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MAY 2003

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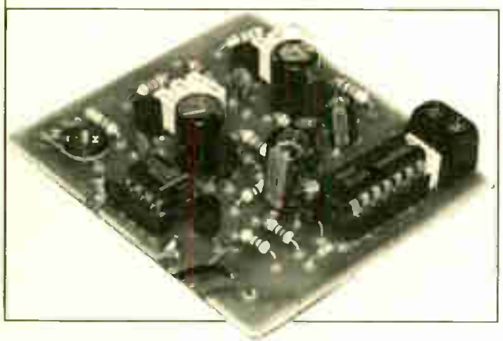

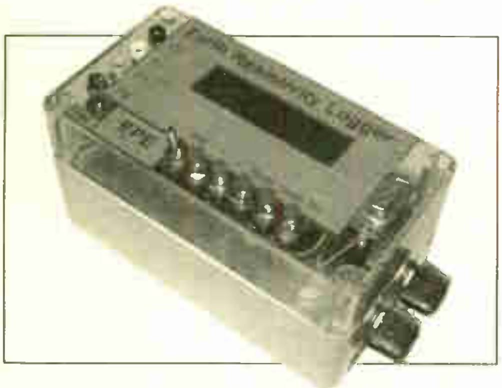

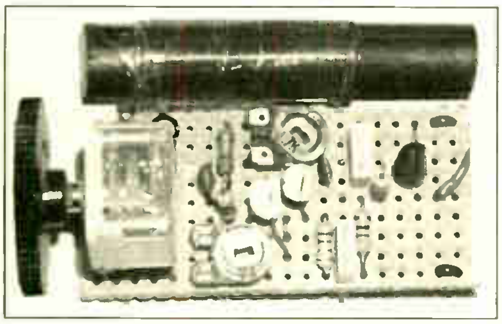

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Our June 2003 issue will be published on Thursday, 8 May 2003. See page 307 for details

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Converts your colour monitor into a QUALITY COLOUR TV!!

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

TELEBOX ST for composite video input type monitors	£36.95
TELEBOX STL as ST but fitted with integral speaker	£39.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification. *For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

NEW State of the art PAL (UK spec) **UHF TV tuner module** with **composite** 1V pp video & **NICAM** hi fi stereo sound outputs. **Micro electronics** all on one small PCB only 73 x 160 x 52 mm enable full tuning control via a **simple 3 wire link** to an IBM pc type computer. Supplied complete with **simple working program** and documentation. Requires +12V & + 5V DC to operate.
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2½" to 3½" conversion kit for Pc's, complete with connectors	£15.95
3½" **COMPAQ** 313706-B21 (IBM) 9 gb ULT/SCSI3 *New*	£199.00
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CGA, EGA, VGA, SVGA

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

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External cables for other types of computers available - CALL

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

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£59.00	**£69.00**	**£79.00**

Supplied in good used condition. Shipping code (D)

VIDEO MONITORS

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with both RGB and standard composite 15.625 Khz video inputs via SCART socket and separate phono jacks. Integral audio power amp and speaker for all audio visual uses. Will connect direct to Amiga and Atari BBC computers. Ideal for all video monitoring / security applications with direct connection to most colour cameras. High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed
Dimensions: W14" x H12¾" x 15½" D. **Only £99.00** (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with **standard composite 15.625 Khz video** input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13½" D. 240 V AC mains powered. **Only £79.00** (D)

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Tiny shoebox sized industrial 40 Mhz 386 PC system measuring only (mm) 266 w X 88 h X 272 d. Ideal for dedicated control applications running DOS, Linux or even Windows ! Steel case contains 85 to 265 V AC 50 / 60 hz 70 Watt PSU, a 3 slot ISA passive backplane and a Rocky 318 (PC104) standard, single board computer with 8 MByte NON VOLATILE solid state 'Disk On Chip' RAMDISK. System comprises: Rocky 318 (PC104) SBC ISA card with 40MHz ALi 386SX CPU, 72 pin SIMM slot with 16 Mbyte SIMM, AMI BIOS, battery backed up real time clock. 2 x 9 pin D 16550 serial ports. EPP/ECP printer port, mini DIN keyboard connector, floppy port, IDE port for hard drives up to 528 MByte capacity, watchdog timer and PC/104 bus socket. The 8 MByte solid state 'disk on a chip' has its own BIOS, and can be fdisked, formatted & booted. Supplied BRAND NEW fully tested and guaranteed. For full data see featured item on website. Order as QG36.
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Order as BC44	**Order as DT20**	**Order as RV36**
External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)	External dimensions mm=2019H x 635D x 603 W. (79.5" H x 25" D x 23¾" W)	External dimensions mm=2019H x 635D x 603 W. (88" H x 25" D x 23¾" W)
Only **£245**	Only **£345**	Only **£410**

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COLOUR CCD CAMERAS

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

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

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

SOFTWARE SPECIALS

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

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Windows 95 CDROM Only - No Licence -	£19.95
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Order as TD91 ***ONLY £24.95*** *(A)*

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TEST EQUIPMENT & SPECIAL INTEREST ITEMS

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

MITSUBISHI FA3445ETKL 14" Ind. spec SVGA monitors	£245
FARNELL 0-60V DC @ 50 Amps, bench Power Supplies	£995
FARNELL AP3080 0-30V DC @ 80 Amps, bench Suppy	£1850
KINGSHILL CZ403/1 0-50V @ DC 200 Amps - NEW	£3950
1kW to 400 kW - 400 Hz 3 phase power sources - ex stock	£POA
IBM 8230 Type 1, Token ring base unit driver	£760
Wayne Kerr RA200 Audio frequency response analyser	£2500
INFODEC 1U, 24 port, RJ45 network patchpanels. #TH93	£49
3COM 16670 12 Port Ethernet hub - RJ45 connectors #LD97	£69
3COM 16671 24 Port Ethernet hub - RJ45 connectors	£89
3COM 16700 8 Port Ethernet hub - RJ45 connectors NEW	£39
IBM 53F5501 Token Ring ICS 20 port lobe modules	£POA
IBM MAU Token ring distribution panel 8228-23-5050N	£45
AIM 501 Low distortion Oscillator 9Hz to 330Khz, IEEE I/O	£550
ALLGON 8360.11805-1880 MHz hybrid power combiners	£250
Trend DSA 274 Data Analyser with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£4500
Marconi 2022C 10KHz-1GHz RF signal generator	£1550
HP1650B Logic Analyser	£3750
HP3781A Pattern generator & **HP3782A** Error Detector	£POA
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts	£1800
HP6264 Rack mount variable 0-20V @ 20A metered PSU	£475
HP54121A DC to 22 GHz four channel test set	£POA
HP8130A opt 020 300 MHz pulse generator, GPIB etc	£7900
HP A1, A0 8 pen HPGL high speed drum plotters - from	£550
HP DRAFTMASTER 1 8 pen high speed plotter	£750
EG+G Brookdeal 95035C Precision lock in amp	£1800
Keithley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel voice recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS - New batteries	£4500
Emerson AP130 2.5KVA industrial spec.UPS	£1499
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£945
HP6030A 0-200V DC @ 17 Amps bench power supply	£1950
Intel SBC 486/125C08 Enhanced Multibus (MSA) New	£1150
Nikon HFX-11 (Ephiphot) exposure control unit	£1450
PHILIPS PM5518 pro. TV signal generator	£1250
Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. **New**	£550
Fujitsu M3041R 600 LPM high speed band printer	£1950
Fujitsu M3041D 600 LPM printer with network interface	£1250
Siemens K4400 64Kb to 140Mb demux analyser	£2950
Perkin Elmer 299B Infrared spectrophotometer	£500
Perkin Elmer 597 Infrared spectrophotometer	£3500
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3250
LightBand 60 output high spec 2u rack mount Video VDA's	£495
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
B&K 2633 Microphone pre amp	£300
Taylor Hobson Tallysurf amplifier / recorder	£750
ADC SS200 Carbon dioxide gas detector / monitor	£1450
BBC AM20/3 PPM Meter (Ernest Turner) + drive electronics	£75
ANRITSU 9654A Optical DC-2.5G/b waveform monitor	£5650
ANRITSU ML93A optical power meter	£990
ANRITSU Fibre optic characteristic test set	£POA
R&S FTDZ Dual sound unit	£650
R&S SBUF-E1 Vision modulator	£775
WILTRON 6630B 12.4 / 20GHz RF sweep generator	£5750
TEK 2445 150 MHz 4 trace oscilloscope	£1250
TEK 2465 300 MHz 300 MHz oscilloscope rack mount	£1955
TEK TDS380 400Mhz digital realtime + disk drive, FFT etc	£2900
TEK TDS524A 500Mhz digital realtime + colour display etc	£5100
HP3585A Opt 907 20Hz to 40 Mhz spectrum analyser	£3950
PHILIPS PW1730/10 60KV XRAY generator & accessories	£POA
VARIACS - Large range from stock - call or see our website	
CLAUDE LYONS 12A 240V single phase auto. volt. regs	£325

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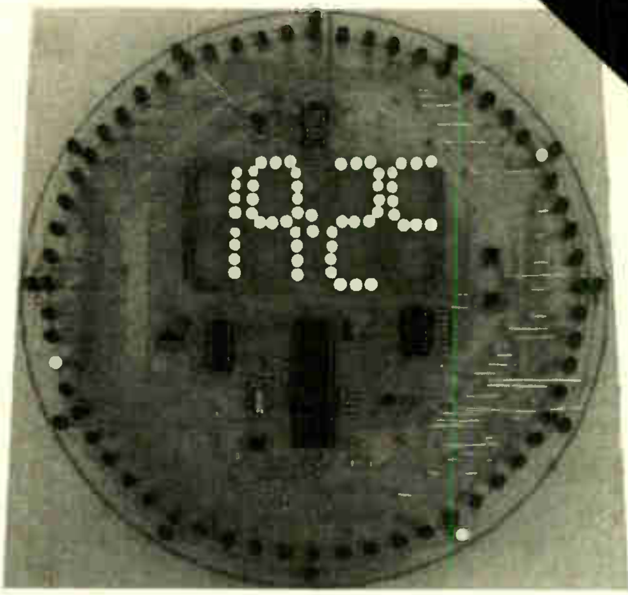
NEXT MONTH

FREE SUPPLEMENT PIC TUTORIAL V2 Part 3

PICRONOS L.E.D. WALL CLOCK



Inspired by a reader whose giant l.e.d. wall clock had ticked its last tock and could not be revived, this design uses a mixture of ancient and modern techniques, old in the form of l.e.d.s for the display rather than an l.c.d., and modern in the form of a PIC microcontroller (inevitably!). It has the following characteristics:

- *Crystal controlled*
- *Circular display having diameter of 250mm (9·3in.)*
- *Inner ring of 60 l.e.d.s displaying both seconds and minutes*
- *Outer ring of 12 l.e.d.s displaying hours in conventional (analogue) 12-hour format*
- *Inner zone of 100 l.e.d.s in 4-digit 7-segment numerical format, cyclically displaying hours (24-hour format) and minutes, months and days of month, and temperature in degrees Celsius*
- *Powered at 9V to 12V d.c. via a mains supply adaptor, with battery back-up*
- *Adjustable brilliance of the l.e.d. numerals to suit personal taste*

RADIO CIRCUITS

Intended to dispel the mysteries of radio, this short series of articles by Raymond Haigh features a variety of circuits for the set builder and experimenter.

Towards the end of the 19th century, sending a radio signal a few hundred yards was considered a major achievement. At the close of the 20th, man was communicating with space probes at the outermost edge of the solar system. No other area of science and technology has affected the lives of people more completely.

This series will view the technology in a historical perspective and try to dispel its mysteries. The main purpose, however, is to present a variety of practical circuits for set builders and experimenters. You will be able to build a wide range of receivers, everything from a crystal set to a superhet.

FIDO PEDOMETER

Fido's designer enjoys trekking in remote regions where estimating the distance walked can be difficult and retracing steps frustrating! He developed Fido to help solve this problem without the expense of buying a GPS navigational aid. Fido can record the distance traversed by a walker or runner and calculates average speed – a useful addition when planning how long it will take to get back to comfort!

A PIC16F84A microcontroller is employed and the unit can be set to work in miles or kilometres. Clever software allows Fido to be taught to stay at heel – to recognise the length of your stride and keep track of your progress.

NO ONE DOES IT BETTER

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JUNE 2003 ISSUE ON SALE THURSDAY, MAY 8

QUASAR ELECTRONICS Number 1 For Kits

www.QuasarElectronics.com

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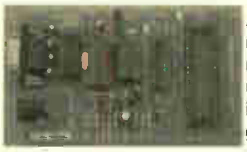
Enhanced 'PICALL' ISP PIC Programmer

Kit will program virtually ALL 8 to 40 pin* serial and parallel programmed PIC micro-controllers. Connects to PC parallel port. Supplied with fully functional pre-registered PICALL DOS and WINDOWS AVR software packages, all components and high quality DSPTH board. Also programs certain ATMEL AVR, SCENIX SX and EEPOM 24C devices. New devices can be added to the software as they are released. Blank chip auto detect feature for super-fast bulk programming. Hardware now supports ISP programming.
*A 40 pin wide ZIF socket is required to program 0·3in. devices (Order Code AZIF40 @ £15.00).

3144KT	Enhanced 'PICALL' ISP PIC Programmer	£59.95
AS3144	Assembled Enhanced 'PICALL' ISP PIC Programmer	£64.95
AS3144ZIF	Assembled Enhanced 'PICALL' ISP PIC Programmer c/w ZIF socket	£79.95

ATMEL AVR Programmer

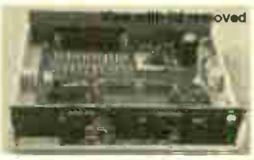


Powerful programmer for Atmel AT90Sxxxx (AVR) micro controller family. All fuse and lock bits are programmable. Connects to serial port. Can be used with ANY computer and operating system. Two LEDs to indicate programming status. Supports 20-pin DIP AT90S1200 & AT90S2313 and 40-pin DIP AT90S4414 & AT90S8515 devices. NO special software required – uses any terminal emulator program (built into Windows). The programmer is supported by BASCOM-AVR Basic Compiler software (see website for details).

3122KT	ATMEL AVR Programmer	£24.95
AS3122	Assembled 3122	£34.95

Atmel 89Cx051 and 89xxx programmers also available.

PC Data Acquisition & Control Unit



With this kit you can use a PC parallel port as a real world interface. Unit can be connected to a mixture of analogue and digital inputs from pressure, temperature, movement, sound, light intensity, weight sensors, etc. (not supplied) to sensing switch and relay states. It can then process the input data and use the information to control up to 11 physical devices such as motors, sirens, other relays, servo motors & two-stepper motors.

