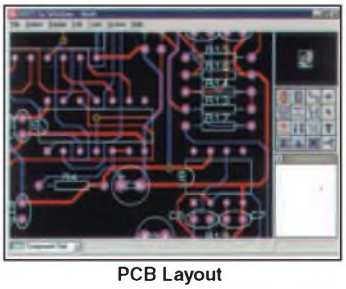
FILTERS



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.

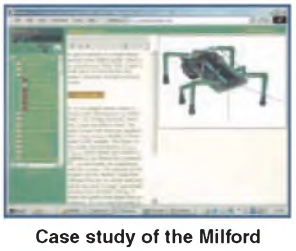
ELECTRONICS CAD PACK



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

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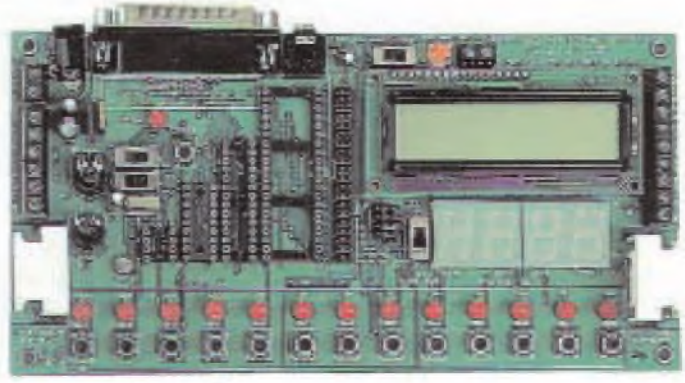
Suitable for use with the three software packages listed below.

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 micro-controller. 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.

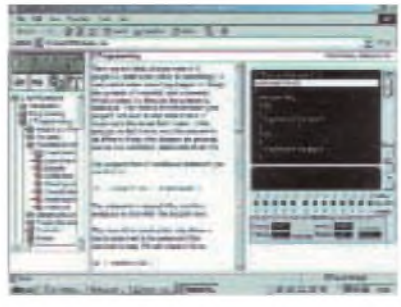
Virtual PICmicro

'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.



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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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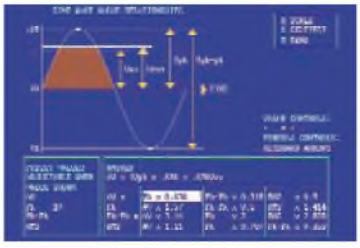

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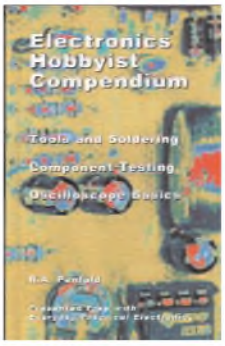

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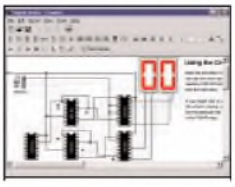

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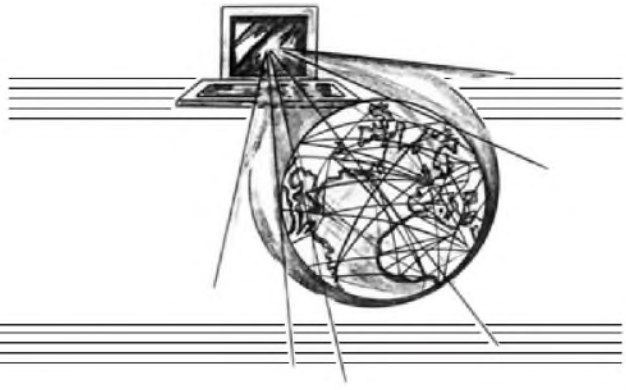


WELCOME to this month's *Net Work* – the column specially written for internet users. For the benefit of new readers, the *EPE* web site (**www.epemag.wimborne.co.uk**) contains a number of useful resources that support the printed magazine, including our **Online Shop,** from where back issues, reprints and many electronics books, video tapes and CD-ROMs can be bought online. You can also subscribe (or renew a subscription) using our secure server.

The **Projects Index** lists details of the last five years' constructional projects and it also includes details of any updates or corrections published subsequently, so that you can track any later developments. Projects that have been updated are denoted with a red cross icon in the Projects listings: readers will hopefully note from the web site that the number of corrections or follow-ups to *EPE* projects is low!

Chat Zone Shenanigans

Also accessible via our web site is the ***EPE* Chat Zone** Message Board, which allows users to leave a message or follow up on an existing posting. In recent months the board has become busier than we have ever known. No login or password is currently necessary and the Chat Zone is open to all users: our American-based web site *EPE* Online (**www.epemag.com**) also feeds into the board. Members of *EPE* staff may also post information or updates into the Chat Zone, so regular readers are advised to check the messages for any project updates or web site service announcements.

We attempt to ensure that the "CZ" is a friendly and welcoming forum where hobbyists of all ages can ask for help, post a query or comment on *EPE* projects. In view of its open accessibility, *EPE* enforces an Acceptable Use Policy (AUP) in order to help protect individual users from certain forms of abuse (and also to protect the publishers!). Users automatically agree to the Chat Zone AUP when they post a message.

Generally the Chat Zone functions perfectly well and proves to be a valuable service to electronics hobbyists everywhere. Please do remember that English may not be the first language of an individual poster, and that they may be young users as well, so due allowances should be made for those factors.

Messages that breach the AUP for any reason may be deleted at the publisher's discretion. One form of abuse to be discouraged is the "troll" – a post or disingenuous comment deliberately designed to inflame, "slow time" or "wind up" other users; the liberal use of smileys helps avoid misunderstandings.

If you have an electronics query or comment and would like to ask your fellow hobbyists, then visit **www.epemag.wimborne.co.uk**, click the "Chat Zone" button on the web site navigation panel, check the AUP and then proceed to the Post A Message link. Messages remain on the board for approximately ten days and are **not** archived. Those interested in vintage radio and old electronics valve (vacuum tube) equipment might also be interested in our popular *Radio Bygones* message board, at **www.radiobygones.co.uk**. We'd like to thank all those regular users who make the CZ such a fascinating and enjoyable forum in which to participate.

Outlook Express Backup

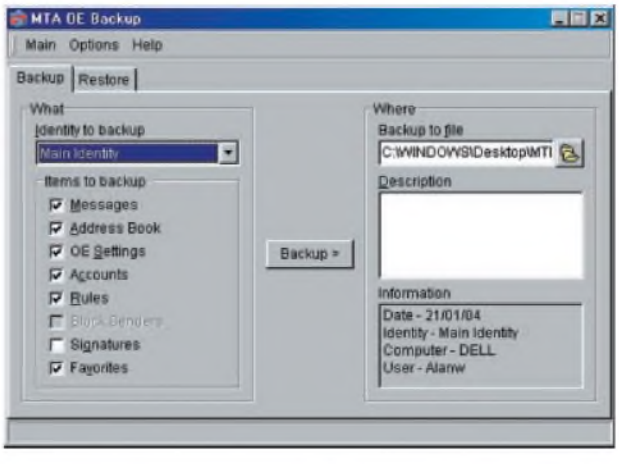
At the end of last year an acquaintance brought his PC in for attention. The machine had suffered a virus attack and was behaving very sluggishly. We eventually decided to reinstall all software from scratch. Onto the dining room table it went!

In trying to back up any valuable data, the problem arose of how best to back up and restore Outlook Express. One problem is that the ubiquitous email software is scattered amongst a number of files and folders on the hard disk. Quite apart from the indispensable Address Book, there are the messages themselves, signatures, rules, accounts and possibly favorites. A search on the web highlighted a simple utility program that proved perfect for the task.

The EPE *Chat Zone Message Board is a friendly and welcoming forum for electronic hobbyists everywhere.*

The MTA OE Backup from MTA Software (**www.mta-soft.com**) is a straightforward but highly effective program that needs little experience or skill to use. It enabled the Address Book and all of OE's settings, messages, rules etc. to be backed up into a single file that was burned onto a CD. The resultant backup file was successfully restored to the new installation. MTA OE Backup is so easy and convenient to use that I recommend it to any OE user, whatever their ability, to back up important email data and addresses. The price is $29.95.

You can contact the author at **alan@epemag.demon.co.uk**.

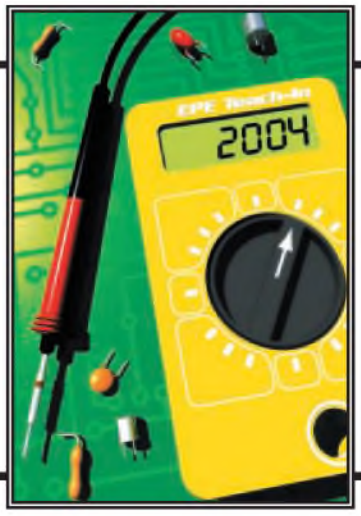


The MTA Outlook Express Backup is an easy and effective way of backing up and restoring email settings and messages.

EPE Tutorial Series

TEACH-IN 2004

Part Five – Logic Gates as Switches



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

THIS month we first show you how to route an audio signal so that several sources can be connected to a single amplifier. We will discuss the obvious method, using switches, then move to a more automated system which will take us into the field of digital multiplexers, counters and latches.

As our chip-count increases, we progress to show that a control system based on a PIC microcontroller can offer a better solution.

STATING THE OBVIOUS

Assuming that you wish to switch a stereo signal, a rotary switch can be employed, as illustrated in Fig.5.1. Many rotary switches have 12 connections, as shown numbered. If a single "pole" is provided, then the switch is known as a "single-pole, 12-way" (1p 12w) switch. If two poles, labelled A and B, are provided as shown in Fig.5.1, then the switch is a 2p 6w type, and ideal for stereo switching.

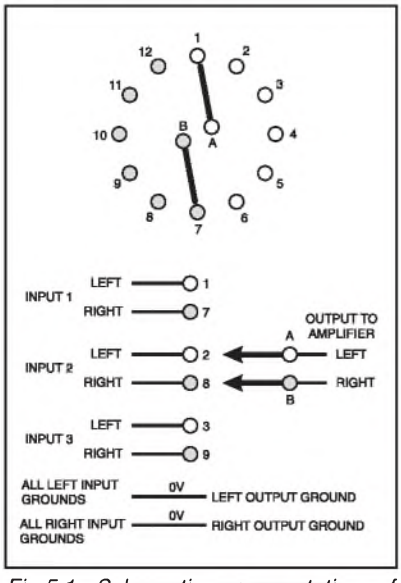


Fig.5.1. Schematic representation of using a 2-pole 6-way rotary switch to select between stereo audio signal sources.