FEATURES:
- 8 Digital Outputs: Open collector, 500mA, 33V max.
- 16 Digital Inputs: 20V max. Protection 1K in series, 5·1V Zener to ground.
- 11 Analogue Inputs: 0-5V, 10 bit (5mV/step.)
- 1 Analogue Output: 0-2·5V or 0-10V. 8 bit (20mV/step.)

All components provided including a plastic case (140mm x 110mm x 35mm) with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo) with screen printed front & rear panels supplied. Software utilities & programming examples supplied.

3093KT	PC Data Acquisition & Control Unit	£99.95
AS3093	Assembled 3093	£124.95

See opposite page for ordering information on these kits

ABC Mini 'Hotchip' Board

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

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

Advanced 32-bit Schematic Capture and Simulation Visual Design Studio

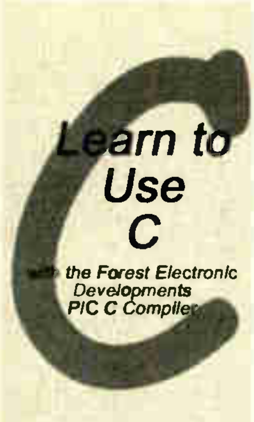
Serial Port Isolated I/O Controller

Kit provides eight relay outputs capable of switching 4 amps at mains voltages and four optically isolated digital inputs. Can be used in a variety of control and sensing applications including load switching, external switch input sensing, contact closure and external voltage sensing. Programmed via a computer serial port, it is compatible with ANY computer & operating system. After programming, PC can be disconnected. Serial cable can be up to 35m long, allowing 'remote' control. User can easily write batch file programs to control the kit using simple text commands. NO special software required – uses any terminal emulator program (built into Windows). All components provided including a plastic case with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo).

3108KT	Serial Port Isolated I/O Controller Kit	£54.95
AS3108	Assembled Serial Port Isolated I/O Controller	£64.95

Learn to Program in C with FED !

Free book provides complete introduction to C programming for the PIC



Our free book will take you through the process of learning C from variables through constants to pointers and then structures and unions. Most of the examples are standalone and are as small as possible to enable the purpose and effect to be easily understood. Nearly all can be run on our PIC C Compiler simulator so you can experiment quickly - but code can also be run on practically any C Compiler.

- Start to use C for the PIC – standard portable code with a standard syntax designed to be "close" to the processor for efficiency in size and speed
- Suitable for beginners or BASIC programmers
- Covers Comments and Statements,Variables and Constants,Expressions,Functions,Program Control,Pointers,Structures & Unions, and the Pre-processor.
- The final example is a comprehensive real time programming application showing the simultaneous use of LCD, keypads, timers, clocks and ports
- Examples will run on our development board
- Soft copy of examples provided - ready to run on the PIC C Compiler
- Examples will run on other C Compilers

Download Free of Charge – www.fored.co.uk/ccomp.htm (follow the link "Learn C with FED")

FED – PIC C Compiler products

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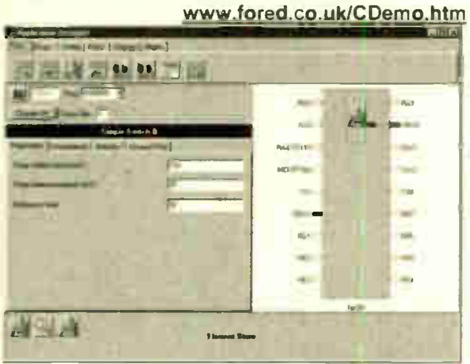

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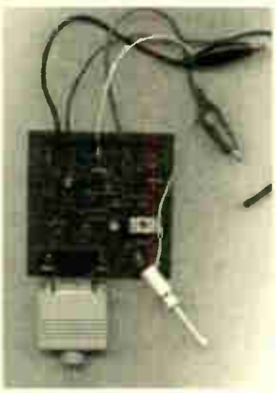

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TIME OUT

Electronics can do all manner of things, quite often some it should not. During a recent overnight stay in a Travel Inn I experienced an unusual fault with the electronics. The TV set in the room had a built-in l.e.d. digital clock with an alarm facility. I set the alarm for 7.30a.m. and went to bed. As is often the case when sleeping in hotels, I woke up during the night at 4.45a.m. as shown by the clock. On waking again, later, I noted the clock still said 4.45, since it was getting light outside I checked my watch to discover it was actually 6.30. Oh well, the clock had somehow "frozen" at 4.45. However, I was surprised when the alarm sounded at 7.30, even though the display still said 4.45 and, to add to my amazement, when I cancelled the alarm the display returned to the correct time.

Now maybe I'm not being too bright – I certainly was not at 4.45a.m. – but then many readers will have experienced unusual phenomena when working with various circuits.

Cost Engineering

I remember many years ago when working in the RGD/KB development labs in Kent that one engineer was employed to cut the cost of various TV designs before they went into production. I was fascinated to see how many components he could strip out of a new TV circuit design and still get the set to work. Of course, some of the mods resulted in a degradation in performance that was unacceptable, but many seemed to make no difference.

The company also spent a great deal of time testing all sorts of components to see which ones would be the most cost effective in their products. For instance, would it be worth paying for a more expensive potentiometer if a cheaper one would last for a few years – say 10,000 operations – without getting "noisy" or breaking down. Remote control had not made much impact in those days so the on/off volume control would be used quite a bit. Cheaper pots would obviously suffice for lesser used controls like brightness and contrast.

With the massive increase in component reliability and reduction in cost over the years, I guess this type of cost saving engineering is not quite so important today. After all, it costs the same to make a chip containing 10,000 components as it does one with only 1,000 components, once the initial design has been finalised.

Mike Kenward

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Constructional Project

SUPER MOTION SENSOR

THOMAS SCARBOROUGH

Responds to minute fluctuations in light level. Will detect a single finger moving at 5 metres or a person crossing a path at 20 metres distance.

THE most basic problem with regard to standard light sensors is that these frequently trigger at a specific light level, while what happens in real life is that ambient light levels fluctuate all the time. Therefore a standard light sensor will function correctly only in a controlled environment, or under highly predictable conditions.

The Super Motion Sensor described here, on the other hand, auto-adjusts over the range of about 50 lux to 60,000 lux (that is, a 40W incandescent light-bulb in a $10m^2$ room to direct sunlight). It really "shines", dare we say, in the mid-range of about 100 lux to 10,000 lux (that is, a modestly lit room to bright shade).

It is what is called a "passive" system, in that it does not generate the light which it detects, nor does it use any additional circuitry for this purpose. At the same time, it may be used in the same way as both "active" and "passive" systems.

BRIGHT IDEAS

In daylight, the Super Motion Sensor will typically detect a single finger moving at a distance of 5 metres – *without* the use of any lenses. It will detect a person crossing a path at 20 metres' distance – without lenses.

Under a.c. lighting, it will typically detect a person walking in front of an ordinary light source (e.g. a 60W incandescent light-bulb) at 20 metres – also without the use of any lenses. Note, however, that in this case the sensor is pointed *directly* at the light source, and its range as a "passive" system under a.c. lighting will typically be only eight metres or so.

Generally speaking, a single lens will double these distances, while the use of two lenses, if an "active" system is used, will multiply the basic range by six or seven. With an inexpensive laser diode, a range of hundreds of metres may be achieved.

Since the circuit responds to *fluctuations* in light level, rather than the crossing of a specific light threshold, it is much more flexible than a typical active system. Also, it is not limited to crossing a light threshold in one direction only, e.g. from brighter to dimmer, but may be used in situations of decreasing *and* increasing light.

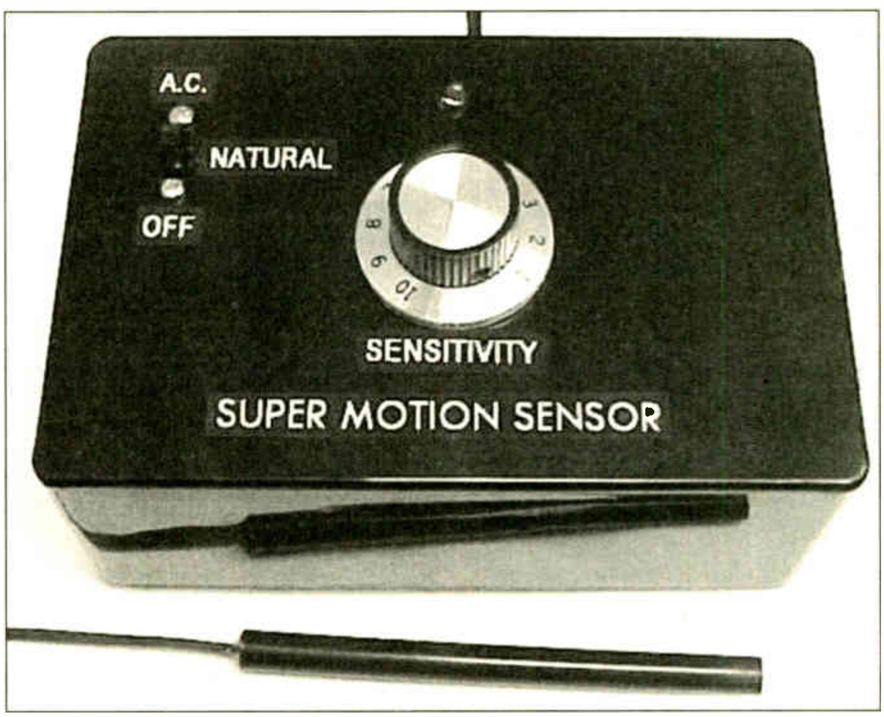
ENLIGHTENING IDEAS

The Super Motion Sensor has several possible applications and no doubt readers will have their own unique ideas, including possibly some of the following:

It may be used as a "light fence" (or broken beam alarm). However, in contrast to the standard light fence, it requires virtually no set-up. It may simply be placed within the line-of-sight of almost any light source, including vague ambient light, and switched on. It may also be used where a beam is "*un*-broken" – for example, where a computer monitor is blocking a beam, and the monitor is removed.

Since it is not limited to the crossing of a specific light threshold, it will respond to a wide range of variations in light and shadow – for instance, a car entering a driveway, a person moving in a room, or wind rustling the leaves of a tree.

The author's original interest came from a three-wheel vehicle which he drove. This vehicle had an open cab, which seemed to invite all-comers to climb into it and play with the controls. In one case, a young boy let off the hand-brake and went careering into a tree! How could the vehicle sense, from a good distance, whether anyone was approaching?



With two light sensors mounted in the roof framework of the cab, one at each side of the vehicle, and "looking" down onto the pavement through plastic tubes, these detected feet moving over a wide range of lighting conditions. The circuit in turn triggered a spoken message – which, alas, seemed to attract yet more curiosity!

In a similar way, the Motion Sensor may be placed in luggage that needs to be protected in a public place, with a light sensor "looking" upwards over a suitable angle. If anyone should reach for the luggage, or stoop over it, or move it, an alarm would be triggered. Moreover, it would continue to trigger as long as the luggage was in motion.

Lastly, it may be used to detect *direction* of movement. If one refers to the author's *Big-Ears Buggy* project (*EPE*, Aug. '02), the two front-end preamplifier stages in that circuit may be replaced with two Super Motion Sensors, with the outputs of the "Sensors" being taken, in each case, from IC3 pin 6 to resistors R15 and R16 of the *Big-Ears Buggy*. In this case – as an example – a person entering a building would be detected, but not a person exiting.

the values of the capacitors were increased, this would further extend the time periods involved. A fire alarm system typically triggers when it detects a rise of 22°C per minute, while the Super Motion Sensor will potentially detect a change of just a fraction of 1°C. (A terrific Temperature Tracker, perhaps?).

When the charge on the capacitor (the potential) at the comparator's inverting (–) input rises higher than that at the non-inverting (+) input, or when the potential at the non-inverting input falls below that of the inverting input, the comparator's output goes "low", thereby triggering a monostable timer and a relay.

As with any detection circuit, there are certain physical variations which the circuit should detect, and others which it should exclude. Perhaps the most important exclusion in this case is natural variations in ambient light – such as sunrise, sunset, or the shadows cast by clouds. This the Motion Sensor achieves by comparing variations in light level at a speed that is *almost* too fast for it to detect slower, natural variations. Unless the circuit is set very sensitively, these are excluded.

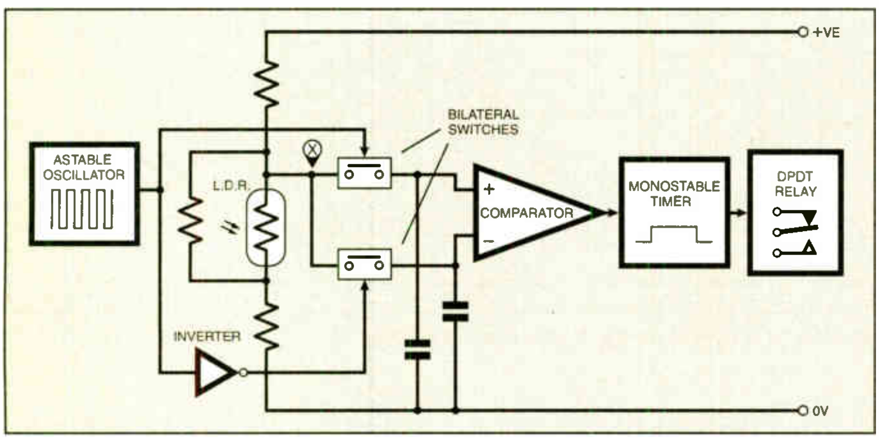


Fig.1. Simplified block schematic diagram of the Super Motion Sensor.

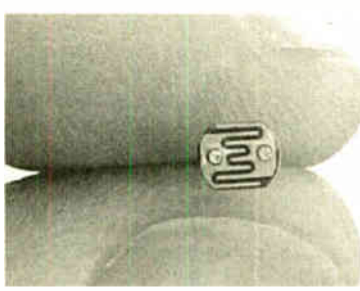
HOW IT WORKS

Block diagram Fig.1 is a simplified representation of the circuit, and gives a good overview as to how the Super Motion Sensor works.

A light dependent resistor (l.d.r.) is so wired in conjunction with the three resistors shown that, between darkness and full sunlight, it offers a potential at point *X* of between roughly one-quarter and three-quarters of the supply voltage. This potential is presented simultaneously to the inputs of two bilateral switches.

An astable oscillator, together with an inverter, switches the two bilateral switches alternately, typically at a few Hertz, so that the two capacitors are alternately charged. Since the resistance of the bilateral switches in the "off" state is very high, and the input impedances of the op.amp comparator very high, the charge on the capacitors is "trapped" in the spaces between the bilateral switches and the comparator. This will ordinarily vary very little during switching. These are referred to as sample-and-hold circuits.

So little, in fact, does the charge on the two capacitors vary over time that the astable oscillator could easily be slowed, and the l.d.r. replaced with a thermistor. If



Miniature light dependent resistor (l.d.r.), about twice size, clasped between thumb and finger.