The diagram shows only three input devices to which the switch can route the signals, but up to six can be connected and switched in the same way.

Notice how the grounds (0V) are connected directly between the inputs and the output. In many cases the left and right channel grounds will also be connected together, but if in doubt, leave them separated as shown.

This method of switching is straightforward, and if the control knob features a pointer, it is always clear which source is selected. But any form of remote control or automation is virtually impossible.

ELECTRONIC SOLUTION

When a switch is closed (on) we could say that it has a low resistance. When a switch is open (off) it has a very high resistance. A transistor can be made to behave like a switch, and a group of transistors connected together can form a *bidirectional* or *bilateral* switch, which behaves like a real switch.

The CMOS 4016 is a quad bilateral switch. In other words, the i.c. has four single-pole single-throw switches, each controlled by a single pin, as shown in Fig.5.2. They can be used to switch analogue signals on or off, depending on the logic level on their control pins.

For example, if Control 1 is at logic 0 (0V) then the resistance between pins 1 and 2 will be very high, and the switch can be considered to be off. If Control 1 is switched to logic 1 (supply voltage) then the resistance between pins 1 and 2 will fall to a few hundred ohms (a value dependent on the supply voltage), and the switch is now on. Because this is a semiconductor switch it is obviously not perfect, but when controlling audio signals, a few hundred ohms is usually of no consequence.

Note that although pins 1 and 2 are labelled In and Out respectively, the signal can pass in either direction. However, a word of caution, the signal voltage *must be within the power supply range used in your circuit*. For example, if you use a 9V battery, the signal being switched should not be lower than 0V or higher than 9V.

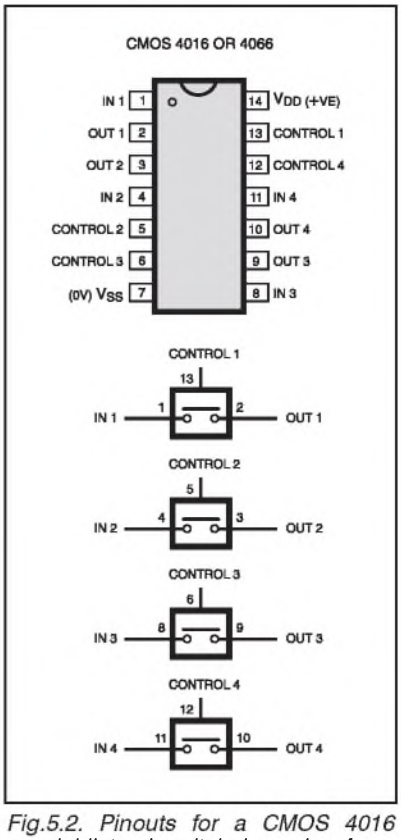


Fig.5.2. Pinouts for a CMOS 4016 quad bilateral switch i.c., plus functional equivalent schematics.

So if you are controlling an audio signal, remember that the signal will likely be swinging above and below zero volts. It will be necessary to raise the average level of the signal well above zero if clipping (and possible damage to the i.c.) is to be avoided. This type of level shifting was discussed in Part 3.

It is worth noting that in most applications the CMOS 4066 can be regarded as a pin-compatible equivalent to the 4016.

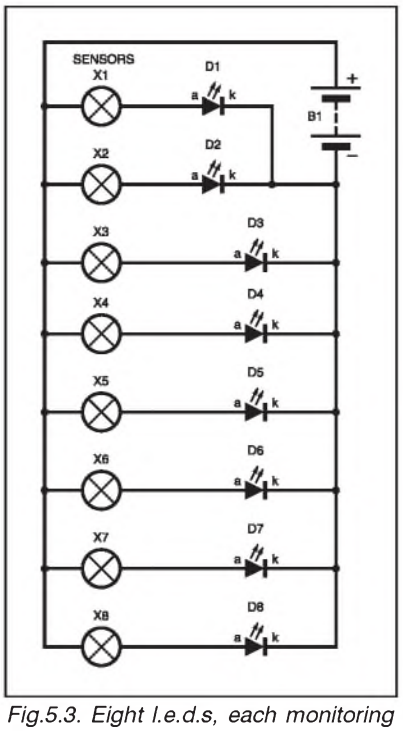


Fig.5.3. Eight l.e.d.s, each monitoring one sensor.

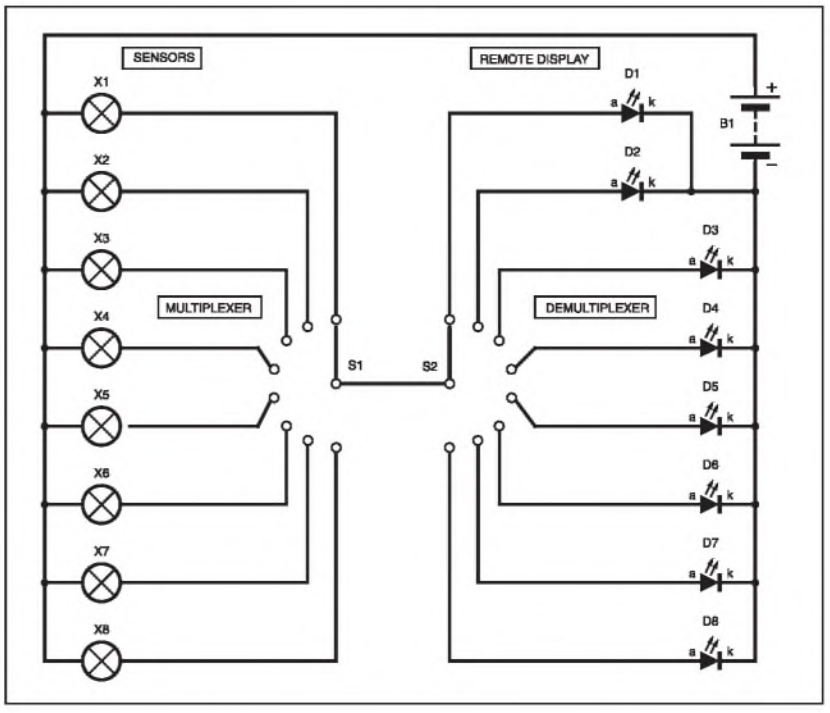


Fig.5.4. Using two rotary switches to multiplex and demultiplex eight sensors and eight l.e.d.s.

BASIC MULTIPLEXING

A browse through the range of i.c.s available for analogue switching reveals the *analogue multiplexer/demultiplexer* group. Some of these i.c.s are from the CMOS 4000 range, namely the 4051, 4052 and 4053. There are also equivalents from the 74HC range (see Part 4), the 74HC4051, 74HC4052 and 74HC4053.

The 74HC range can generally handle more current than the CMOS 4000 series, but 74HC require a supply of between 2V and 6V. So if we wish to use 9V or 12V we must stay with the 4000 series.

Multiplexing is a means by which several streams of information are sent across a single medium. We say that the information is multiplexed at the transmitter and demultiplexed by the receiver. There are two main types of multiplexing, *Frequency Division* and *Time Division*. We will consider the latter.

The principle is best understood by taking a simple example. Suppose you wish to know the depth of water in a well. You wish to use a cable to link the set of sensors to your house. You require eight sensors (sounds a lot, but it illustrates the point!).

Each sensor, when wet, causes an l.e.d. to light, so producing a bargraph effect of the water level. The idea is shown in simplified form in Fig.5.3, and you will see that the link between the house and the well requires nine wires.

Now consider the system in Fig.5.4. Notice how the number of wires between the well and the house has been reduced to just two (though we will see later that in a practical system four more are needed).

In Fig.5.4 we use two rotary switches, S1 which *multiplexes* the information onto one wire, and S2 which *demultiplexes* it from one wire to eight. If both switches are positioned as shown, sensor X1 is connected to l.e.d. D1. If both switches are moved one step then X2 will connect with D2.

Now imagine that both switches are rotated at speed, but in exact step with each other. Each sensor will connect with its respective l.e.d. for one eighth of the time for each revolution. So you will have a display, but it may appear to flicker.

If the speed of the rotary switches is further increased, the flickering will appear to stop – rather like your TV picture appears reasonably stable even though it is formed by one spot travelling very quickly across and down the screen.

The l.e.d.s will not be as bright as with the circuit in Fig.5.3, but this can be compensated for by a suitable choice of l.e.d. types and current limiting resistor(s).

The circuit in Fig.5.4 illustrates an example of *time division multiplexing*. The information from each sensor is sent sequentially (one after the other) along a single wire.

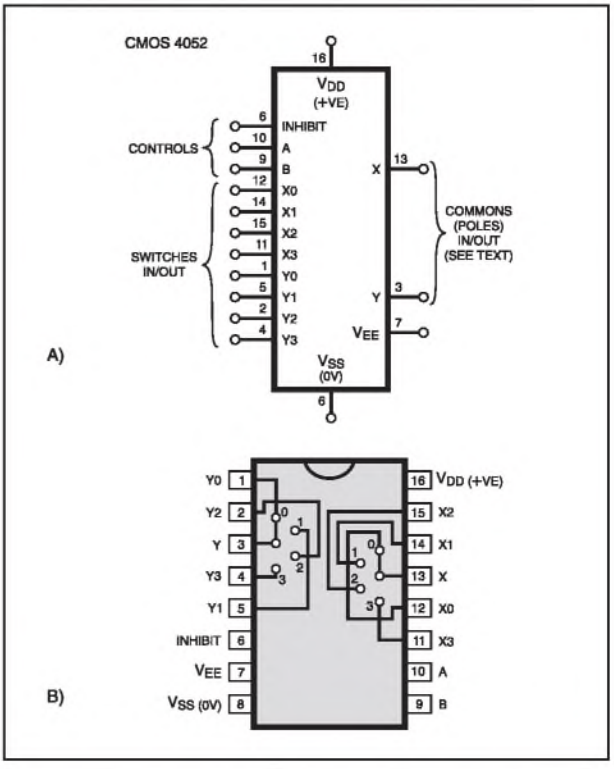


Fig.5.5. Pinouts and functional equivalent for a type 4052 dual 4-channel analogue multiplexer/demultiplier.