While still on the *concept* of the Super Motion Sensor, a difficulty arises when a.c. lighting is used, as it does with most light sensor circuits. This is because a.c. lighting fluctuates at a rate of 50 cycles per second (60 in the USA), and while the eye does not normally see this, due to persistence of vision, the fluctuation or flicker of a.c. lighting can be sufficient to trigger the circuit. The more the light flickers (e.g. fluorescent lighting), the greater the difficulty this presents.

DANGER LEVEL

A simple solution is given later with the circuit shown in Fig.2 – but consider for a moment a more sophisticated alternative (this was *not* incorporated in the present design, since it would have made it an "experienced constructors only" project). **The following should under no circumstances be tried unless the constructor is experienced with circuits that are connected to the mains. Mains electricity can kill you.**

Consider that the two bilateral switches receive their timing from the a.c. mains rather than the astable oscillator incorporated in the circuit. This would cause the circuit to switch in sympathy with fluctuations in a.c. lighting, thus making it virtually completely immune to 50Hz flicker (60Hz in the USA). Sensitivity under a.c. lighting would be significantly increased, and the need for any readjustment when moving the circuit from natural lighting to a.c. would be obviated.

The author tested this successfully by connecting a low voltage pulse derived from the a.c. mains supply to the control pins of the bilateral switches. In this case, the link wire adjacent to pin A (Fig.4) is removed from the printed circuit board (p.c.b.), and the peak voltage pulse is adjusted to just below 12V.

This last concept opens the possibility of a Defective Lighting Detector. If a.c. lighting should waver or become defective, the Super Motion Sensor would immediately pick this up. The author's prototype picked up several "brownouts" (voltage/lighting drops) during testing.

ANALOGUE vs DIGITAL

Originally, the author took a *digital* approach, translating light level to binary numbers, then making a binary comparison over time. This was done by converting the resistance of the l.d.r. to frequency, and the frequency to binary numbers. If a series of binary comparisons showed themselves to be unequal, then a motion was detected.

This approach, however, ran into an unthought-of hitch. In order to obtain two binary numbers which were sufficiently accurate to compare reliably, at high sensitivity (thus obtaining an equal result if the light level remained constant), a high degree of timing accuracy was required. While this would not have been too difficult to achieve, it would have considerably complicated the circuit.

Another problem presented itself with this approach, in that if a relatively constant light level caused the least significant binary digit to switch between a 0 and a 1, or to vacillate between the two, this gave the illusion of detection having taken place. A solution which was tried successfully was to make a *series* of binary comparisons instead of only one.

The present analogue approach, besides avoiding these difficulties, obviates the need for three or four digital i.c.s. or a microcontroller at the core of the circuit.

CIRCUIT DETAILS

We are now in a position, we might say, to "shed more light" on the full Super Motion Sensor circuit – see Fig.2.

One half of a 7556 CMOS timer i.c. (IC1a) is wired as an astable oscillator, and, with the help of IC2c, configured as an inverter, this is used to switch bilateral switches IC2a and IC2b alternately. This circuit configuration is seldom seen, due

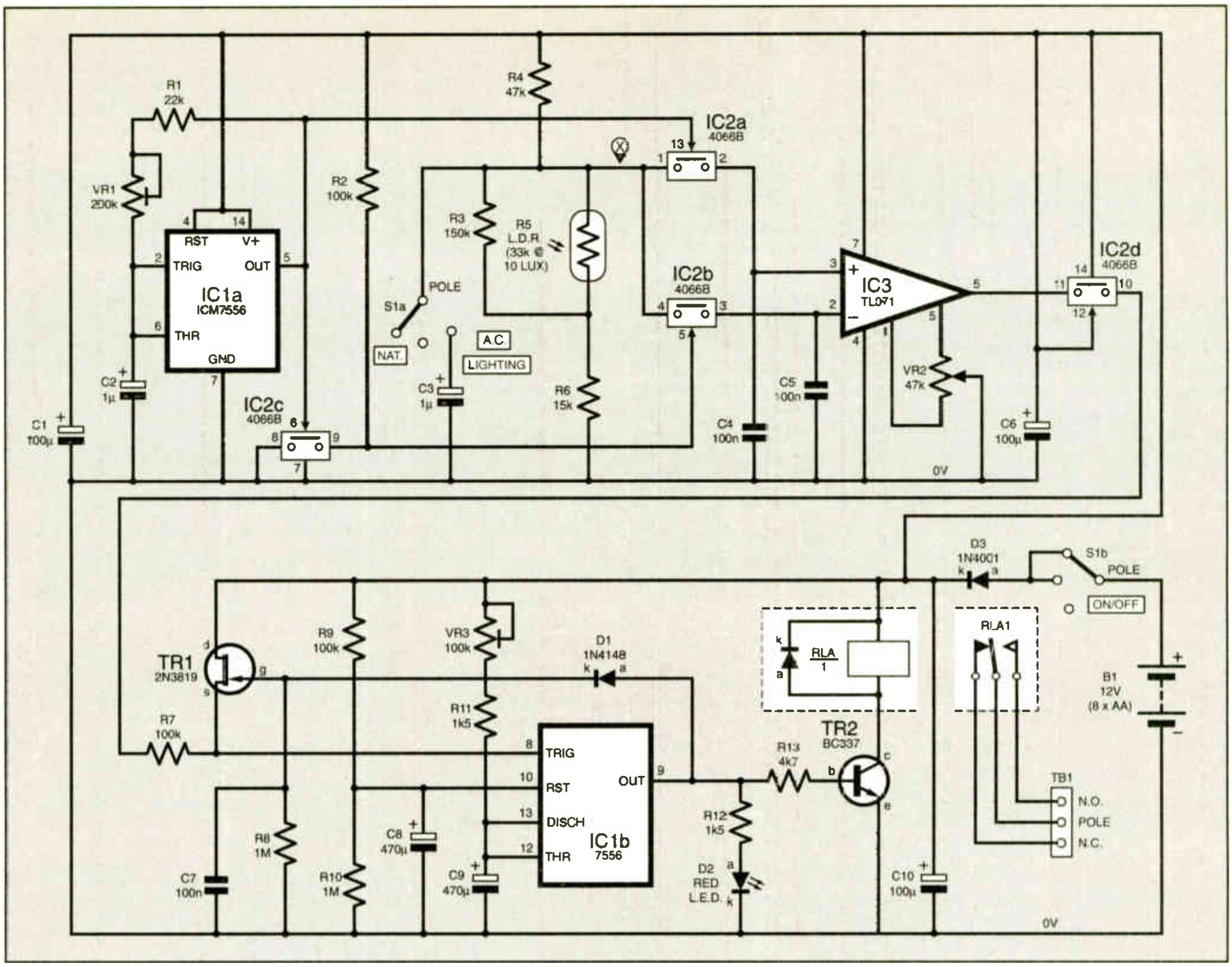


Fig.2. Complete circuit diagram for the Super Motion Sensor.

probably to its inability to be more than lightly loaded without disturbing the timing. However, in this case IC2's control pins have a very high input resistance, and this configuration represents an easy means of obtaining the required 1:1 mark-space ratio which the "orthodox" configuration does not so simply provide.

Potential divider network R3 to R6, including the l.d.r., provides the required potential at point *X* to charge capacitors C4 and C5 through the bilateral switches. The values of R3, R4 and R6 are chosen so that, regardless of the light sensor used, the potential at point *X* stays between 24% and 78% of supply voltage. This means that a wide variety of sensors may be used in place of the specified l.d.r., including phototransistors, photodiodes, and infrared and ultra-violet devices.

INTERCHANGE

Although l.d.r.s have slower response times than other devices, an l.d.r. was chosen here because it may easily be interchanged with similar devices of the same family. This is not always the case with phototransistors and photodiodes, which have some awkward relatives. Note that if a photodiode is used, the cathode (k) would normally be wired to the junction of R3 and R4. An l.d.r. is completely non-polar.

Consider now that if the light level remains constant over time, there will be a similar charge on capacitors C4 and C5. However, if the light level *changes* over time, one of the two capacitors will retain a higher or lower charge than the other. This triggers op.amp comparator IC3 (that is, it goes "low" at its output).

Strictly speaking, the comparator triggers only if the voltage at the inverting input rises above that at the non-inverting input – i.e. if the voltage at the inverting input rises, or if the voltage at the non-inverting input falls. However, bear in mind that every increase in light level is followed by an attendant decrease and vice versa, so has little consequence in practice.

The two bilateral switches, IC2a and IC2b, are switched between about 3Hz and 30Hz, depending on the setting of preset VR1. Faster switching will mean smaller differences in charge between C4 and C5 (thus lesser sensitivity), but will react more readily to faster fluctuations in light level. Slower switching will mean the opposite, and would make the circuit a little more sensitive to natural variations such as moving clouds. Preset VR1's mid-position should suit in most cases.

ROUGH AND READY

With regard to a.c. lighting, the present circuit offers a rough and ready solution in the form of smoothing capacitor C3 at point *X*, which smooths out the worst of a.c. flicker. A necessary result of this, unfortunately, is some loss of sensitivity, although it does present a reasonably good solution. For particularly bad lighting situations, the value of C3 may be increased.

Op.amp comparator IC3 was chosen particularly for its high input impedance, which is necessary so that capacitors C4 and C5 should retain their charge. It was also chosen specifically for its provision of an offset-null, which is used to balance the differential input stage so that the inverting input is normally "higher" than the non-inverting input.

Failing this, the potentials at the two inputs would be "too close for comfort", and might or might not trigger IC3. A method that is frequently used to "balance" such circuits is a potential divider at the inverting input, but for a number of reasons, this is less satisfactory.

SENSE OF AMBIENCE

Bilateral switch IC2d represents another circuit option. As it stands, IC2d has its control pin (12) wired to the positive rail, so that the corresponding bilateral switch will always conduct.

However, if IC2d pin 12 were taken to a potential divider incorporating a second l.d.r., as shown in Fig.3, IC2d could be used to disable the Motion Sensor as ambient light levels either increased or decreased.

As shown, the circuit is disabled with increasing light level. If R1 and VR1 were swapped around with the l.d.r., the circuit would be disabled with *decreasing* light level.

EXTREMELY SENSITIVE

The present circuit is one of extreme sensitivity, and the first stages especially require "quietness" to function properly. Therefore, no l.e.d. is used to display the switching action of IC1a (although this might be helpful). Also, no l.e.d. is used to show the state of the output of IC3. A relatively small value is chosen for timing capacitor C2, and supply decoupling is employed throughout (C1, C6, and C10).

A special problem presents itself, however, in the form of relay RLA. This carries a relatively heavy current when switched by monostable IC1b, and would ordinarily upset the circuit and reduce its sensitivity.

This problem is overcome by "blanking" the relay's action through transistor TR1, which disables the trigger input (pin 8) of timer IC1b, allowing a short period (a fraction of a second) for the circuit to settle

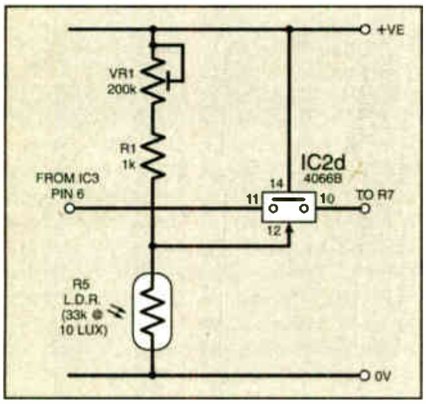


Fig.3. Circuit addition, using a second l.d.r., to achieve daytime/night-time switching.

after relay RLA has disengaged. At the same time, l.e.d. D2 is included in this blanking, so that it, too, may not upset the normal operation of the circuit.

The blanking action works as follows: When the output of IC1b goes "high", capacitor C7 is charged, and TR1's gate is held "high". This means that it conducts, and the potential at the junction of TR1 source and R7 is also high.

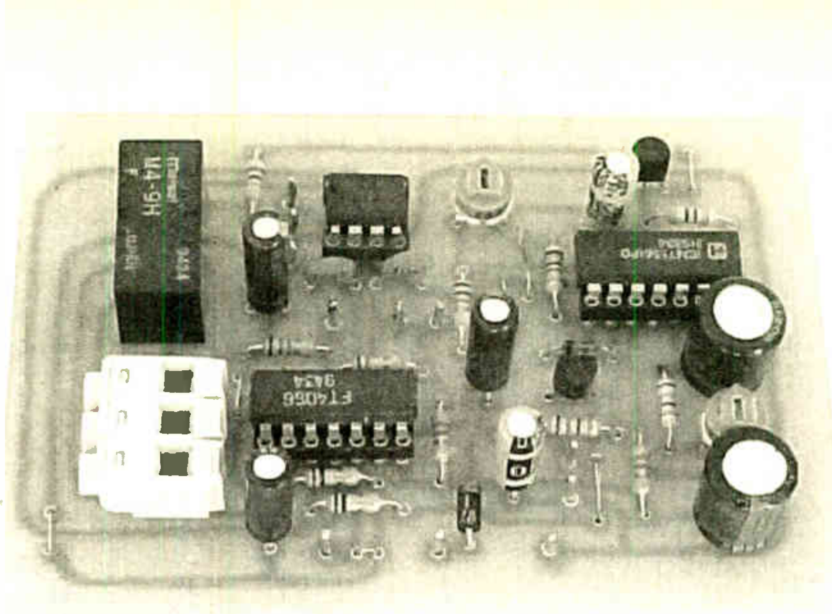
Therefore, with trigger pin 8 being held "high", this is disabled for a moment, giving the circuit time to settle after relay RLA has disengaged. Capacitor C7 discharges mainly through resistor R8.

Current consumption of the circuit is less than 10mA on standby, so that battery operation (e.g. 8 × AA batteries) is feasible.

CONSTRUCTION

The Super Motion Sensor is built on a printed circuit board (p.c.b.), measuring 65mm × 95mm. The topside component layout and full-size underside copper foil master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 391.

Begin construction by soldering in position the three dual-in-line (d.i.l.) sockets and the board lead-off solder pins. This should be followed by the resistors, capacitors and the preset potentiometers VR1 and VR3. Next, the diodes D1, D3 and the two transistors should be inserted on the p.c.b., paying particular care to their polarity.



Layout of components on the completed circuit board. The relay can be seen top left.