ELECTRONIC MULTIPLEXING

Of course, the two switches must remain exactly in step with each other, and this would be hard to achieve with mechanical switches. So we need electronic rotary switches – i.e. electronic multiplexer/demultiplexers.

The CMOS 4052 is a dual 4-channel multiplexer/demultiplexer. Its functional pinout diagram is shown in Fig.5.5a. An equivalent view of the switching is shown in Fig.5.5b.

It should be clear that pin X is the pole of one switch, and pin Y is the pole of the other switch. The four switch positions are labelled 0, 1, 2, 3, prefixed by X or Y. So the 4052 device offers 2-pole 4-way switching.

Note that multiplexer type 4051 offers a single-pole 8-way switch, and the 4053 provides three poles, each 2-way.

The function of the pin marked V_{EE} will be discussed later.

UNDERSTANDING BINARY

The switch positions are controlled electronically by the control lines labelled A and B. Whereas a single-way (on-off) switch can be controlled by a single line, a 4-way switch requires two control lines, and an 8-way switch requires three control lines.

The control lines use a system known as *binary*, where any number is represented by combinations of logic 1 and logic 0. An example is shown in Table 5.1.

Table 5.1. Decimal to binary conversion example

Decimal	8s	4s	2s	1s	Binary
0	0	0	0	0	0000
1	0	0	0	1	0001
2	0	0	1	0	0010
3	0	0	1	1	0011
4	0	1	0	0	0100
5	0	1	0	1	0101
6	0	1	1	0	0110
7	0	1	1	1	0111
8	1	0	0	0	1000

etc.

Notice that decimal 0 is equal to binary 0, and decimal 1 = binary 1. The table shows decimal 1 as binary 0001, but we normally ignore leading zeros.

In decimal, when you add 1 to 9, you move to the next column, so 9 + 1 = 10. In other words you place "1" in the tens column, and '0' in the units column. In binary, if you add 1 to 1, you move to the next column (shown in the table as the 2's column), so binary 1 + 1 = binary 10, or decimal 2.

The table shows that decimal 3 consists of "1" in the 2's column, plus "1" in the 1's column, hence decimal 3 = binary 11.

You can convert a number of any size by adding more columns to the left of the 8's column in the sequence 16, 32, 64, 128, 256 etc. These numbers will be familiar to computer users!

MULTIPLEX SWITCHING

The position of the two switches within the 4052 device is determined by the logic levels at the control pins, A and B. If both A and B are at logic 0, then both switches will connect to way 0. Now if we count up in binary, the switches move through the ways step-by-step as follows:

Way	B	A
0	0	0
1	0	1
2	1	0
3	1	1

It is important to note that the switch routing is only performed if the device's Inhibit pin is at logic 0. If Inhibit is at logic 1, then both switches become open circuit.

A 1-pole 8-way system, based for example on the 4051, would need three control lines, as follows:

Way	C	B	A
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

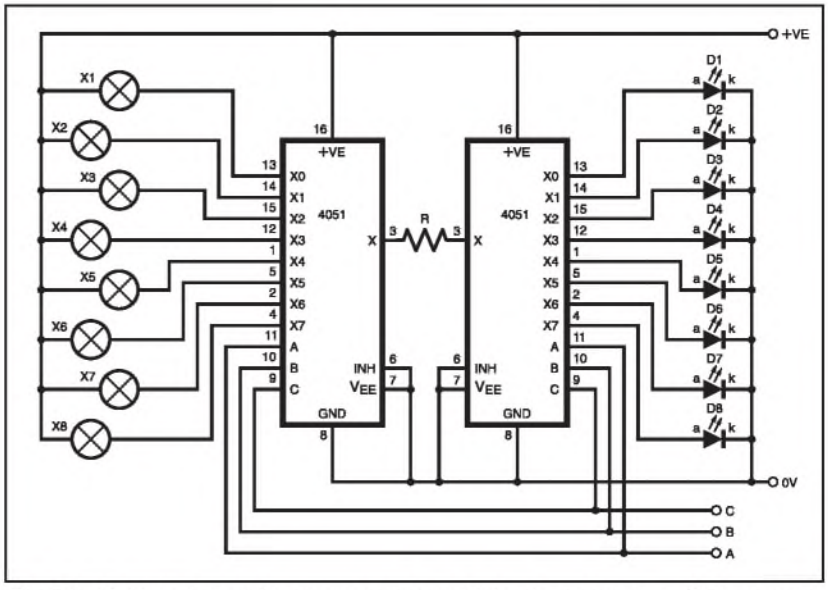


Fig.5.6. Multiplexing eight sensors and eight l.e.d.s using two 4051 analogue multiplexers.

Returning to our water well example for a moment, if we wanted to ensure that the electronic switches in Fig.5.4 were always in step, we would need three control lines, A, B and C. The system also requires positive and 0V power lines. So the total number of wires running between the two ends is six.

A schematic representation of the system, in which two 4051 devices are used, is shown in Fig.5.6. Be aware that a practical implementation of it would depend on the sensor types. Also note that the l.e.d.s. require only one current-limiting resistor (R) between them as only one l.e.d. can ever be on at a time.

You will no doubt think that this multiplexed system seems less productive than indicated in Fig.5.4. But add just one more control line (D) and the number of ways increases to 16. Add one more (E) and the number of ways doubles to 32, and so on.

In reality, analogue multiplex devices having more than three control lines do not exist, but there are techniques for getting round this. One method is to use several banks of multiplexers with their Inhibit lines controlled by another multiplexer.

ELECTRONIC COUNTERS

We may want the multiplex control to cycle continuously, or we may want it to move by a given number of steps when we press a single button or remote control. Either way, we will probably need a counting circuit to produce the binary code to be applied to the control pins.

Most electronic counting circuits operate in binary, and so we require an i.c. which increments (counts up) or decrements (counts down) each time its clock input is pulsed in a particular logic-change direction.

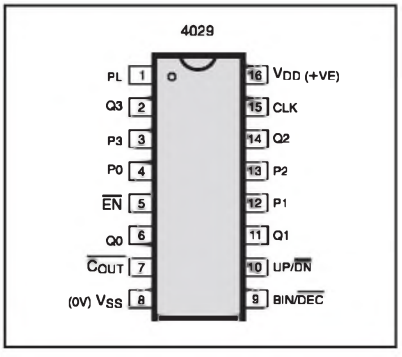


Fig.5.7. Pinouts for the 4029 counter.

There are several counting i.c.s available, but a particularly flexible one is the CMOS 4029. It is a synchronous up/down binary/decade counter. Its pinouts are shown in Fig.5.7, and their functions in Table 5.2.

Being flexible, the 4029 can also appear complicated. If you wish to explore it further, the datasheet is available from many electronics component suppliers, or via the internet by typing "datasheet 4029" into **www.google.com**. Other similar statements can also achieve results.

The Philips Semiconductors' datasheet for it is available from **http://www.semi**

Table 5.2. Pin functions for the 4029 synchronous up/down binary/decade counter

PL: Parallel load. Effectively the reset pin, i.e. when switched from logic 0 to logic 1, the Q0 to Q3 outputs are reset to the logic on the P0 to P3 data inputs.

P0 to P3: Parallel data inputs.

Q0 to Q3: Parallel data outputs.

BIN/$\overline{\text{DEC}}$: If high, reset will occur after 15 (binary counting). If low, reset will occur after 9 (decimal counting.)

UP/$\overline{\text{DN}}$: If high, the counter counts up. If low, the counter counts down.

$\overline{\text{EN}}$: Enable. If low the counter is allowed to count. If high the counter cannot count.

$\overline{C}_{out}$: Carry Out. Goes low to signify a Carry. Needed only if cascading several 4029s to count larger numbers.

CLK: Clock input. Causes the i.c. to count whenever it *changes* from low to high (i.e. edge triggered).

conductors.philips.com/acrobat/datasheets/HEF4029B_CNV_3.pdf

Further explanation of the Preset and Carry functions is as follows:

PRESETS

The Preset inputs are used to make the Q outputs jump to a particular number at reset. If all the Presets are connected to 0V, the outputs become 0000.

In some applications you may want the count to start at a number other than zero. For example, an automatic dice number generator would need to cascade through the numbers 1 to 6, stopping randomly. In this case you would connect pin P0 to positive so that the i.c. jumped to 1 instead of 0 at the start of each count.

CARRY

Note that some pin labels in Fig.5.7 are shown with a barline above them. The line indicates that they are "active low". In other words, the $\overline{EN}$ (Enable) pin should be normally held at logic 0 to enable the counter to count. The $\overline{C}_{out}$ (Carry Out) pin is normally high, but switches low when the counter needs to output a Carry signal.

The Enable and Carry Out functions enable the i.c.s to be cascaded to count up to any required number.

SIMPLE COUNTER

The circuit diagram in Fig.5.8 shows the simplest way in which the 4029 counter can be used.

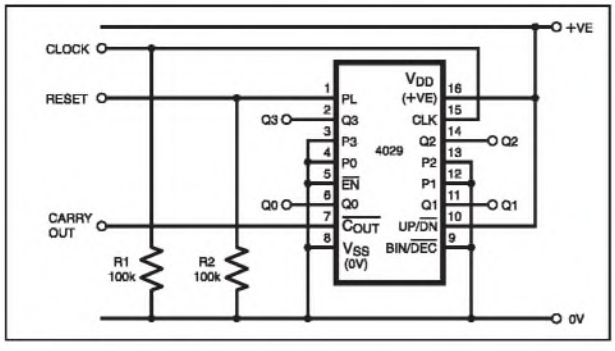


Fig.5.8. Simple counting circuit using the 4029 counter.

Inputs must always be connected to a definite logic level, otherwise static electricity may cause instability, or could even damage the i.c., as discussed in Part 4. The $\overline{EN}$ pin is connected to 0V to allow the device to count..

Inputs P0 to P3 are also tied to 0V since the counter only needs to be reset to zero.

The BIN/$\overline{DEC}$ pin has been connected to 0V, making the i.c. reset after a count of 9.