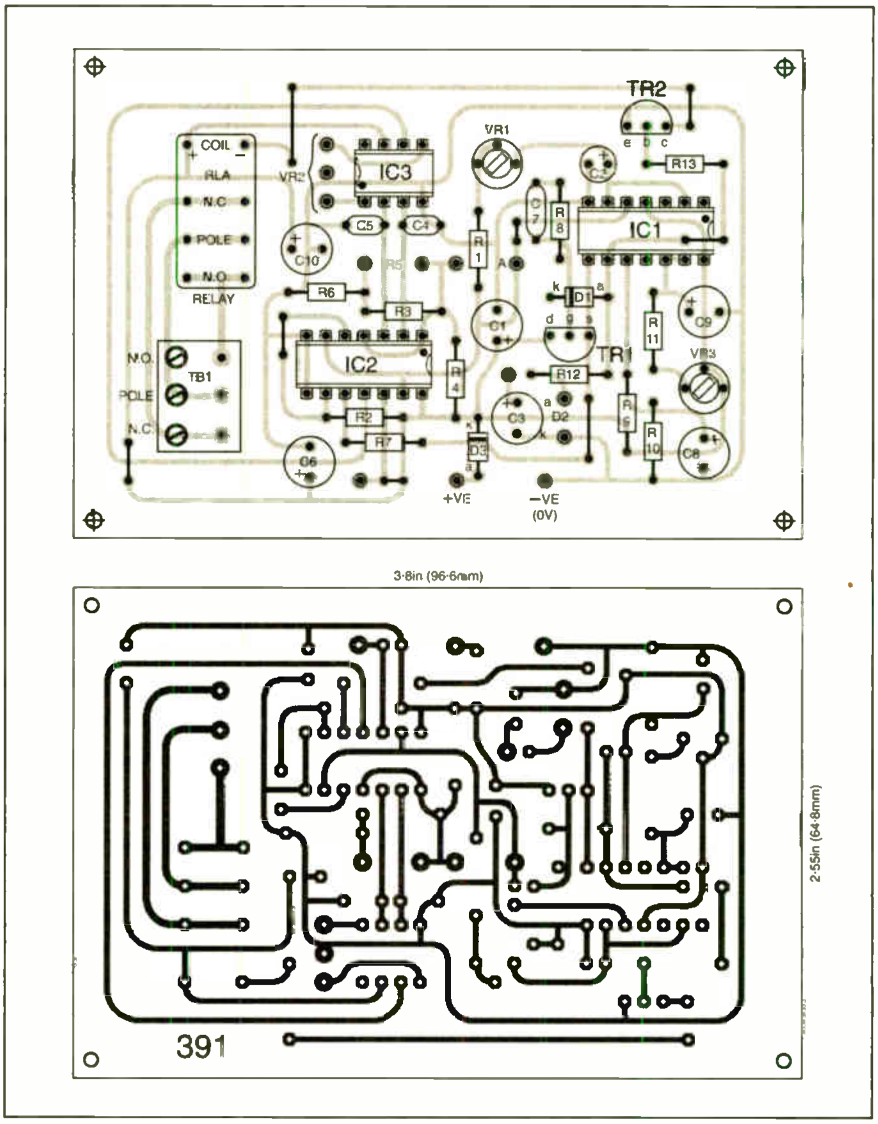


Fig.4. Printed circuit board topside component layout and full-size underside copper foil master pattern for the Super Motion Sensor.

Finally, the relay and the three-way terminal block should be installed on the board.

Use suitable lengths of connecting wire to wire up the off-board components VR2, l.e.d. D2, slide switch S1 and the battery clip. The author used a length of 8-way ribbon cable to provide a neat result.

LIGHT SENSOR

When an l.d.r. is in its "naked" state, it has a very wide viewing angle, and its sensitivity is low. The sensitivity may be greatly enhanced by making it "look" down the length of a narrow, black tube (see Fig.5 and photograph). In this way the distances described earlier were achieved.

The tube may be cut from the shaft of a felt pen. The leads of the l.d.r. are then stuck through a small, firm piece of foam rubber (not conductive foam rubber!), soldered to a suitable length of "twin-flex" wire, and pushed into the tube.

Epoxy glue is used to set the whole in place, and a rubber grommet may be added to the case for neatness. The sensor is then soldered to the p.c.b. as shown in the interwiring diagram Fig.5.

CASING-UP

Once soldering is complete, insert the i.c.s in the d.i.l. sockets, observing the correct orientation (note: these are orientated differently). Note that IC1 and IC2 are CMOS devices, and require care when handling (first discharge your body to ground). In the author's experience, j.f.e.t. TR1 is also more fragile, and it, too, requires some care.

Mount the Sensitivity control VR2, l.e.d. D2 and slide switch S1 on the case base; now the top. The constructor might also wish to replace presets VR1 and VR3 with shafted potentiometers, and mount these on the case for easy adjustment. The p.c.b. was mounted on the lid (bottom) of the case, and a partition was slotted into the case to hold the batteries.

While the circuit diagram Fig.2 shows a 12V power supply, the circuit may also be powered off 9V if desired. Note that the relay's voltage rating will need to match the supply voltage. Alternatively, a lower voltage rating may be used for the relay (e.g. 5V), if the link wire at TR2's collector is replaced with a suitable resistor.

If in doubt, use a one kilohm (1k) preset potentiometer here wired as a variable resistor, beginning at 1k and turning it back until the relay triggers in sync with l.e.d. D2. The preset may then be replaced with a fixed resistor.

Generally speaking, a Telecom relay (for which the p.c.b. is designed) will carry about 60W across its switching contacts – but check specifications first.

The author used an ultrabright red l.e.d. for D2, so that the circuit could be tested at a distance. In some cases, the range of the circuit is such that an ordinary l.e.d. may not be seen without binoculars!

A p.c.b.-mounting terminal block is used to connect the unit to external circuits (e.g. a siren). The provision of "blanking", as described earlier, enables one to run such circuits off the Super Motion Sensor's own power supply.

CALIBRATION AND USE

Commence the setting up of the Sensor by turning preset VR1 and potentiometer VR2 to their mid positions, and turn preset VR3 back (anticlockwise) completely, then switch on – selecting natural or a.c. lighting with switch S1.

The circuit will take a few seconds to settle and come to life, as capacitor C8 charges and IC1b's reset pin goes "high". L.E.D. When VR2 is suitably adjusted, D2 should illuminate and the relay click as a hand is moved over the l.d.r.

If l.e.d. D2 illuminates repeatedly, turn back VR2 (anticlockwise). If it does not illuminate at all, turn it up (clockwise).

If the circuit does not work as described, immediately switch off and disconnect the power, and carefully re-check. Ensure that there are no solder bridges on the p.c.b., that all components are inserted correctly, and that all interwiring is correct.

Once it has been established that the circuit is working, presets VR1 and VR3 may be further adjusted. The function of VR1 has been described above. Preset VR3 adjusts the trigger period of monostable IC1b and thus the "on" time of the relay between about half a second and 30 seconds.

The Super Motion Sensor will work best in situations of good contrast (e.g. shadows on a white wall). It would be best to adjust it to a little less than its maximum sensitivity.

What ultimately matters is that it should exclude any variations in light level that might cause unwanted triggering – e.g.

COMPONENTS

See SHOP TALK page

Resistors

R1	22k
R2, R7, R9	100k (3 off)
R3	150k
R4	47k
R5	min. light dependent resistor (l.d.r.), 33k @ 10 lux (or similar – see text)
R6	15k
R8, R10	1M (2 off)
R11, R12	1k5 (2 off)
R13	4k7

All 0·25W 5% carbon film, except R5

Potentiometers

VR1	200k cermet preset
VR2	47k rotary carbon, linear
VR3	100k cermet preset

Capacitors

C1, C6, C10	100µ radial elect. 16V (3 off)
C2, C3	1µ radial elect. 16V (2 off)
C4, C5, C7	100n ceramic disc (3 off)
C8, C9	470µ radial elect. 16V (2 off)

Semiconductors

D1	1N4148 signal diode
D2	5mm ultrabright red l.e.d.
D3	1N4001 50V 1A diode
TR1	2N3819 *n*-channel field effect transistor
TR2	BC337 *npn* medium power transistor
IC1	7556 CMOS dual timer
IC2	4066B quad bilateral switch (or equivalent)
IC3	TL071CN j.f.e.t. op.amp

Miscellaneous

S1	2-pole 3-position slide switch
RLA	12V coil, p.c.b. mounting relay, Telecom type with built-in protection diode (see text)
TB1	3-way, p.c.b. mounting, terminal block, 5mm pitch

Printed circuit board available from the *EPE PCB Service*, code 391; ABS plastic case, size to suit; 8-pin dual-in-line (d.i.l.) socket; 14-pin d.i.l. socket (2 off); calibrated knob; black plastic tube for l.d.r. housing (see text); 8 x AA battery holder; battery clip; 8-way ribbon cable (optional); "twin-flex" wire; link wire; solder pins; solder, etc.

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

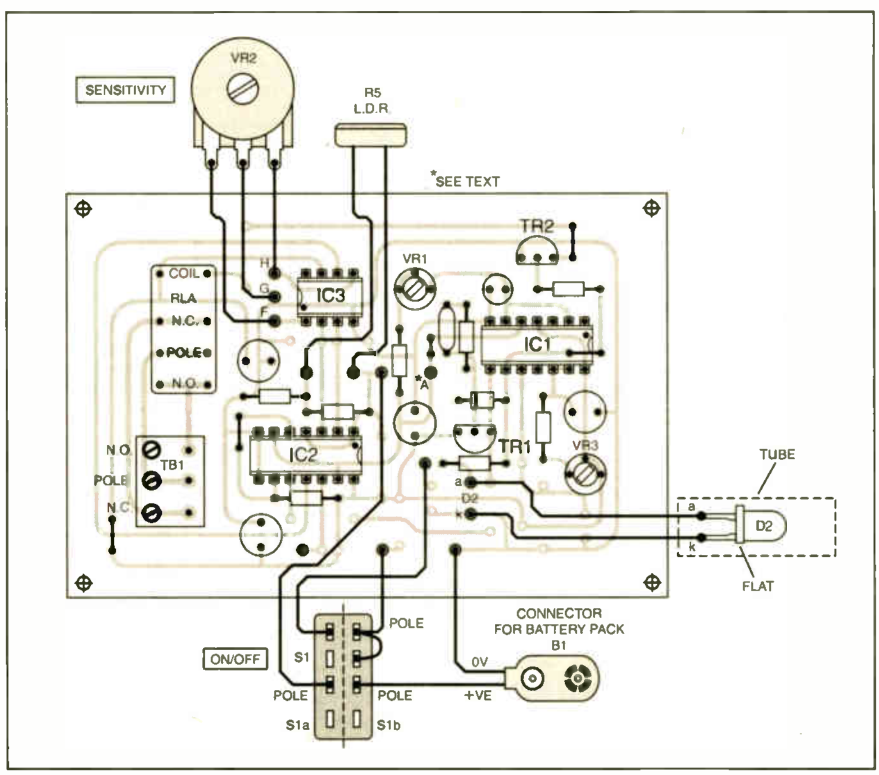


Fig.5. Details of the interwiring from the circuit board to off-board components. Note that the On/Off slider switch contact line-up may differ to that shown.

Completed Sensor showing front panel Sensitivity control and the lighting conditions slide switch.

birds flying past, leaves fluttering, or cloud movements. Even if sensitivity is reduced by, say, one-quarter, the circuit remains unusually responsive.

With some experimentation, it may be set to transition seamlessly from Natural to A.C. lighting – but this, unfortunately, will not occur at maximum sensitivity for both.

If maximum sensitivity under natural lighting triggers the circuit under a.c., then adjust for maximum sensitivity under a.c. – and vice versa. □

Tiny Tags Talk Volumes

Barcodes are set to disappear! Andy Emmerson explains.

FOR many people (including the author!) "retail therapy" is an ideal means of lifting the spirit but even then the pleasure can easily vanish when faced with a long checkout queue and a barcode scanner that refuses to recognise product codes. At this stage cashiers tend to panic and call for assistance leaving shoppers to seethe while the queue that they haplessly chose is log-jammed.

Barcode scanning may soon be a thing of the past, however, if the current plans for r.f. tagging keep to schedule. And time is at the heart of this story simply because time is money to retailers.

Barcodes take time to scan, simply because they have to be passed manually in front of a scanning device. The more goods you are buying, the longer the process is and the slower the transaction. Obvious that may be but it's also highly relevant to supermarket customers in a hurry to get home at 6pm on a Friday evening.

TOUCHLESS TECHNIQUE

A far better solution would be one in which each product you have bought "told" the till its details without prompting or handling. The same applies to luggage transiting airports, and commuters boarding buses or trains in the rush hour. For all of these a touchless solution would be far preferable.

Commuters are lucky. In several major cities season ticket holders now have a radio-activated pass that needs only to be waved near a sensor (no more shoving tickets into slots). The same technique is used to protect high-value goods in retail stores; try walking out of a clothing store with an unpaid-for garment, then stand by for action as the alarm goes off.

All of these systems rely on tuned radio circuits embedded in tags or tickets detuning a low-power radio frequency field. The same principle underpins the new RFID (radio frequency identification) tags proposed to replace barcodes on retail goods and travellers' baggage.

Applying an RFID tag to every product out on the shelves is the retailer's ultimate dream, a concept endorsed at the annual Retail Automation Conference in London last autumn. At this stage the cost of the tags and the new equipment to interrogate them is still prohibitive but this is set to plummet as the idea catches on. Unified standards need to be drawn up too before the practice becomes commonplace or even universal, but the idea is to create a single, globally recognised numbering scheme similar to the universal product code employed on barcodes now. There are also data privacy issues to be resolved if retailers associate RFID tag data with customers' loyalty card details.

One firm that has committed to RFID tagging is personal hygiene manufacturer Gillette, which has purchased 50 million tags for use in the UK and USA. Tesco is its first retail partner and will trial tagged Gillette products in Cambridge. Other early adopters, such as Woolworths in the UK and the GAP fashion stores in the USA, have already conducted trials and seen the merits of the system. Data accuracy is stated as 99·7 per cent, far better than previous systems, and the feeling is that companies should concentrate on the benefits rather than the cost.

FOOD CHAIN

Even if you do not spot RFID tags immediately in your local supermarket, that does not mean the idea has failed. They will still be used for coding products by the crate or tray load further back in the food chain, for instance at Marks & Spencer. The upmarket retailer recently announced the world's largest rollout of RFID tagging, with a scheme to tag 3·5 million food trays passing through its warehouse and distribution system.

As pallets or cases of goods leave one location for another, they will pass readers that will pinpoint the progress of each and every consignment. As well as helping pinpoint slow-moving inventory, the system will also provide automatic proof-of-delivery at each point along the line of route, assisting both Marks and their suppliers. "Stock shrinkage" (*theft* to the rest of us) will be reduced too, as it will be possible to spot the exact stage where items go missing. The same technique is already in use in parts of the automotive industry.

The savings suppliers make can be passed on to consumers and there are other end-user benefits too. Greater information capture means better stock control; wastage will be reduced and shelves should never go empty under normal conditions. It will also be easier to identify, in real time, batches of products that need to be recalled or replaced for any reason.