The UP/$\overline{DN}$ pin has been connected to positive, making the i.c. count up.

The two input connections required are Clock and Reset (PL). They have been biased to 0V via 100kΩ resistors, R1 and R2. This allows either input to be made positive simply by means of a push-to-make switch connected between the appropriate input and the positive line.

TEST CIRCUIT

Since our intention is to connect the counter to the 4052 4-way multiplexer discussed earlier, we need to automatically reset the counter at the count of 4, i.e. 0, 1, 2, 3, reset back to 0, 1, 2, etc. This is achieved simply by connecting output Q2 to the Reset input as shown at the left in Fig.5.9. Consequently, bias resistor R2 in Fig.5.8 is not needed in Fig.5.9 since the Reset pin is now connected to a definite logic level, namely output Q2.

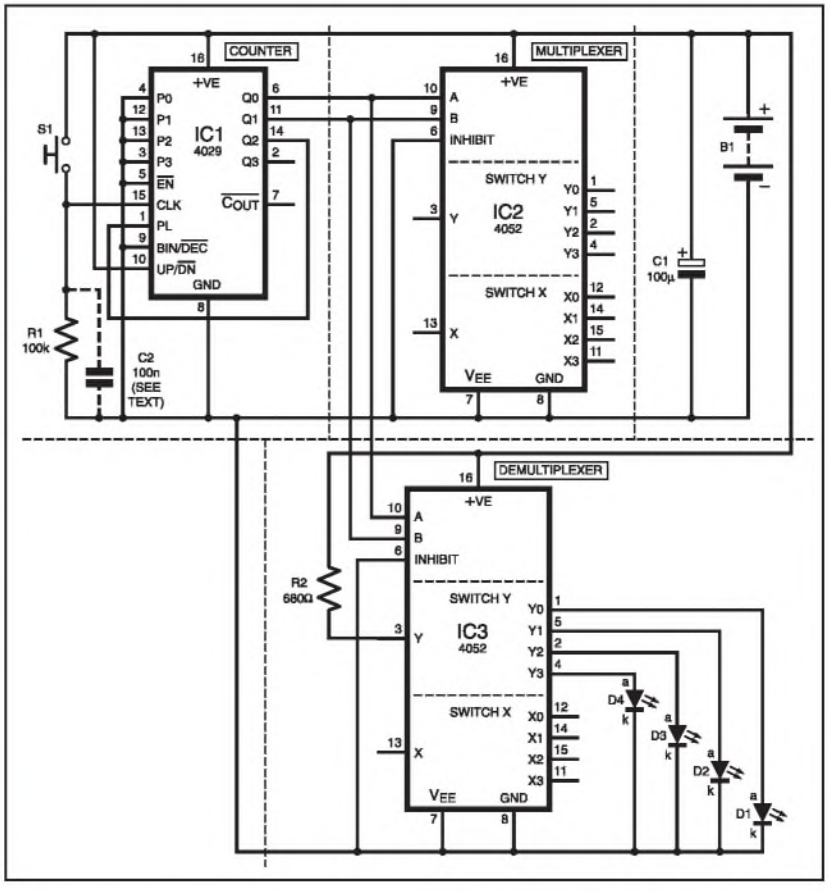


Fig.5.9. A type 4029 counter controlling two 4052 multiplexers.

The circuit in Fig.5.9 is not intended to be a finished project, but illustrates how the counter and two 4-channel multiplexers can be connected together. The breadboard test assembly is shown in Photo 5.1. The l.e.d.s on IC3 channel Y illustrate how the multiplexer is cycled through its 16-way count as the counter is incremented by switch S1.

You could also connect l.e.d.s. and a 680Ω resistor to IC2 in the same way to prove that it responds in synchronisation with IC3. You can similarly check the operation of the X channels of both multiplexers.

It is worth noting that as channel X copies exactly the action of channel Y, the multiplexers can be used for stereo sound control as shown later.

SWITCH BOUNCE

When pressing switch S1, you may notice that the behaviour of the circuit sometimes seems a bit random, jumping erratically between count values, rather than in strict numerical order.

This is due to a characteristic known as *switch-bounce*. When you press any switch, the contacts vibrate for a moment, opening

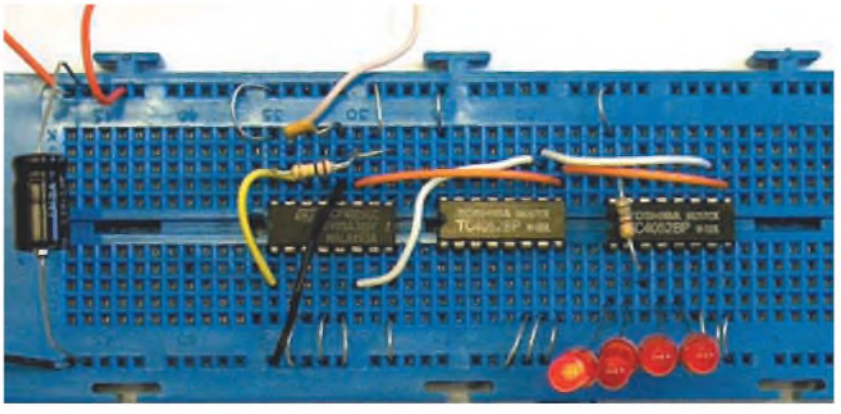


Photo 5.1. Breadboard test assembly for the circuit in Fig.5.9.

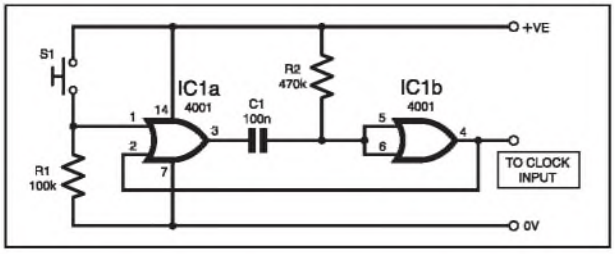


Fig.5.10. Monostable circuit suitable for switch debouncing.

and closing rapidly. Each vibration sends a signal to the clock input of the i.c., so making it count in an apparently random way.

A simple if crude way of reducing the effect of switch bounce is to add capacitor C2, shown dotted in Fig.5.9. This will enable you to check that the circuit is working, by allowing a progressive count instead of a rather random result. The value of the capacitor is not critical, and suggested values are between 100nF and 1μF.

The monostable we discussed in Part 4, Fig.4.24, is better for removing switch-bounce, and the circuit is reproduced with slight modifications in Fig.5.10. Note that the timing period is quite short (about 7ms with the components shown).

When switch S1 is pressed, the output at pin 4 changes cleanly to logic 1, then stays at logic 1 for a period longer than the likely bounce period of the switch. There is a slight risk that the system will be triggered again when the switch is released, and if necessary, the period can be lengthened by increasing the values of resistor R1 or capacitor C1, or both. If the period is too great, though, it will not be possible to increment the multiplexer switch at anything beyond a snail's pace. If in doubt, experiment.

When connecting the monostable to the counter in Fig.5.9, resistor R1 and switch S1 in that circuit should be removed.

Alternatively, instead of using a switch to trigger the system, you could use an astable (oscillator) circuit to automatically control the counter. We looked at astables in Part 4, and a suitable circuit was shown in Fig.4.26.

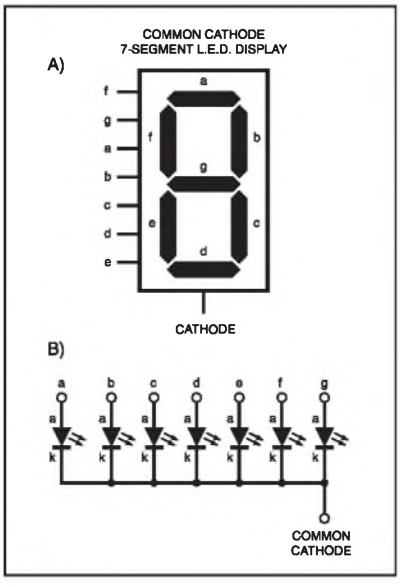


Fig.5.11. How a 7-segment l.e.d. display is formed.

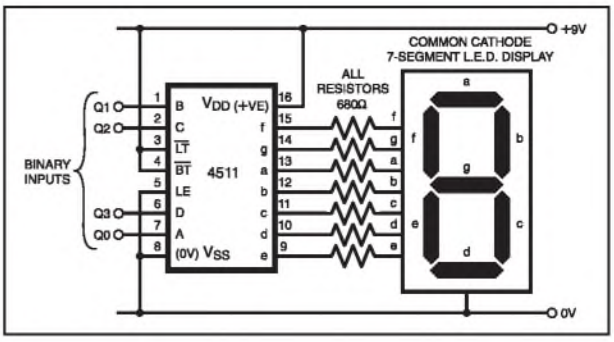


Fig.5.13. Using a 4511 to drive a 7-segment l.e.d. display.

NUMERIC DISPLAYS

Since the purpose of our system is to eventually provide audio switching, it will be useful to know which audio source is selected at any one time. If we add a set of individual buttons to select the sources, we can make the latching circuits provide the indication, as shown later, but in this section we will explore other ways of providing displays.

We have shown that a set of individual l.e.d.s can be used to show which source is selected. This, though, is not the clearest way of showing such information.

Instead, the counter's four binary outputs can be decoded to show numeric values on a 7-segment l.e.d. display if preferred. These displays are arranged as shown in Fig.5.11a, where each segment's l.e.d. is labelled *a, b, c*, etc.

There are two main types of 7-segment display: *common anode*, and *common cathode*. We will demonstrate the use of the latter, in which all the cathodes (*k*) of the l.e.d.s are joined together at a single pin on the display unit, as in Fig.5.11b. This simplifies the connections needed.

When buying a display, check that the catalogue supplies the data necessary to show which pin is connected to which segment. All 7-segment displays conform to the segment order shown in Fig.5.11a, but pin layouts vary.

A display of "1" is shown when segments *b* and *c* light up; a "2" is made by lighting up segments *a, b, g, e, d*. Making the appropriate combinations light up correctly is quite a complex task, but of course, a specialised i.c., such as CMOS 4511, can do the whole job of converting a binary input to a correctly organised 7-segment output. The outline of the 4511 is shown in Fig.5.12. The pins are as follows:

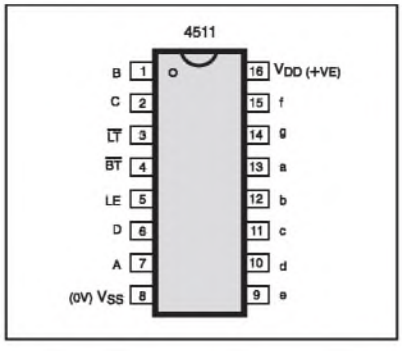


Fig.5.12. Pinouts for the 4511 7-segment l.e.d. driver.

Pins A, B, C, D: Binary code inputs

Pins *a, b, c, d, e, f, g*: Segment control pins

Pin $\overline{LT}$, Lamp Test: normally connected to positive; when connected to 0V, all l.e.d. segments light up – mainly used for testing

Pin $\overline{BT}$, Blanking: normally connected to positive; when connected to 0V, all l.e.d. segments are switched off – useful for blanking out unwanted leading zeros

Pin LE, Latch Enable: normally connected to 0V. When made positive, the display latches, i.e. remains fixed on the number being displayed.

An example of connecting the 4511 to the 7-segment display is shown in Fig.5.13. All the unused functions have been disabled by connecting their respective pins to positive or 0V as required.

To use the 4511 decoder with the 4029 counter in Fig.5.8, connect output Q0 to input A, and output Q1 to input B. Inputs C and D of the 4511 should be connected to 0V to prevent static electricity causing random effects.

The 7-segment display anodes are connected via current limiting resistors, and the value of 680Ω assumes a 9V or 12V supply. If the circuit is operated on 5V the display may appear a little dim, and so the resistors could be reduced to, say, 330Ω.

LATCHES

A convenient way of selecting the required audio source is by means of a row of pushbutton switches. In fact, amplifiers sometimes used to employ mechanically-latching switches to select sources, and very old TVs used a similar system – in the days when there were only four TV stations!

Electronic latches are simpler to build, and we showed some basic latching circuits in Part 4. The bistable circuit shown last month in Fig.4.22 is probably the most useful, since it is designed to be easily unlatched (reset) and provides a very clean output, free of spikes and glitches.

We could build a latching system based around NOR gates, but money and time will be saved if we use a ready-made system based on a type 4043 quad NOR R/S latch. This has four reset/set latches in one i.c. – just what we need!

The pinouts and equivalent functions of the 4043 are shown in Fig.5.14. If Set input S0 is taken high, output Q0 will go high, and will latch into this state. If Reset input R0 is taken high, output Q0 will go low, i.e. it is reset.

When the Enable pin is high, the i.c. behaves normally, but when taken low, all the outputs become open-circuit, i.e. disconnected.

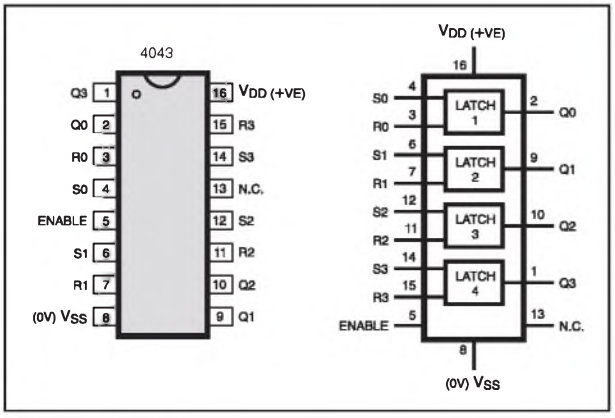


Fig.5.14. Pinouts and functions for the type 4043 quad NOR R/S latch.

Note the NC label at pin 13 – this means *No Connection* (internally the pin is not connected to anything).

AUTOMATIC UNLATCHING

When a pushbutton switch is pressed on a mechanical system, the previously set button is automatically pushed out. We need our electronic system to copy this. There are several methods, and the system shown in Fig.5.15 is one of several ways of achieving the same result. Photo 5.2 shows the prototype breadboard assembly.

Resistors R1 to R8 hold the eight inputs of latch IC1 at 0V. If switch S1 is pressed, then Set input S3 goes high, and so output Q3 latches high. At the same time diodes D1, D2 and D3 force the Reset inputs R0, R1 and R2 high, so unlatching any previously latched outputs. The other switches work in the same way.

The problem is that the 4052 i.c. is expecting an input coded in binary, and so our latching circuit must also provide a binary output. In fact, converting to binary in this instance is quite straightforward, requiring that outputs Q1 and Q2 are each connected to a resistor/diode pair, R9/D13 and R10/D14.

When output Q0 goes high, we want multiplexer IC2 to be at position (way) 0. So both binary inputs to IC2 must be low. This is achieved by leaving Q0 unconnected, so all that happens is that the other outputs, Q1, Q2, Q3, are simply reset low. Since output Q0 is actually redundant to the control of multiplexer IC2, you could in fact omit the diodes which are connected to Reset input R0 (i.e. D3, D6, D9). They must be included, though, if you want the four outputs of IC1 to each drive an l.e.d., as discussed shortly.

When output Q1 goes high, we need binary line A of the 4052 to copy it. When Q2 goes high, we need binary line B to copy it. But when Q3 goes high we need both binary lines A and B to go high (decimal 3 = binary 11). This is achieved by means of diodes D13 and D14.

Resistors R9 and R10 are necessary to prevent the current from Q3 shorting back into Q1 and Q2 when they are low.

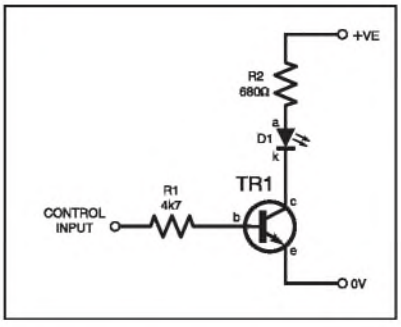


Fig.5.16. Interface to drive an l.e.d. from a CMOS 4000 series output.

L.E.D. INTERFACE

As discussed in Part 4, the CMOS 4000 series cannot provide enough current to adequately light a normal l.e.d. (although low-current, high-brightness l.e.d.s. are available). Consequently, if you want to drive an l.e.d. from each of the four outputs of IC1, a simple interface circuit is needed for each. A suitable circuit is shown in Fig.5.16.

Resistor R1 limits the current flowing from the selected output into the base (b) of *npn* transistor TR1. As described in Part 2, when current flows into the base of an

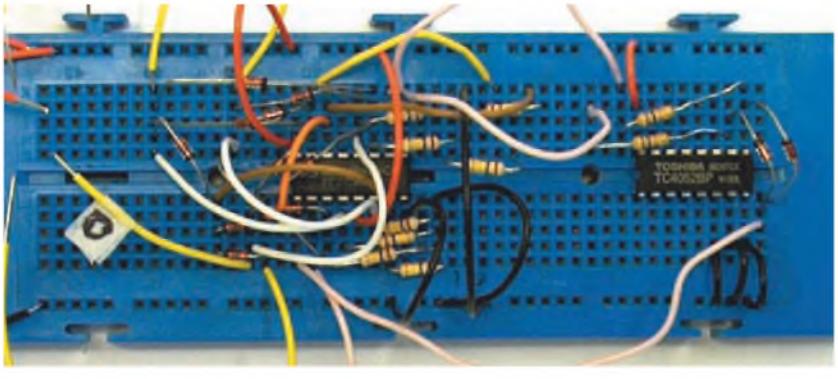


Photo 5.2. Breadboard test assembly for the circuit in Fig.5.15.

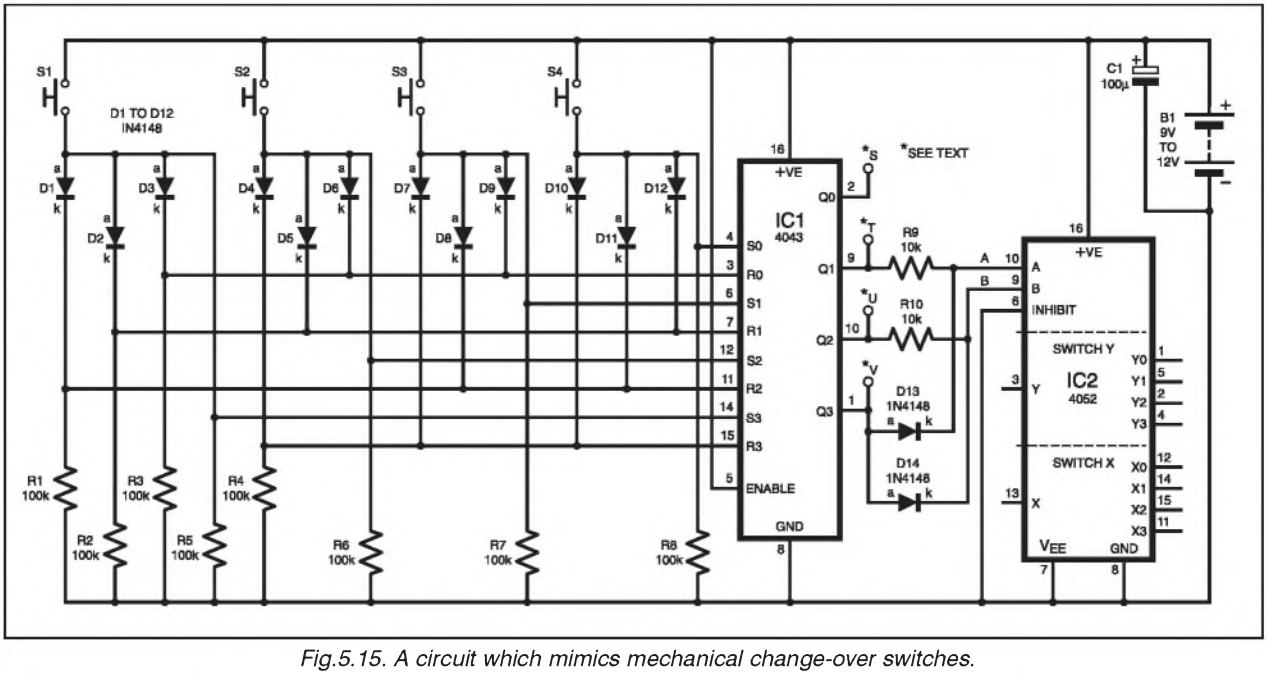


Fig.5.15. A circuit which mimics mechanical change-over switches.

npn transistor, current then flows from the positive power line, through the transistor's collector (c) and emitter (e) path, and to the 0V line. The transistor is then said to be "turned on".