TECHY STUFF

So much for the benefits, how exactly do RFID tags work? Tags can be active (with an integrated battery) or else passive (deriving energy from the r.f. field generated by the reader). Active tags have longer range and can transmit more information but carry a heavy cost penalty. Passive tags are much lighter, less expensive and should last more or less forever.

A company in the USA, Allen Technology, produces a read-only tag with 64-bit memory weighing 25 grams. It operates on 915MHz, a licence-free band for industrial, scientific and medical purposes in North America (used for cellular radio here in Europe). Another US firm, Matrics, also uses this band; its products have a read range of three metres and the product is totally tamperproof.

In Europe Philips has joined forces with Tagsys to develop a low-cost smart label system operating at 13·56MHz. These tags, which are similar in size to the sticky label security tags already used to prevent theft, incorporate tiny i.c.s made by Philips, used with r.f. equipment made by Tagsys, and can be read at a rate of 150 items per second.

The actual data that can be contained in RFID tags is awesome and far greater than the humble barcode can carry. Tags applied to some EMI CD albums already state a global product identification code that embraces their origin and final retail destination. This is only the tip of the proverbial iceberg and the data has the potential to document a complete product history, including date and place of manufacture, ownership and far more.

READY FOR TAKE OFF

There is a general agreement that RFID tagging will take off when the cost of the tag drops to one per cent of the cost of the product it is applied to, and that date is still some way off. Semiconductors made of organic materials are cited as one way of reaching this price break but the jury is still out on the feasibility of the manufacturing process. It is, nonetheless, a matter of when rather than whether, simply because the benefits are so attractive.

A report by analysts AMR Research indicates that early adopters have reaped cost savings equalling five per cent of sales turnover, an advantage not to be sniffed at. 2005 is the date that the research firm says when r.f. tagging becomes viable and until then we must wait and see.

Ancient Optical Comms

Mechanics' Magazine 7 January 1826 describes an ingenious "Gas-Light Night Telegraph" which, despite thoughts to the contrary, was not an April Fool project.

Six gas lanterns were arranged in a triangle and could be illuminated or extinguished rapidly by opening and closing gas taps to the main supply, concealed pilot flames doing the actual lighting. Combinations of lamps lit would indicate letters of the alphabet, rather as pointing needles did in the electric telegraphs of Cooke and Wheatstone that followed soon afterwards – and rendered this form of optical communication still-born.

News . . .

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

ATRAC-TIVE MUSIC SNACKING

Barry Fox highlights Sony's system that can rip 30 music CDs onto one.

SONY has announced a major modification of the CD system which lets home copiers rip at least 30 music CDs onto a single blank CD, and play the music back on a £100 portable stereo.

Sony's system, to go on sale in May, uses Atrac3Plus, a much improved version of the ATRAC compression system which Sony developed ten years ago for Mini Disc. Now that the patents on CD have run out, Sony is free to adapt ATRAC for use with CD. Sony has coined the phrase "music snacking" because one disc can hold enough different music to satisfy every taste or mood.

By analysing the music in 52 separate frequency bands before converting it into digits, and then tweaking the digits, ATRAC records stereo onto a blank CD at 48Kbps, which is around a third the amount of data needed for MP3 and one thirtieth the amount used for CD. So one blank CD, costing a few pence, can now hold 30 hours of music.

Sony's new ATRAC CD Walkman will start at under £100 and play either the new home-recorded 30 hour discs, or conventional CDs, or MP3 discs. The price includes free ATRAC compression software, called Sonic Stage "Simple Burner", that lets a home computer do the recording.

The player comes with rechargeable batteries which allows up to 150 hours playing time. This, reminds Sony, is "enough to fly to Australia and back three times".

Sound quality will be acceptable for people who are used to listening to MP3.

Jack Rabbit

Philips, the company which jointly owned the patents on CD, is doing things differently. Philips' new DVD PC burner works at four times normal speed to record music in MP3 format onto blank DVDs – which hold at least seven times as much music as a blank CD. The MP3 DVDs then play back on a portable DVD player called Jack Rabbit, costing around £200.

News of both developments came as a surprise to the music industry's trade bodies, the International Federation for the Phonographic Industry and Recording Industries Association of America. But both bodies were surprisingly sanguine. The RIAA did not feel the need to make any comment and the IFPI says its faith is in "the availability of legitimate on-line music services". These, the IFPI hopes, will encourage people to buy music instead of copying it for free from CDs or unauthorised Internet sites.

Less surprising, Sony Music also refused to comment.

SAVE WITH FLUKE

FLUKE is offering a 24% saving when purchasing their Combo Kit. This includes the top of the range 179 DMM, which is a true r.m.s. meter, an integrated temperature probe, set of silicon test leads and hook clips, and alternative leads with special electronic test probes.

The meter offers 0·09% basic d.c. accuracy, has a large easy to read 6000 count backlit display and features an analogue bargraph. Frequency, capacitance and resistance ranges are up to 100kHz, 10,000μF and 50MΩ respectively. Temperatures up to +260°C can be read with the plug-in Fluke 80BK thermocouple probe.

In addition the meter offers enhanced troubleshooting features, which include Min/Max/Avg recording, with an audible warning, AutoHold and Display Hold. A set of the latest 1·5m long SureGrip silicone test leads are included, plus a meter and accessory case, a pair of test probes offering 1mm replaceable steel and spring loaded gold tips, and a hook set with a 6·4mm opening.

The suggested retail price for the kit is £188, representing a 24% saving over the purchase of the individual items. It is available from authorised Fluke distributors. Browse **www.fluke.co.uk**.

ALLIGATOR CLIPS

POMONA Electronics have introduced a complete family of flexible boot alligator test clip products. They have a CAT III 1000V 10A rating and are adaptable to meet a variety of test needs, attaching to terminals up to 7·6mm o.d.

Pomona's offering includes two probe tip adapters, two patch cords and one alligator clip for test lead attachment. The probe adaptors interface to standard 2mm and 4mm lantern tip DMM probes. The patch cords include alligator-to-alligator, and alligator-to-rightangle sheathed banana plug and are offered with flexible heat resistant silicone wire.

For more information browse:
www.pomona.cc and **www.pomonaelectronics.com**.

OUT THE WINDOWS

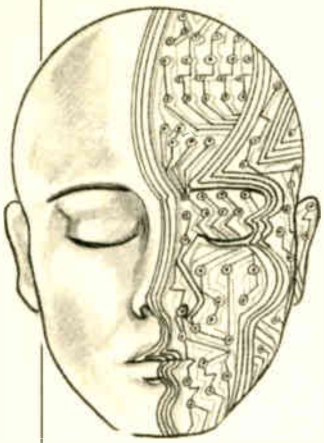
By Barry Fox

NOT everyone wants Windows. In October '02, Microsoft and Orange staged a mega event in London to announce the world's first Windows-powered Smartphone service. SPV will offer Sound, Pictures and Video on the move for 40 million Orange subscribers in 21 countries, using GPRS cell-phones with the Windows operating system and Internet Explorer. The Orange phones are made under contract in Taiwan by HTC.

At the launch Microsoft and Orange proudly announced outside support from Sendo, the go-getting cell-phone company started by ex-Philips management and now selling high spec, low cost phones in over twenty countries in Europe and Asia. Sendo was at the Microsoft event to show off the Windows-powered Z100 "world's smartest phone". But now Sendo has dumped Microsoft Windows and switched to the rival Nokia/Symbian operating system.

Sendo says that "for legal reasons" it cannot say why it canned the deal with Microsoft, just weeks before launch of the Z100. But a spokeswoman confirms that Sendo now wants to work with a company which lets its partners work with the source code. Microsoft won't, Nokia will.

INGENUITY UNLIMITED



Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: *Ingenuity Unlimited*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.) Your ideas could earn you some cash **and a prize!**

WIN A PICO PC BASED OSCILLOSCOPE WORTH £586

- 100MS/s Dual Channel Storage Oscilloscope
- 50MHz Spectrum Analyser
- Multimeter • Frequency Meter
- Signal Generator

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours. Every 12 months, Pico Technology will be awarding an ADC200-100 digital storage oscilloscope for the best IU submission. In addition, a DrDAQ Data Logger/Scope worth £69 will be presented to the runner up.

Fully Automatic Egg Timer – Just White

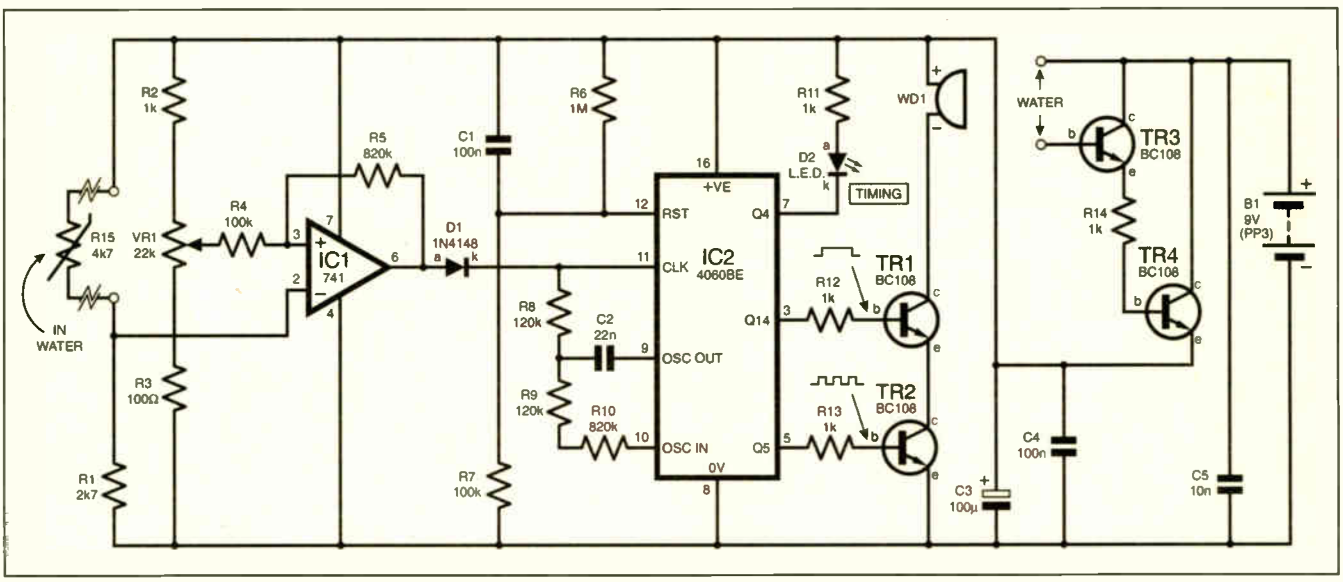


Fig.1. Complete circuit diagram for the Fully Automatic Egg Timer.

ONE of the most tasty and natural sources of protein is without doubt the humble boiled egg, however desirable results can often be difficult to attain (i.e. solid egg white and liquid yolk) without prior experimentation. Egg connoisseurs everywhere will appreciate the inexpensive circuit of Fig.1, which produces almost perfect results with a wide variety of pan sizes, water volumes and heat rates.

Egg Thermidor

Thermistor R15 is placed in the pan of water and forms a bridge arrangement with resistors Rl, R2 and R3 and potentiometer VR1. A low value of 4k7 has deliberately been chosen for R15, so that in the event of water breaching the seal around its leads, the resistance of the water (approx. 50k) in parallel with it will have minimal overall effect.

Op.amp IC1 operates in comparator mode, with resistors R4 and R5 providing hysteresis in order to ensure a clean switching action. Potentiometer VR1 is set so that when the water reaches 70°C, the point at which the eggs actually begin to cook, IC1 is triggered and a logic 1 appears at its output.

Consequently, pin 11 of a 4060 ripple counter IC2 is now at logic 1 and a countdown of four minutes, forty seconds (± about 7 seconds) commences, a period determined by resistors R8, R9, R10 and polystyrene close tolerance capacitor C2. Substituted components cannot be used in place of C2, as this would significantly affect accuracy.

Capacitor C1 in series with resistor R7 applies a power-on reset to IC2, so that it begins operation in a predictable state when timing commences. Resistor R6 discharges C1 when the device is switched off.

Light Work

The l.e.d. D2 is illuminated upon power-up via current limiting resistor R11, as pin 7 of IC2 at this point is at logic 0. Once the timer has been activated, pin 7 begins to oscillate between logic 0 and 1 at a low frequency of 1Hz to 2Hz, resulting in D2 flashing instead.

After four minutes and forty seconds, pin 3 of IC2 switches from logic 0 to 1 and turns on transistor TR1 via current limiting resistor R12, which activates the buzzer WD1. As TR2 is constantly pulsed by pin 5 at approximately 2Hz, the buzzer is given a more noticeable "beep, beep . . ." sound, rather than a constant tone. Capacitors C3 to C5 are noise decoupling components that help stabilize the power supply.

Transistors TR3 and TR4 and resistor R14 form a water-activated switch that automatically applies power to the circuit when the sensor prods are immersed in the water; these are located on a probe containing the thermistor. The circuit should be housed in a metal box and clipped onto the end of the pan handle so that heat and steam cannot come into contact with the components.

It should be noted that once the alarm has sounded, the eggs must be cut open immediately, so that they cannot continue to cook from the heat retained in them.

M. A. Jones, Harrogate, N. Yorkshire

Heart Rate Monitor – See The Beat

THE simple but very reliable monitor shown in Fig.2 will be an asset to those who have difficulty finding their pulse in their wrist. It is also useful for checking the pulse rate immediately after exercise, which should be well above the normal rate of 60-80 beats per minute if any benefit from the exercise is to be derived.

Light Finger

The device depends for its operation on variations in light intensity. When a finger is placed on a light dependent resistor R2, the l.d.r. detects the minute changes in light level caused by variations in blood flow as the heart pumps. These light changes are translated into minute voltage fluctuations that are subsequently amplified through a two-stage amplifier, a non-inverting op.amp (IC1a) and an inverting op.amp (IC1b), by a gain of approximately 800 as determined by resistors R5, R7 and R10.

At the output (pin 7 of IC1b), each heartbeat is reflected in the rhythmical swing of a meter needle across the dial of a milliammeter (ME1) or other suitable panel meter. No special lighting is needed as the l.d.r. is able to "see" through a finger tip in normal daylight.

The gain of the first op.amp is fed into the second and the overall gain is sufficient to obtain a healthy swing of the meter needle. Almost any moving coil meter can be pressed into service because we are not concerned with voltage or current measurement, only the needle deflections across the dial.