As shown in Fig.5.16, resistor R2 and l.e.d. D1 are in series between the positive power line and the collector. Consequently, when the transistor is turned on, the l.e.d. will light.

MICROCONTROLLED ALTERNATIVE

In the first paragraph of this part, we said that we would show you how to route an audio signal so that several sources can be connected to a single amplifier.

In essence, the circuit in Fig.5.15 is well suited to having four stereo audio signals fed into the two sections of the 4052 multiplexer, with the outputs feeding into a stereo amplifier system. This would require, though, that signals were buffered by capacitors in the manner described in Part 3, when op.amp circuits were discussed.

So at this point we must stand back and decide whether the circuit in Fig.5.15 represents the best solution. If it provides everything required then its low cost and good functionality make it an attractive option.

But, for example, you might like the option of auto-sound sensing, where an active sound source automatically switches the selector, then although this is possible, the whole circuit will begin to be even more complicated!

There is, however, another technique that could be employed – namely using a microcontroller, suitably programmed to provide the control of the 4052, to light l.e.d.s without the need for a transistor interface, and respond easily to the output of an auto-sensing circuit. Moreover, you could place a "time-catch" in the control program, so that a source has to be active for, say, 200ms or so, before the system switches over. This would avoid problems caused by stray "glitches" in the circuit.

The microcontroller would also allow us to add a single switch which steps through the sources, without the addition of any elaborate electronics, making remote control a simple option.

Such a microcontroller is familiar to many *EPE* readers, that known generally as a PIC microcontroller.

If you require such flexibility as just described, then a PIC offers a better solution, though the price is a little higher, and you have to program the i.c. via a PC-compatible computer in conjunction with a dedicated hardware system. With *EPE*'s published PIC designs you can also buy one ready programmed.

We have based the microcontroller option on the PIC16F627. Its program has been developed in BASIC, using a system known as PICAXE, although a hex file (the data codes required by the PIC) suitable for those readers with PIC programmers can be downloaded from the *EPE* website. The source code has explanatory comments within it.

PICAXE is a system developed by Revolution Education, who supply PIC16F627 devices configured (i.e. part-programmed) as what they call PICAXE-18 devices. This means that a program written in a form of BASIC can be directly downloaded to the device via the serial output of a PC. This is carried out after building the circuit. A 3-pin connector is used so that programming is performed in-circuit.

You can modify your program and download it as many times as you like. With the PICAXE system, you do not need special programming hardware, and if you already own a PC, then the cost of the required serial lead and connector is little more than the cost of the chip.

The PICAXE-18 devices, connector and serial lead are all available from Revolution Education. The controlling software and documentation required is available free of charge over the net (**www.picaxe.co.uk**), or can be supplied by Revolution Electronics on disk, see later.

PIC CONTROL CIRCUIT

The basic circuit diagram for the PIC-based controller is shown in Fig.5.17, the prototype test assembly is shown in Photo 5.3. At the heart of the circuit is the PIC microcontroller, IC1, which can either be the PICAXE-18, or a PIC16F627. If the latter is employed, connector TB1 can be omitted. If the PICAXE-18 is used, TB1 allows the circuit to be linked to a computer via a serial lead, allowing programming directly from BASIC.

There are five push-button switches, S1 to S5, and these set their respective PIC inputs high when they are pressed. When any switch is not pressed, resistors R4 and R10 to R13 pull the respective inputs to 0V. Switches S2 to S5 are used to select the sound source, and S1 is used to turn on the auto-sensing circuit(s) described later, via the output labelled Inhibit (IC1 pin RB7).

Pins RB0 and RB1 are set as outputs and control the audio signal path multiplexer. Pins RB2 to RB6 are used to drive a set of l.e.d.s which indicate which audio source has been selected. They are buffered by resistors R5 to R9. PIC outputs can typically supply about 25mA, and so can easily drive an l.e.d.

The circuit can be powered at about 4·5V to 6V. The latter value **must not** be exceeded. Capacitor C1 provides decoupling for the circuit.

AUDIO CONTROL

The audio inputs and outputs at the multiplexer, IC2, are shown in Fig.5.18. It is assumed that the audio signals will be taken from the RCA (phono) sockets of the signal source. The outputs from the multiplexer are intended for feeding to the inputs of a power amplifier. Ensure that all the signal grounds are connected to the 0V rail in the circuit.

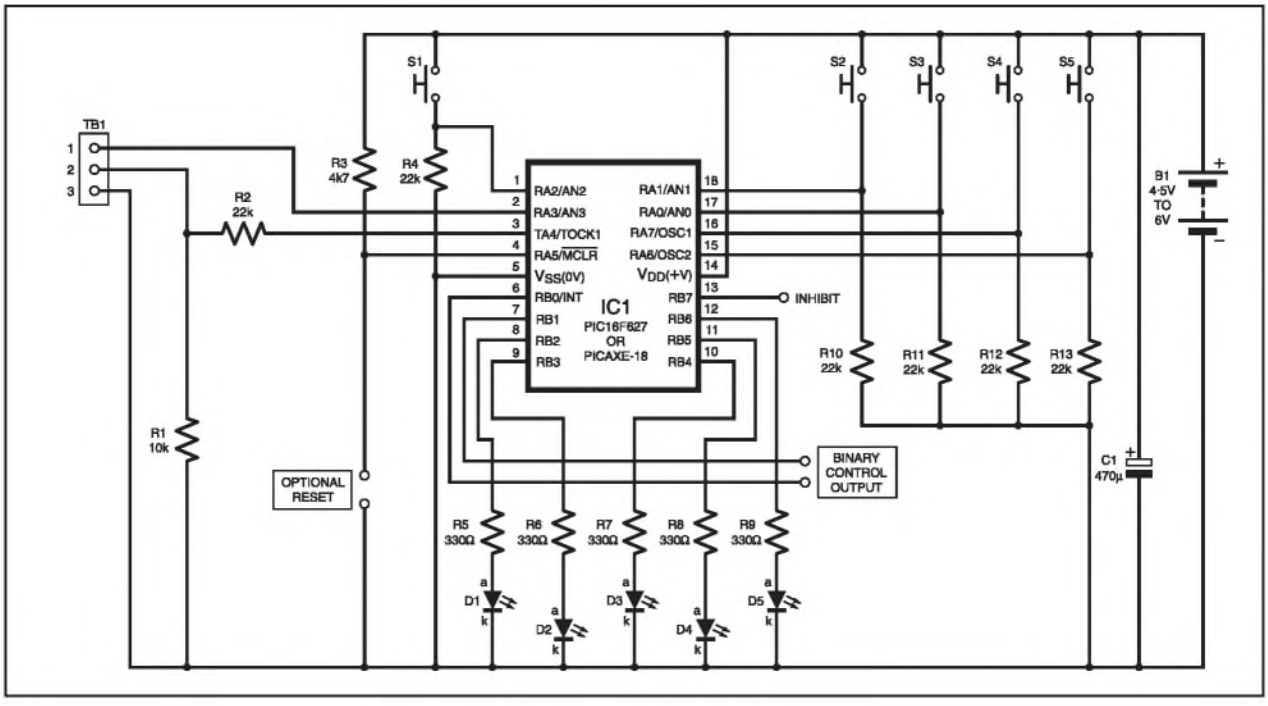


Fig.5.17. PIC-based circuit for controlling the multiplex circuit in Fig.5.18.

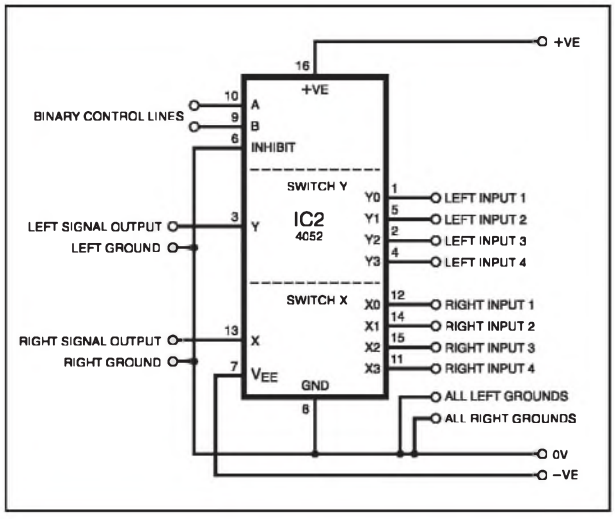


Fig.5.18. Audio signal multiplexing circuit which can be controlled by the circuit in Fig.5.17.

MULTIPLEXER V_{EE} PIN

In the foregoing multiplexer circuits, the pin marked V_{EE} has been connected to 0V. This pin determines whether or not the multiplexer can accept audio signals that swing below 0V (i.e. go negative). In the previous circuits none of the signals being switched went below 0V.

If negative signals *are* to be fed through the multiplexer, pin V_{EE} should be connected to a negative supply, at least as great as the signal. Since the audio signals swing above and below 0V, the V_{EE} pin should be connected to a negative voltage source, of at least –5V.

One way of providing the negative voltage is to use a second 6V battery, connected to form a dual-rail power supply, as discussed in Part 3.

Alternatively, a negative supply can be generated by a circuit powered from the same battery as the rest of the circuit. An ICL7660 voltage converter chip can be used for this, as shown in the circuit of Fig.5.19.

The positive supply at pin 8 is inverted and available at pin 5 as a negative supply equal in magnitude to the positive supply.

Of course, only a limited current is available from the negative output, but it is more than sufficient for the purpose in the circuit of Fig.5.18.. Both capacitors C1 and C2 in Fig.5.19 are electrolytic, and care must be taken to connect them the correct way round – noting especially that C2 "looks wrong" in the schematic diagram – but remember that pin 5 is more negative than 0V.