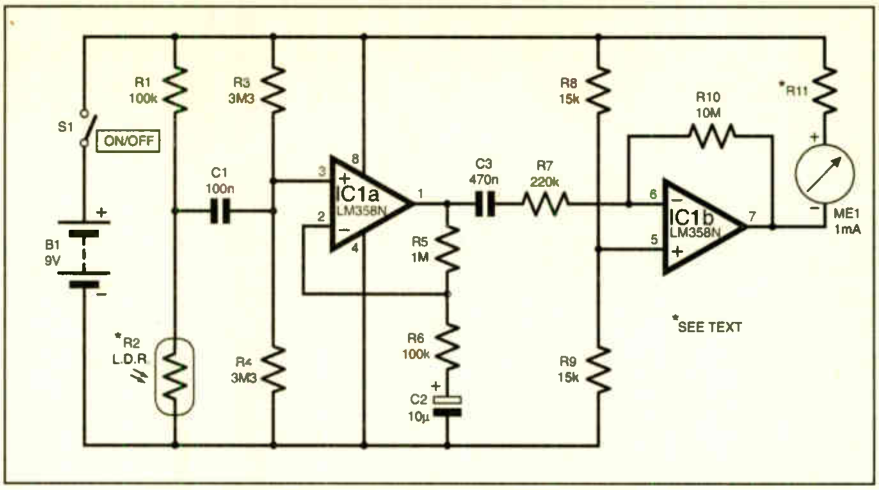


Fig.2. Heart Rate Monitor circuit diagram.

However, be sure to fit a series limiting resistor R11 to suit the meter and prevent damage.

A miniature button-type l.d.r. is preferred to the bulkier ORP12 so that the finger can completely cover the sensor surface and prevent stray lighting from reaching it. Two discrete 741 op.amps could be used in place of the LM358N if more readily available.

Although not shown here, the prototype also housed a 30-second timer, using a 555 with an l.e.d. indicator. When the timer is initiated, the needle movements are counted during the 30 second period, then doubled to obtain pulses per minute. The circuit could also be adapted as a front-end to more advanced monitoring systems.

In use, after the unit is switched on, allow several seconds for the meter needle to stabilise somewhere about mid-scale. Place the fleshy part of the middle finger tip on the l.d.r. and rest the hand comfortably while keeping it still, then monitor the meter needle movement. If the meter needle responds by only a small amount, it is probably because your hand is excessively cold and the circulation is sluggish.

Tony Lee,
Old Reynella, Australia

Microwatt L.E.D. Flasher – Relaxing Light

THE circuit of Fig.3 is a complementary relaxation oscillator that has been utilised to form a low power l.e.d. flasher. The heart of the circuit is the 5·1V 0·5W Zener diode D2, the absence of which reduces the operating efficiency of the circuit. Current from the anode of the Zener diode provides base bias for transistor TR2.

In order to reduce the current requirement of TR2 to a minimum, a high gain *npn* transistor (BC549C) has been selected. The resistor R1 is the energy saver which acts in conjunction with capacitor C1, a reservoir for the whole circuit. Transistor TR1 (BC559) is a *pnp* type that provides current for the flash.

To get a flash of fairly good intensity C1 has to be kept fully charged and the action is obtained by keeping the time constant of R1/C1 smaller than the time constant of the timing circuit around TR2, which consists of components R3 to R5 and C2. The capacitors should ideally be low leakage tantalum types.

Using component values as per the circuit diagram, the flash rate obtained was approximately 40 per minute with fairly good intensity using a 9V battery. The actual current consumption at the precise time of flash is well below 0·4mA. The circuit is tolerant of voltages ranging from 6V to 12V though a frequency variation is noticeable when supply voltage varies.

Unlike many other flasher circuits, this one has a very short flash duration. The instantaneous release of energy from the 100µF capacitor (C1) has to be fully utilised to illuminate the l.e.d., and a 3mm clear red l.e.d. was chosen as a satisfactory compromise.

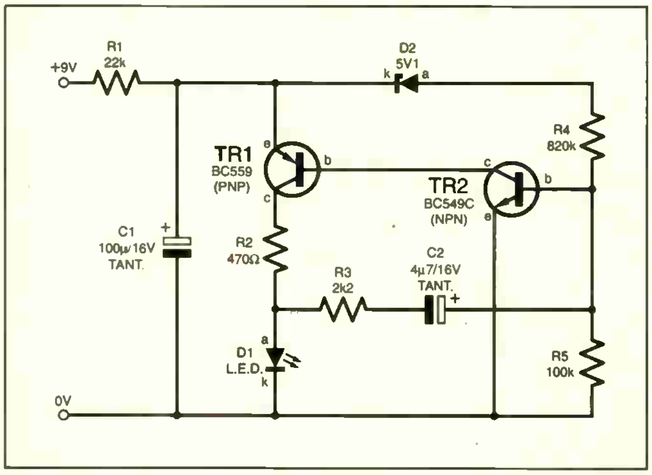


Fig.3. Circuit diagram for a Microwatt L.E.D. Flasher.

Experimenters might find various other applications due to the very economical power consumption, e.g. by replacing R1 with a 2k2 resistor and addition of a small piezo buzzer in place of the l.e.d. or in parallel with it, thus converting it into a low current bleeper.

K.N.S. Nair,
Selangor, Malaysia.

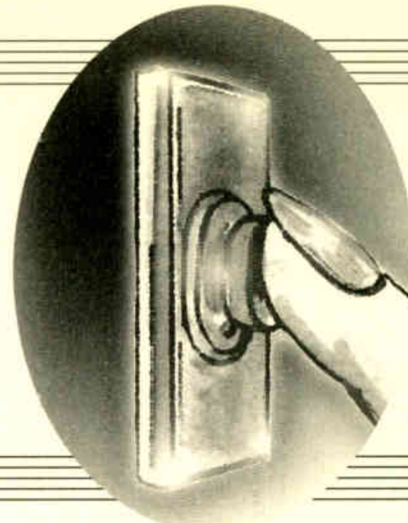
Signing Off . . .

Sadly this is the last *Ingenuity Unlimited* column that I will be hosting, but don't worry, *IU* will continue. It has been my pleasure to help bring you almost 300 readers' circuits since the original *Practical Electronics* column was relaunched in *EPE* nearly ten years ago. Unfortunately, pressure of work has gained the upper hand, and so I will be handing over to the Editorial staff at *EPE* HQ who will continue to publish a selection of your circuit ideas with valuable prizes donated by Pico Technology for the best.

I'll still be working hard as usual over at *Circuit Surgery* and *Net Work* – the Internet column, and working on a number of other projects as well. I would like to express my gratitude to all those readers, correspondents and friends around the world who have sent their good wishes and offered me their encouragement over the years. It is much appreciated, and it has been great fun. *Alan Winstanley.*

Constructional Project

DOOR CHIME



BART TREPAK

Add a touch of nostalgia to your front door and have a real "ding-a-ling" with this low-cost unit.

In the good old days, when computers were huge monsters that lived on the air conditioned top floors of banks and insurance company headquarters and PICs were used with shovels on building sites to dig holes, life was so much simpler.

Nobody in their right mind would want to use either of these to announce the arrival of a visitor to their door and instead a far simpler solution was found – the door chime, which had the added advantage of not playing the Wedding March for twenty minutes each time a double glazing salesman came to call.

Luckily, these did not exist either and only the familiar "ding-dong" sound of the lady selling cosmetics disturbed the peace and tranquillity of the family as they huddled around their warm valve wireless set listening to the Home Service instead of arguing about which of the hundred and fifty odd channels to watch or record on their top of the range digital satellite TV/DVD recorder . . . Ah, those were the days . . . now even nostalgia isn't what it used to be!

To try to return to those simpler times, the author decided to build a door chime that would recreate the sound of the original with electronics (well some things have to move on) but without recourse to microcontrollers, ROMs or hard to obtain special i.c.s.

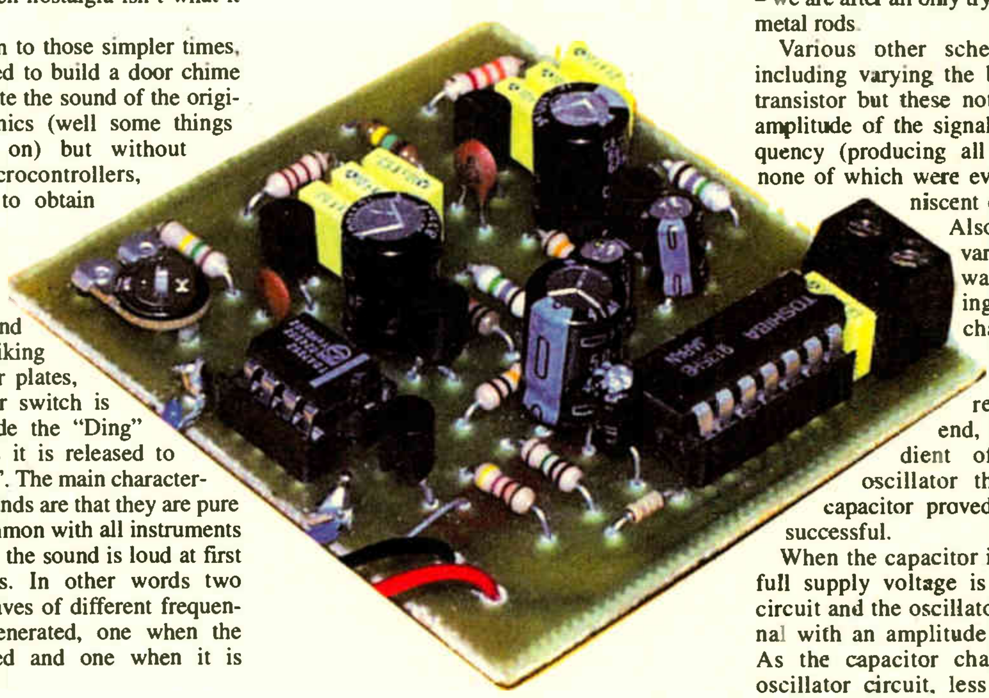
Mechanical door chimes produced their characteristic sound by alternately striking two steel rods or plates, once as the door switch is pushed to provide the "Ding" and the other as it is released to sound the "Dong". The main characteristics of these sounds are that they are pure tones and, in common with all instruments which are struck, the sound is loud at first and then decays. In other words two decaying sine waves of different frequencies must be generated, one when the switch is pressed and one when it is released.

SINE WAVE OSCILLATORS

At first glance this seems simple enough to do and there are many circuits for producing sine waves. Basically, an inverting amplifier with its output connected to a feedback network which at a certain frequency produces a phase change of 180 degrees is all that is required.

When this is coupled to the input of the amplifier which itself exhibits a 180 degree phase change between its input and output, the total phase change becomes 360 degrees (i.e. in phase). This means that the circuit will oscillate but only if the gain is high enough to replace the inevitable losses in the feedback circuit.

If the gain is too high, the amplitude of the output waveform will grow until it limits or clips on the supply rails producing distortion or a square wave (which does not sound so pleasing). If it is too low the circuit may not start to oscillate at all. Many sine wave oscillators therefore employ some form of circuit to control the gain of the amplifier and keep it stable.



PHASE SHIFT

The circuit chosen was a phase shift oscillator where the feedback is provided by a three-stage high-pass network with each stage providing a phase shift of 60 degrees. Here oscillation occurs at the frequency at which the phase shift through the network is 180 degrees and this depends on the values of the capacitors and resistors used.

Normally they will have the same value, although making one of the resistors variable allows the frequency to be adjusted within limits. The frequency of oscillation is given by the formula: $f = 1/2\sqrt{(6RC)}$. The gain required to sustain oscillation is easily supplied by a simple transistor amplifier.

DELAYED RESPONSE

To produce a decaying output rather than one which persists for as long as the battery is connected appeared much more difficult. Some form of voltage controlled amplifier or attenuator was considered but this was rejected as being too complicated – we are after all only trying to replace two metal rods.

Various other schemes were tried including varying the base drive to the transistor but these not only varied the amplitude of the signal but also its frequency (producing all sorts of sounds none of which were even vaguely reminiscent of a door chime). Also, the amplitude varied in the wrong way hardly changing at first and then changing rapidly rather than smoothly as required. In the end, the simple expedient of powering the oscillator through a (large) capacitor proved to be the most successful.

When the capacitor is discharged, the full supply voltage is available to the circuit and the oscillator produces a signal with an amplitude of several volts. As the capacitor charges up via the oscillator circuit, less and less of the supply voltage is available across the oscillator itself and so its amplitude falls until eventually the signal becomes inaudible.

The circuit continues to oscillate without clipping or suddenly cutting out at a certain minimum voltage level thus producing a smoothly reducing signal. It also has the great advantage in a door chime circuit, which spends most of its time in the stand-by state, in reducing the current drain to zero once the capacitor is fully charged. In this state it draws no current and is ready for the next caller requiring only the capacitor to be discharged to initiate another cycle.

A SWITCH IN TIME

Since two tones must be generated, two oscillators are required together with their associated capacitors. In theory, the capacitor could be discharged by the door switch but since the two tones do not sound simultaneously, the capacitors need to be discharged sequentially – the first when the switch is closed and the second when it opens. As well as this, both contacts would have to remain open during the stand-by condition so that neither capacitor was shorted out and this would require some pretty fancy switching.

Nowadays, of course, you can have any type of doorbell switch you like on your door – as long as it is a simple push-to-make type. Double-pole or changeover types suitable for mounting on your front door are not readily available (if at all) and you would probably not want to change your existing one anyway so that a further circuit must be added to switch on the oscillators in the correct sequence under the control of a single contact.

CIRCUIT DETAILS

The full circuit diagram of the Door Chime is shown in Fig.1 and consists of two oscillators built around TR1 and TR3, the circuitry for switching them on and an audio amplifier, IC2, to drive the speaker.

The switching stage is centred on IC1, a quad CMOS NAND gate and all of the gates are connected as logic inverters. When the doorbell switch S1 is pressed, the input of the first inverter, IC1a, goes high causing its output to go low and the output of the second inverter, IC1b, to go high.

Both of these inverters drive *pnp* transistors, TR2 and TR4, via capacitors C5 and C10, so that when the output of an inverter goes low, the associated transistor is switched on, briefly discharging its output capacitor (C6/C11 as appropriate) and switching on its oscillator. When the output of the inverter goes high however, it has no effect on the transistor which remains off.

Thus when the door switch is pressed, TR2 turns on briefly and when it is released, TR4 is turned on so that the two oscillators are switched on sequentially. Note that if the switch is held depressed, then only the first (Ding) oscillator TR1 is switched on and the second (or Dong) oscillator TR3 will only sound when the switch is released.

SWITCH-OFF

The two oscillators switch off automatically by themselves (when the voltage on the negative plates of capacitors C6 and C11 falls) but the audio amplifier, IC2, must also be switched off in order to reduce the current drain of the circuit. This is done by wiring the remaining two gates, IC1c and IC1d, as a monostable.

When the input of IC1c goes low (which happens when the switch is pressed) its output will go high and capacitor C14 will charge quickly via diode D1. This will cause the output of IC1d to go low switching on transistor TR5 and the supply to the audio amplifier IC2. Note that the transistor will remain on for as long as the door switch is held pressed.