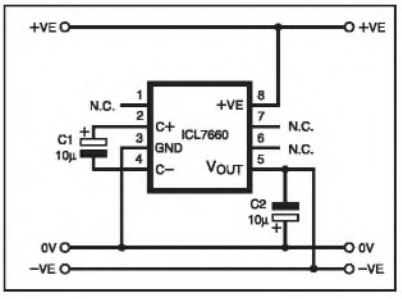


Fig.5.19. A circuit for generating a negative voltage from a positive power supply.

AUTO-SENSING

Assuming that only one sound source is playing at any one time, it is possible to make the circuit automatically select the "live" source. There are a number of approaches, but the suggested one is shown in Fig.5.20.

The auto-sensing circuit first needs to extract a very small part of the incoming signal, from one channel of one source. Transistor TR1 amplifies this signal, passes it through capacitor C2 , it is then rectified by diodes D1 and D2, to charge capacitor C3 (see Part 1).

If sufficient audio signal is detected C3 will charge to a point where transistor TR2 is turned on. The voltage at the collector of TR2 will then switch from positive to 0V. Transistor TR3 inverts this signal, switching from low to high whenever a sound signal is received.

The collector of TR3 (labelled Output) should be connected to any of the chosen inputs i.e. pins 15, 16, 17 or 18 of the PIC, in place of the switches S2 to S5. Resistors R10 to R13 may be omitted

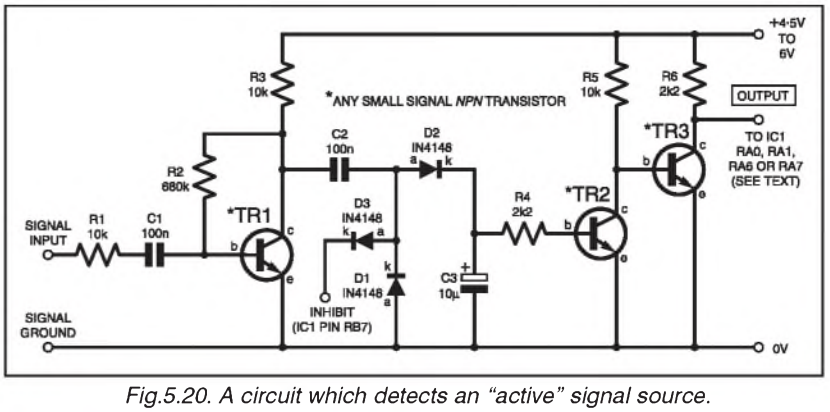


Fig.5.20. A circuit which detects an "active" signal source.

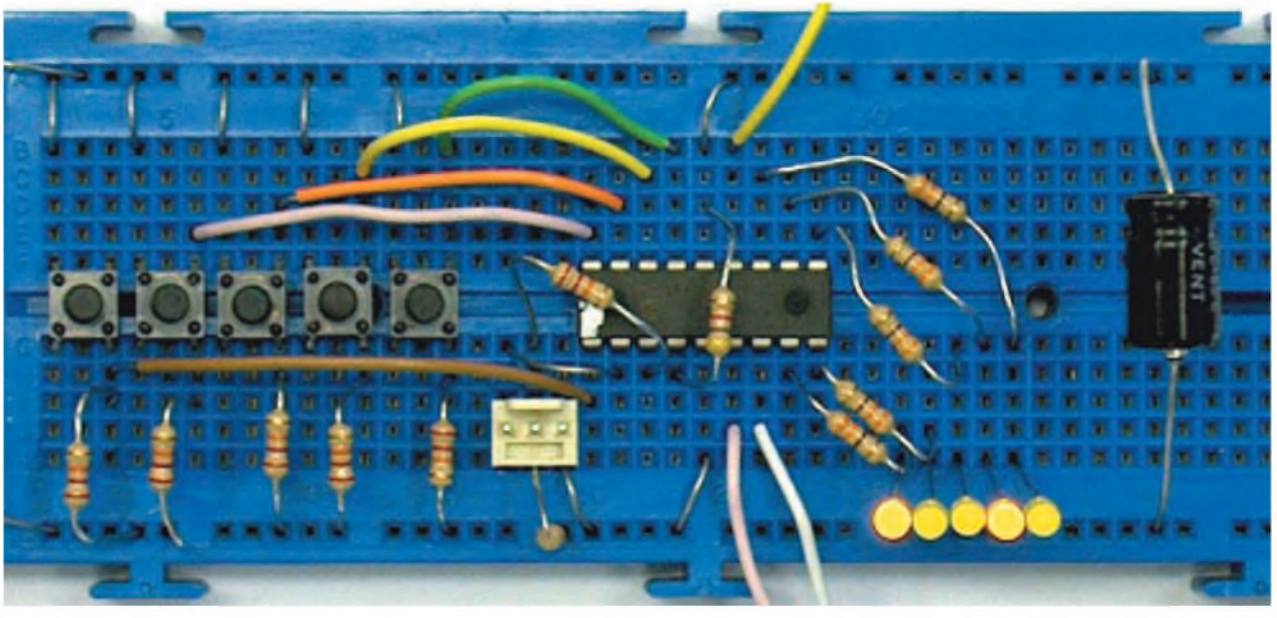


Photo 5.3. Breadboard test assembly for the circuit in Fig.5.17.

(although it does not matter if they are not). One sensor is needed for each source.

It is only necessary to add the auto-sensing circuit to the output of the left channel of any source, since it is unlikely that the right-hand channel will contain a sound signal without the left. Since the auto-sensing circuit is a separate module, it can be added to as many or as few inputs as required.

The auto-sensing circuit(s) should be powered from the same supply as the rest of the system (i.e. 4·5V to 6V).

There may be circumstances in which the auto-sensing circuits need to be switched off. Hence an Inhibit function has been included on the control circuit (Fig.5.17). This is connected to each of the auto-sensing circuits, at the point labelled Inhibit (IC1 pin RB7). When Inhibit is low, the auto-sensing circuits are unable to function.

FINAL TESTING

A double beam oscilloscope is ideal for testing this type of circuit since you can compare the input signal with the output to ensure the circuit is working perfectly. A sine wave should be reproduced without any distortion, as should a square wave – a much more difficult waveform for an audio system to reproduce accurately. If an oscilloscope is not available, some critical listening tests will suffice!

RESOURCES

Preprogrammed PIC microcontrollers for the circuit in Fig.5.17 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 5. 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: Tech-Supplies, Dept. *EPE*, 4 Old Dairy Business Centre, Melcombe Road, Bath BA2 3LR.

The telephone number of Revolution Education is: 01225 340563, and their web-site is at **www.rev-ed.co.uk**.

NEXT MONTH

In Part Six next month we examine sound level measurement, with example detection and display circuits using op.amps, l.e.d.s and bargraphs.

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 ★

TEACHING OLD DOGS

Dear EPE,

Many years ago, I started building radios – I built my first in 1966 using transistors(!) – and bought *Practical Wireless* every month, and *Practical Television* and *Practical Electronics* less often. A changing life forced me to drop my activities in things electrical and electronic until a few years ago when a copy of *EPE* on a newsagent's shelf caught my eye and re-kindled my interest. I now subscribe to *EPE* and have built several projects from the magazine.

I was very interested to read Raymond Haigh's recent series on radios and congratulate you on presenting the articles. I will definitely build some of the projects in the near future, although the test gear required to align the final project is a bit off-putting. Please can we have more of the like in future issues? How about a series of articles on constructing test gear?

However, I have always felt that using PICs was "cheating" and not real electronics. I have built the *Brainibot Buggy* (Feb '03) and can see the advantages of using PICs as it would take a lot of discrete electronic components to produce the same behaviour. Until, that is, I saw the *PIC LCF Meter* in the Feb '04 issue – you have finally convinced me that there is a place in the workshop for PICs and this is one project I simply must build! Maybe it *is* possible to teach an old dog new tricks!

Martin Cox, Halifax, via email

Thanks for your comments Martin – whilst there's still much room for "conventional" electronics, PICs have really revolutionised things – and my own life. We'll keep your suggestion in mind. Welcome back to the fold – we hope you stay "doggedly" interested!

BIT TWIDDLERS' SITE

Reader ***Colin Barnard*** *recently posted a message on our* Chat Zone *(access via* ***www.epemag.wimborne.co.uk****):*

For the algorithm gurus and bit twiddlers a site: **www.hackersdelight.org/index.htm**.

This site is an adjunct to the book *Hacker's Delight* by Dr Henry Warren (Addison-Wesley, 2003). The book has everything you need to know about obscure and not so obscure algorithms for bit and byte manipulation. A *must have* for the byte reorganisation fraternity.

Do not be put off by the book's title, it refers to hackers as in playing with bytes.

Thanks Colin, the site looks interesting and I'm pleased to pass your discovery on to other readers.

ZAPPER BLUES

Dear EPE,

I have read Andy Flind's *PIC Virus Zapper MkII* (Dec '03) and get the feeling that grasping two copper tubes in your hands has more effect than the pulsed electricals flying about. After all, thousands swear by copper rings and bracelets as instant cure-alls.

As to all the effects of the various forms of radiation flying about attacking our cells, it is common practice for radio amateurs to sit close to hundreds of watts of short wave energy that can cause an unconnected fluorescent lamp in the room to glow, yet suffer no ill effects. I have never seen any two-headed workers come out of the BBC transmitter sites.

The oddest thing of all is the astronauts that went to the moon and were supposed to have been dosed with high levels radiation from corona flares, and all seemed to have grown old the same way as the rest of us do. If all forms of radiation are so dangerous, how come the practice of subjecting patients to powerful magnetic resonance scans have increased enormously with no apparent ill effects? I had such a scan and the only side-effect was a feeling of claustrophobia lying inside the tiny tube inside the machine. If it had not been so noisy in there I would have dozed off.

With things medical, I am always amazed at the dark conspiracy theories that spring up. Anything unusual is met with a theory which takes on a life of its own as it gets passed around.

Most scare stories often have facts that seem to fit. A power linesman once told me that trees under the cables grow faster than the rest. Yes, they do but its because they are regularly cut back, and as the roots are not, the tops grow all the faster. Trees on the side of the routes do not grow inwards!

When you consider the fact that as a community we live inside a 50Hz grid of cables and survive the massive line timebase radiation from TV sets, then according to the gloom and doom mobile phone complainers, we should all be sitting there glowing blue!

G.S. Chatley, via email

On your first comment GS, I've never heard proof of the effectiveness of copper in this context – only hearsay, so I can't comment.

My mind remains open on the problems or otherwise regarding electric fields. I acknowledge, though, that as we all have electrons zipping around inside, the presence of other electrons around us is bound to cause some sort of interaction. As to how significant this may prove to be I wouldn't like to speculate. But as I've said before, Society as we know it would cease to exist if we abandoned the use of electric current.

Regarding your BBC reference – so you've never seen Zaphod Beeblebrox then? (!)

SPAM WASH

Dear EPE,

First thanks for a great mag. Regarding your Editorial, "Spam", in the December '03 issue – a very useful site for free download of a working version of an email spam wash facility is at **www.mailwasher.net/**. This is a fantastic program – it bounces the junk back to the origin and pretends you aren't there.

It also (if you chose to activate it) incorporates the "SpamCop" list of blacklisted sources and marks the incoming emails automatically. You can also blacklist any others you don't like and next time they appear, they will be so marked for automatic bounce.

Nick Bolton asks for a small donation for the full version – a worthy cause.

John (no surname offered), via email

Thanks John, I like that bounce idea! (But I suppose bouncing back just serves to clutter the web even more and slow down genuine traffic). It's amazing what our own filter has done to reduce spam since it was installed.

Increasingly now though, junk is beginning to come through which is captioned with seemingly innocuous words which have nothing to do with the actual content, and which frequently have no grammatical meaning. I would have thought that such emails are self defeating – it is obvious to the human eye that they are junk, and so are dealt with accordingly (sound of chain being pulled!).

METERING-OUT PRAISE

Dear EPE,

First of all, belated thanks for the digital multimeter sent to me about three years ago as a prize for my *Letter of the Month*! It has come in very handy when building my second *Damp-Stat Electronic Thermostat* (Dec '98).

Why two you may ask? The first *Damp-Stat* proved very successful indeed, so much so that when it came to selling our bungalow the Estate Agent could not believe how dry the shack was considering it was only single skinned.

The mistake I made was incorporating the *Damp-Stat* into the fabric of the shack and therefore had to leave it behind when we moved last year. Now that I have a shack again, smaller than before, another *Damp-Stat* has been built.

I can now move the rest of my gear into a "dry" shack, thus freeing up a room so the "Boss" can turn it into a second bedroom.

Awaiting future issues of your magazine – I have found it addressing more of my interests than those of your "rivals".

Nick Biggs,
via email

Andy Flind, designer of the Damp-Stat *will be delighted that you're so pleased with it Nick, and so are we, of course!*

I reckon you should resist Boss's intentions though, you deserve a workshop indoors as well as out!

BOARD ON RADIO

Dear EPE,

I have a problem, in as much as I am not able, using Adobe Acrobat, to print p.c.b. track layouts from the *EPE Online* editions at the correct size. As a result of this, I'm not able to make my own boards. I suppose I could "transpose" them, by drawing them out in the correct scale, but I suspect that approach is similar to using a 6-inch howitzer to kill a mouse!

My preferred method is to take a copy of the trackside of the p.c.b., then I stick it to the copper side of the copper-clad board, and drill the holes where the components go. The template is then removed, and I then draw in the tracks with a suitable etch resist pen.

I know that your "ready made" p.c.b.s are available, but being of Scots/Yorkshire "breeding", I try to keep my costs down. This is particularly true of Raymond Haigh's recent *Practical Radio Circuits* series, which has kept me enthralled this past six months.

I would be pleased if you would pass on my grateful thanks to Raymond, as his approach to radio designs in general, and the *Practical Radio Circuits* series in particular, has had me gathering up the components to start building one of his sets.

If I were to be asked to suggest a "follow on" article to compliment the apparently excellent double superhet design, it would be the provision of a digital frequency readout for this set.

I have been a subscriber to the On-line version of your magazine for a not inconsiderable time, and you are to be congratulated on producing a magazine which has kept me informed, educated and amused.

I have the ambition to make up some of the circuits described in the series even though I own a fair collection of radio receivers already. They range from a venerable Eddystone 840C through to a Realistic DX-390 from Tandy. Admittedly the Eddystone is a tad long in the tooth, but I intend changing its "diet" from "raw" a.c. to smoothed and stabilised d.c. and see what difference that makes.

Harry Wellborne, via email

I regret, Harry, that it's a problem for which I don't know a definitive answer. I suspect, though, that if I had to solve the problem for myself, I would print out the tracks image to paper at what ever size Acrobat allows. Then take the image to a photocopying shop and get them to enlarge/reduce it to the actual size required, which is stated alongside the layout images on our pages.

You could also ask readers via our Chat Zone at ***www.epemag.wimborne.co.uk*** *to see how anyone else has cracked it.*

Thanks for your kind comments about Raymond and for the suggestion.

As you are interested in old radios, I wonder if you take our sister publication Radio Bygones*? It contains articles on radio restoration and repair, history, circuit techniques, personalities, reminiscences and just plain nostalgia. Adverts for it appear in our pages from time to time, and you can also find out more via* ***www.radiobygones.co.uk****.*

STABILISING TANKS

Dear EPE,

I am hoping that through your magazine someone may be able to come up with a simple solution to help someone who is electronically challenged!

A few others and I are trying to simulate the stabilisation system for elevation/depression as seen on British Army main battle tanks. The reason for this is to incorporate the system into our 1/6 scale working models, as these are becoming more and more popular as a hobby. Our vehicles are totally scratch-built, while the remainder are kits from Russia.

The principle of the stabiliser in its simplest form can be seen when watching a tank move across country, the gun barrel appears to remain level. With our models being of a Chieftain, the long gun barrel is most apparent. The lack of the stabilising feature would greatly detract from the appearance of the model.

To date I have tried to use the following off-the-shelf systems: a heading-hold gyroscope as used in model helicopters, which seemed promising but was found it needs a very large force to make it react, whereas our tank is simply moving over undulating ground; a model submarine depth-keeping device, which has possibilities but the levelling system employs a ball completing a circuit between two sensors as the sub dives, this gives an all or nothing effect, whereas a proportional effect is desired.

I favoured a simple pendulum device that would react to the movement of the vehicle and send a signal to the radio control servo to move the required amount. This we found in a servo tester, which basically is a potentiometer with its own power source that can be used to test a servo independently of the radio control system. It is a simple and possibly effective idea, but the problems are that the potentiometer is not sensitive enough and the amount of movement is great. Also the pendulum weight and length was excessive due to the tightness of the potentiometer.

The system on the real vehicle works by a gyro under the gun sending signals to the elevation electric motor, thus keeping the gun level.

What I am hoping is that one of your readers could come up with either a source for a better potentiometer, or a better idea that could easily be built. If anyone does have a solution they can write to me:

R. Griffin, 22 Bristol Road,
Quedgeley, Gloucester GL2 4ND.

I hope that readers might be able to help you, let us know if they do. The only thought that comes to my mind is to wonder whether an inertia sensor such as the Analog Devices ADXL105, as used in the Pocket g-Meter *of July '00, might be worth looking into.*

If you have internet access, you could also try asking other readers via our Chat Zone at ***www.epemag.wimborne.co.uk****.*

RADIONICS

Dear EPE,

I wonder if your readers remember the Radionic Series of construction kits and think the idea was not exploited to the full? Buying blank component mounts it was easy to try out new circuits and modifications. It was also very easy to make voltage and current measurements etc. The Radionic idea was later taken up by Scientific Systems Ltd of Swindon for use by schools. Are they still in existence?

What I suggest is for someone to start a Radionics User Group to exploit the usefulness of the idea, working with the published circuits and bringing in new ones in a progressive manner. I wonder how many of your readers have customised their Radionic sets? For example, larger Perspex panels for more complex circuits, alternative methods of mounting components e.g. E-Z Hook's (USA) spring-loaded component and wire grippers on screw mounts, p.c.b. modules with 6BA screw mounting connectors to miniaturise commonly used sections, etc.

James Garvin,
Ballymena, N. Ireland

Doing a quick Google of the Web doesn't reveal anything relevant to this, James – I wonder if readers have any info?

SUNDIALS

Dear EPE,

Following on from "Wanted" and "Eddyfying" in *Readout* Dec '03 and Jan '04 – it reminds me of the various puns that we developed during my student days pretty much along the same lines and very funny indeed.

Continuing in the same light-hearted lines may I draw the attention of your readers to a very useful sundial – for use at night! Yes, it is quite true, such a "sundial" was suggested by a Mr F. O'Brian and, so the story goes, mass production was started in Hong Kong. This must be a fact because I read about it in a book published by *Readers Digest* entitled *Extraordinary Inventions* and printed in 1983.

Do you think one could be developed for PIC use?!

Peter Mitchell,
via email

Ah, Peter, the amusement of bad puns (and the best puns are always described as "bad" . . .). I've loved them since childhood (which some might say I'm still in – well second one anyway!)

Night-time sundials? What a splendid idea! It must have been in their April issue though! But, I wonder . . . where's my thinking cap?

And out of curiosity I asked Google for info on such contraptions. One link implied they had some "backlit for convenient night-time use". (But the site timed-out on me when trying to access it, so I don't know any more!)

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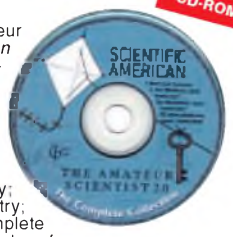

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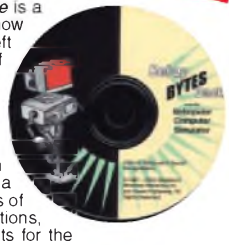

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DIGITAL ELECTRONICS – A PRACTICAL APPROACH
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FREE SOFTWARE

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer-aided design including the FREE software.
There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.
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OSCILLOSCOPES – FIFTH EDITION
Ian Hickman

Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.
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The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscilloscopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.
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Clive "Max" Maxfield and Kuhoo Goyal Edson

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Robin Pain

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Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.
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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Steve Money

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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.
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Theory and Reference

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Ian Sinclair
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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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Project Building

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R. A. Penfold
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The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

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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.

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R. A. Penfold
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None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

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R. A. Penfold
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There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

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