When the switch is released, C14 discharges via resistor R15 until eventually the gate output goes low, switching off the transistor and the supply to the amplifier. The values of C14 and R15 are chosen to ensure that this will happen only after the second oscillator has ceased to function.

AUDIO AMPLIFIER

The audio amplifier (IC2) chosen is the TDA7052 power amp i.c. which, in fact, contains two amplifiers which drive loudspeaker LS1 in a bridge configuration. This gives an output which is typically four times greater than that which could be achieved with a single-ended output and ensures a loud signal even with a relatively low supply voltage.

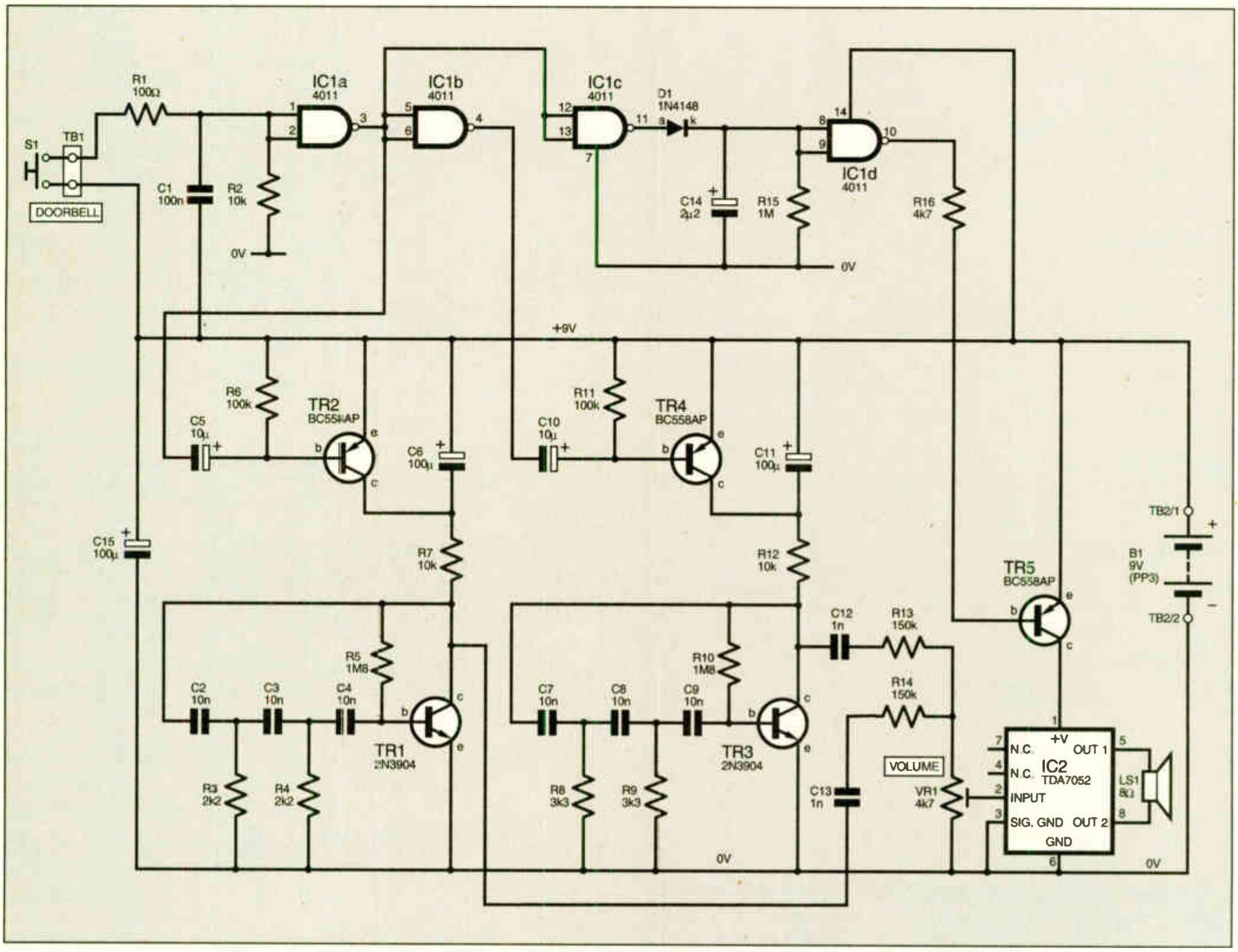


Fig.1. Complete circuit diagram for the Door Chime. S1 is the doorbell pushswitch.

As there is no d.c. voltage across the loudspeaker in amplifiers using this configuration, the usual large value coupling capacitor is not required. Apart from a supply decoupling capacitor (C15), the only other component needed is a Volume control which in this case is preset type (VR1).

The outputs of the oscillators are fed to the amplifier input (IC2 pin 2) via capacitors C12 and C13 and resistors R13 and R14 which attenuate and mix the two oscillator outputs across level-setting preset VR1.

As mentioned, to reduce the current drain, the supply to the amplifier is also switched off when the chimes stop. The absence of a speaker coupling capacitor is therefore an advantage as there are no audible clicks when the supply is switched on and off.

The circuit is powered by a 9 volt battery and the current drain in stand-by, which with this sort of application is most of the time, is virtually zero so that battery life will be close to the shelf life.

CONSTRUCTION

Initially it was intended to build the circuit on stripboard but as the number of components grew it was decided to design a printed circuit board. This will simplify construction quite considerably.

The final component layout, full-size copper foil master and wiring details are shown in Fig.2. This board is available from the *EPE PCB Service*, code 390.

All of the components except for the loudspeaker and battery (and, of course, the doorbell switch) are mounted on the board and these are connected to the p.c.b. via flying leads, either soldered directly to the board or through terminal blocks. The components are all pretty standard and no special precautions need be taken other than to make sure all electrolytic capacitors, transistors and other polarity sensitive components are mounted the correct way around.

Note also that transistors TR1 and TR3 are *npn* types while TR2, TR4 and TR5 are *pnp*. The pinouts of the *npn* types specified are slightly unusual and so if you intend to use substitute devices, such as BC548 or BC182, you will need to check their pinouts first. Being a CMOS device, IC2 should be handled with care and mounted in a 14-pin socket. Although IC1 is not sensitive to static, a socket was also used for this device.

The circuit is powered by a 9V PP3 battery and although the layout shows a terminal block, TB2, to connect this, a simple PP3 battery connector and its leads may be used and soldered directly in its place. Note that there is also a wire link adjacent to this terminal block which can be made from a discarded component lead.

The loudspeaker LS1 can be a miniature one and this should be soldered to the board at the position shown using flying leads. It is a good idea to use solder pins here (and for the battery connector if a terminal block is not used) to avoid damaging the p.c.b. tracks as wires soldered directly to the board often break at this point leading to repeated soldering operations.

TESTING

Provided the circuit layout has been carefully followed, the unit should work as soon as a speaker and battery are connected. The Volume control preset VR1 should be adjusted to give a pleasing sound without distortion which can occur at high volumes if the output of the amplifier clips on the supply rails.

Although the component values given should produce an acceptable door chime sound, this can be modified according to personal taste. As mentioned, the basic oscillator frequencies can be altered by varying one of the resistors in the ladder network.

COMPONENTS

Resistors

R1	100Ω
R2, R7, R12	10k (3 off)
R3, R4	2k2 (2 off)
R5, R10	1M8 (2 off)
R6, R11	100k (2 off)
R8, R9	3k3 (2 off)
R13, R14	150k (2 off)
R15	1M
R16	4k7

All 0·25W 5% carbon film

See SHOP TALK page

Potentiometer

VR1	4k7 carbon preset, horizontal

Capacitors

C1	100n polyester
C2 to C4, C7 to C9	10n polyester (6 off)
C5, C10	10μ radial elect. 16V (2 off)
C6, C11, C15	100μ radial elect. 16V (3 off)
C12, C13	1n disc ceramic (2 off)
C14	2μ2 radial elect. 16V

Semiconductors

D1	1N4148 signal diode
TR1, TR3	2N3904 *npn* low power transistor (2 off)
TR2, TR4, TR5	BC558 *pnp* low power transistor (3 off)
IC1	4011 CMOS quad 2-input NAND gate
IC2	TDA7052 power amp.

Miscellaneous

LS1	8 ohm miniature loudspeaker
B1	9V battery (PP3), with clips and leads
TB1, TB2	2-way, p.c.b. mounting, screw terminal block (2 off)

Printed circuit board available from the *EPE PCB Service*, code 390; plastic case, size and type to choice; doorbell switch, push-to-make (see text); 8-pin d.i.l. socket; 14-pin d.i.l. socket; connecting wire; solder pins; solder etc.

Approx. Cost Guidance Only **£12** *excl. batts & speaker*

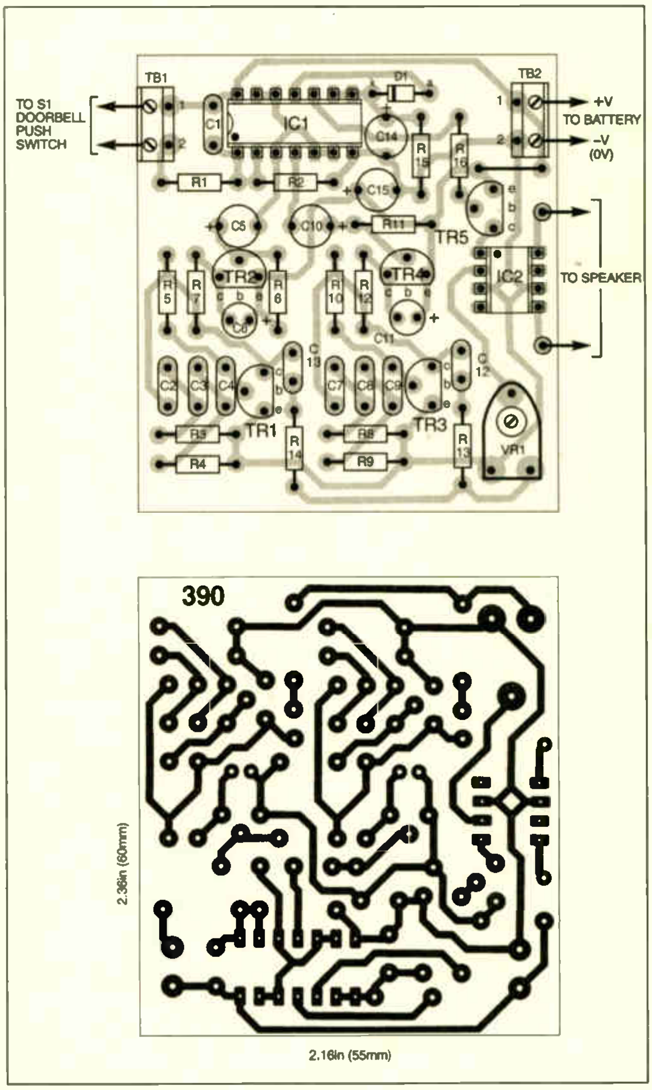


Fig.2. Printed circuit board component layout, wiring details and full-size copper foil master for the Door Chime.

This is perhaps done most easily by substituting a preset potentiometer in place of the resistors R4 and/or R9 and adjusting it to get the desired effect. Note that as well as altering the frequency, it will also change the amplitude of the note which can cause distortion of the wave shape by over driving the output amplifier but this can usually be corrected by adjusting the volume control preset.

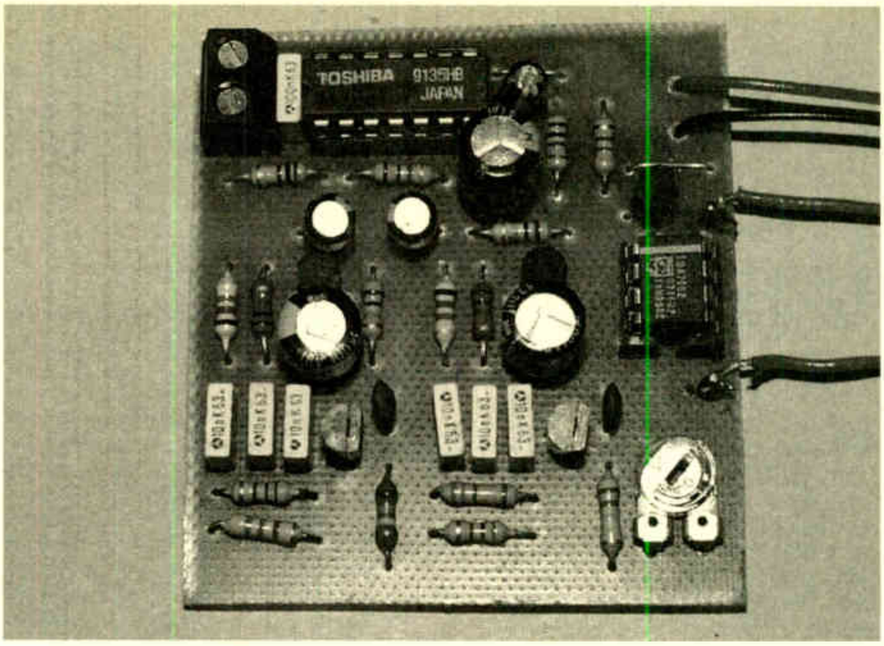
It can also produce less than pleasing results especially when mixed with the output of the other oscillator. If a radically different frequency is required, it is probably better to change the values of the capacitors.

DECAY TIME

The other characteristic which can be altered is the decay time and this is controlled by the current drain of the oscillator transistors (which is probably best left as it is) and the values of the series capacitors C6 and C11. These may be increased to 470μF or beyond or indeed decreased depending on taste, although both should have the same value to preserve the "ding-dong" effect.

In this case, the value of C14 would also need to be increased to ensure that the amplifier remains powered until the tone has died away. The values of C5 and C10 may also need to be increased to ensure that the capacitors are fully discharged at the start of each tone.

If the first tone is still sounding loudly when the second one commences, the two frequencies will beat together resulting in harmonics being generated and this can lead to the production of some more or less pleasant (or interesting) sounds.



Unlike custom i.c.s where the timing and the frequencies generated are all derived from one master clock oscillator, here each note can be adjusted to produce any sound of any duration required. By swapping the values of R4 and R9 for example, a "dong-ding" effect can be produced.

There is also no reason why a further oscillator could not be added to provide a 3-note chime or indeed a larger number to recreate the Westminster chimes. Although, in these cases the oscillator switching signals would need to be derived from a counter such as the CMOS 4017 with the pushswitch providing only the start signal.

While these modifications may be suitable as a door chime to produce just the sound you were looking for, they will do little to recreate those "good old days"! □

New Technology Update

Antennae with a high dielectric constant are less prone to proximity effects in mobile phones. Ian Poole reports.

MENTION an antenna to anyone and it conjures up an image of either a television Yagi antenna array on the chimneystack of a house, or a view of an amateur radio wire antenna.

In recent years it has been possible to implement far better antenna designs as a result of a vast array of simulation software that is available. It is possible to predict performance in terms of gain, direction pattern and many other parameters before any metal is put together.

These simulations can also take account of nearby objects that may affect the performance. As a result, major improvements have been made in the way antennas are designed, enabling far more efficient designs to be made more quickly. The need to perform many long tests on an antenna test site has been vastly reduced as the designs can be made almost perfectly first time.

A considerable amount of work has been put into the development methods for conventional conducting antennas. However, there has been plenty of development directed towards new ideas for antennas. With the increasing requirements for wireless links, antennas need to be made smaller, and to be incorporated into equipment more easily.

Proximity Effects

One of the major restrictions with antennas that use existing techniques is that nearby objects have a considerable effect on the performance. This means that for antennas such as those used in mobile phones, the proximity of other parts of the phone need to be taken into consideration. Naturally hand and body capacitance from the user has a major effect on the antenna and this will vary quite considerably dependent upon a number of factors, including the way the user is holding the phone, the electrical characteristics of his or her body and so forth.

Antennas on mobile phones themselves may only be 45% efficient under ideal conditions. However when the phone is held close to the head this can drop to as low as just a few percent. This means that the transmitter section of the phone needs to generate more power to enable reliable communication to be maintained with the base station, and this results in a much greater level of drain on the battery.

High Dielectric Antennae

To address these problems a Cambridge (UK) based company named Antenova has developed a new type of antenna called a high dielectric antenna (HDA). This type of antenna uses material with a high dielectric constant as the basis of the radiating element rather than a conducting element as used in a conventional antenna.

The idea has been known about for many years. The first ideas were postulated in the 1930s. However, it has not been possible to develop them until recently. The electric and magnetic fields are contained within the dielectric and as a result it was not possible to measure them. Some early experimental models were built to demonstrate the principal in the laboratory, but their bandwidth was small, and they were not repeatable because of a lack of understanding of the electric and magnetic modes being excited within the dielectric.

During the 1990s development of simulation software took place and as a result it was possible to gain a much clearer picture of what was happening within the dielectric. It became possible to plot the electric and magnetic fields and from this an understanding of the modes in which the dielectric was being excited could be gained.

Physical Aspects

The antennas may be constructed using a small cylinder of dielectric material with a disc attached. A small metal or conducting probe is inserted into the material to act as a launcher and this is fed with the RF signal. If the relationship between the radio frequency signal and the dimensions of the dielectric are correct then a displacement current standing wave pattern will be set up. Using Maxwell's equations it has been predicted that this will radiate, and this indeed is what actually happens.

These dielectric antennas are physically smaller than their conducting counterparts. Under some circumstances they may be only a tenth the size and this can be a distinct advantage. Many of today's wireless devices are small, requiring low profile antennas and the new HDAs are ideal candidates for these applications because they can be accommodated more easily within the electronics.

A further advantage is that they are less affected by nearby objects and this too enables them to be incorporated more easily onto a circuit card or other item. The fields are almost totally contained within the dielectric of the antenna itself, whereas the fields from a conventional antenna extend out by a wavelength and more, with the result that any objects within this range have a major effect on performance.

As a result of the relative immunity to nearby objects it is possible to have an HDA design where two separate antennas are placed very close to one another without any noticeable effect on performance.

Bluetooth

The new technology is ideal for many of the emerging wireless communications systems. Bluetooth, WiFi, and the like, all need small antennas that can be incorporated into a small electronics card. They also lend themselves well to many cellular telecomms applications, although the technology is better suited to frequencies above around 900MHz.

Whilst they can be used for bands within the 850MHz to 900MHz region, the higher frequency bands around 1800MHz and 1900MHz are far more applicable, along with many of the new 3G allocations that are slightly higher in frequency.

Antenova have built relationships with cellphone manufacturers and it is expected the new technology will be used extensively in this arena before long.

Currently much of the development work that is under way is focussed on frequencies around 5·8GHz. This is one of the so-called "unlicensed" bands that are starting to be used by some of the wireless LAN cards.

At the moment the 2·4GHz band is the most popular, but with the rapidly growing requirement for even faster data rates, people are migrating to 5·8GHz where the levels of interference are less and the bandwidth is greater, both elements enabling higher data rates to be achieved.

Diversity Reception

The fact that two antennas can operate close to one another provides the opportunity to provide what is called diversity reception. This form of reception is required because signals often reach a receiver via several paths. When they combine at the receiving antenna they may combine constructively to provide a better signal or they may tend to cancel one another out.

The interference patterns set up by the signals arriving via several paths mean that even a relatively short change in distance can make a large difference to the signal. As a result, the problem can be overcome by having two separate receiver front ends and two antennas relatively close to one another. The best signal is then used by the overall receiver system. As the HDAs can be operated close to one another they are ideal for using for diversity reception systems.

Further information can be gained from the Antenova website at **www.antenova.com** and more information about new technology can be found at **www.radio-electronics.com**.

New Product

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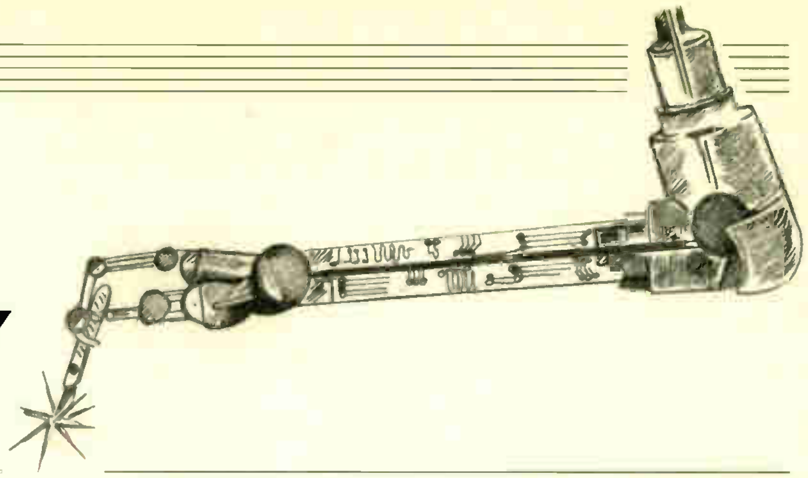


CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

This month, we unravel a subtle timing problem on a reader's digital circuit. We also offer more circuit diagram tips for beginners, illustrated with a selection of schematic symbols of common components.

Perfect Timing

Dr. G. L. Manning of Edgware wrote to describe his interesting experiences of timing problems with digital counters, about which we can make some enlightening observations. Some excerpts of his letter follow:

In the circuit shown in Fig.1 (which is part of a larger circuit), the required count length is from 0 through to 5 (0101 binary). The various binary values are decoded to an active low 1-of-n code by IC4. The NAND gate detects the 6 condition and resets the counter by a low signal applied to $\overline{CLR}$.

The small time the counter spends in the 6 state is not a problem in this application, however, it is this resetting that goes wrong. It worked as required on a breadboard with its stray capacitance but only worked on a p.c.b. once an extra delaying capacitance was added in the form of C14.

On my unmodified p.c.b. version the count sequence was 0 1 2 3 0... (binary 0000 0001 0010 0011 0000). I suspect that the synchronous flip-flops in IC2 take slightly different times to settle, so after 0011 the next output could be 0111 for just long enough to trigger a reset, prior to settling at the steady state of 0100. Hence, the capacitor C14 slows down the transition of the bit C so that the intermediate combination does not occur.

Further investigation involved replacing IC2 with a ripple (asynchronous) counter which has the advantage that bit C is not clocked (low-to-high transition) until preceding bit B settles to zero (its high-to-low transition). Perfect function is observed without the need for C14.

Finally Dr. Manning adds a couple of questions:

Directly clearing the synchronous counter directly from output Y6 (omitting IC3A and C14) also works correctly. Is there some subtle timing/propagation delay in IC4 which means that it does not respond to the intermediate output value?

A final observation is that all chips tested behaved the same, but all were from the same manufacturer. Are such critical timing errors manufacturer-dependent? Thanks from ***Godfrey Manning, G4GLM***

Let's deal with the questions first. The response of digital circuits to (relatively) short duration pulses (glitches) is rather like the inertia of objects when they are pushed. Objects may or may not move when given a (relatively) gentle push (due to friction), and logic circuits may or may not respond when a glitch is applied to one of their inputs.

The "inertia" is different for different circuits, so it is quite natural to find that the NAND gate responds to the short duration intermediate state from the counter, whereas the decoder does not. This behaviour can be described as a subtle timing issue, but it is not an error. There is, however, another possible explanation for this behaviour, which we discuss later.

The response to glitches does not just vary between different circuit "designs" (e.g. NAND gate and decoder); it also varies between individual instances of circuits or gates (e.g. two individual decoder chips). Manufacturer's datasheets usually specify the typical delay and longest delay for the response of the logic chip. If a chip is *slower* than the *longest* delay specified, then it has not met the specification and you may have a right to replacement; however, there is usually no *minimum* delay specified so a particularly fast device is not usually regarded as being out of specification.

Therefore, two manufacturers could produce nominally the same i.c. type (74LS161 or whatever) and one manufacturer's devices could well be on average much faster than an other. Thus it is possible to find circuits that will work (at least most of the time) with one manufacturer's chips and fail (at least most of the time) with another's. In practice this is pretty rare, but it does happen.

The Chips Are Down

We know of cases where production lines have been halted due to almost 100 per cent failures of a circuit board after a change of chip manufacturer for a basic logic device, or after the chip manufacturer changed their production process and suddenly an i.c. was (for example) much faster than before. If the "new" chip is in specification then the board manufacturer has no claim against the chip manufacturer.

Such problems occur in circuit designs that are too sensitive to possible variations in circuit parameters (such as gate delay). Asynchronously resetting counters as shown in Fig.1 is an example of this – it is quite common practice, but it does not always work.

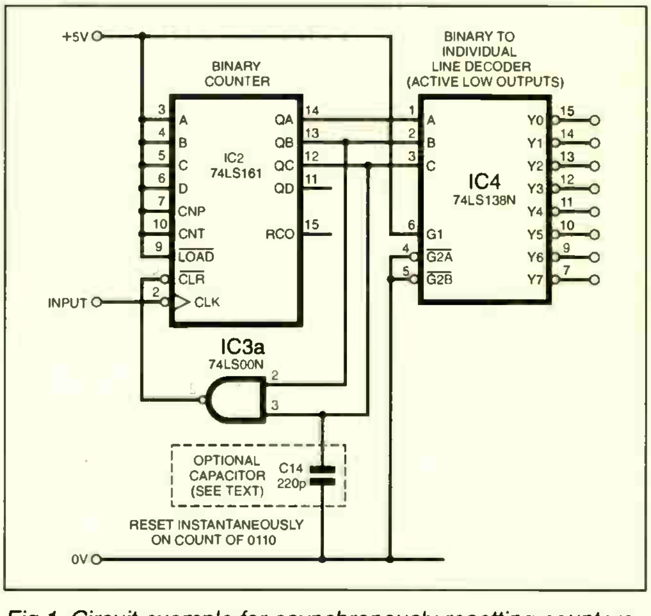


Fig.1. Circuit example for asynchronously resetting counters.

For mass-produced commercial electronic designs it is usually better to avoid such sensitivities, but for hobbyist designs, where typically only one copy of the circuit is made the fact that tweaks such as adding a capacitor can make the circuit work means that it is not so critical. Having said that, it is good practice for the amateur designer to try to avoid having to use tweaks, by designing a more robust circuit in the first place.

There are a few variations on Fig.1 that could help in this respect: one approach is to use a counter that is guaranteed not to produce a reset glitch on the wrong count. The reader's use of the asynchronous counter would appear to be a solution here, but it is a bit ironic as asynchronous counters are often avoided in circuits like this because of their tendency to produce glitches due to intermediate output states. Although it worked in this case it is not a general solution!

Bit of a Problem

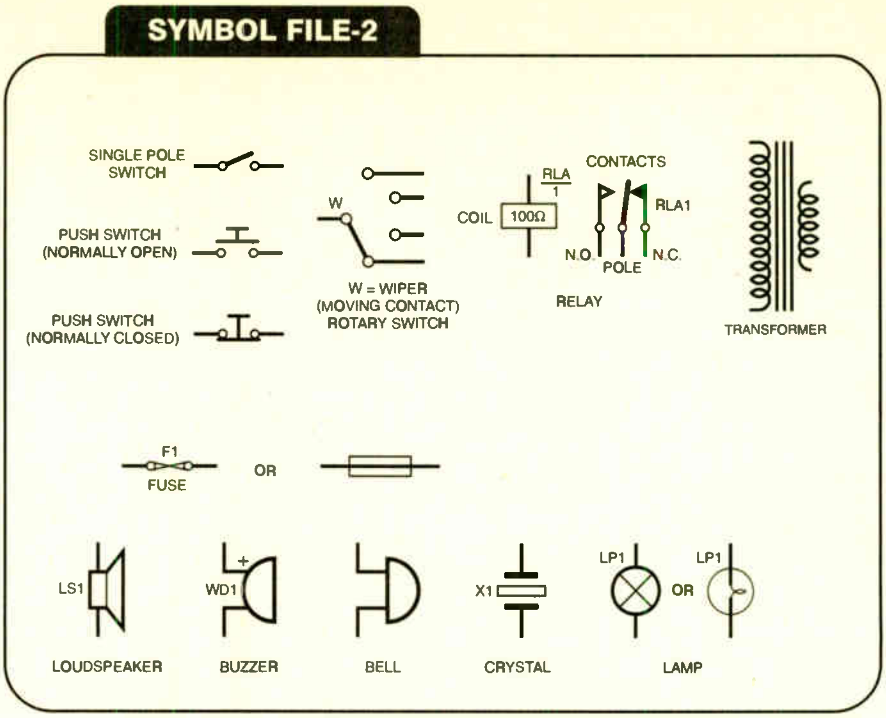
One potential problem with the circuit shown in Fig.1 is that the reset is produced by detecting bits B and C being equal to 1, irrespective of bit A. This allows the circuit to reset on a 0111 intermediate output as hypothesized by Dr. Manning.

If a three-input NAND gate were used to detect 0110, then the 0111 intermediate state would be unlikely to trigger the reset. Of course, the A bit would have to be inverted before connection to the NAND gate.

This may also be why using the Y6 output to reset the counter worked – the Y6 output from IC4 is decoded using all the counter's outputs so fewer intermediate states will decode as Y6. This may account for the variation in the circuit's behaviours using the IC3a and Y6 to drive the reset, rather than their different "inertias" as discussed earlier.

A more robust design is obtained by using a *synchronous* reset rather than the asynchronous one employed in Fig.1. The **74LS163** has such a reset, but is otherwise like the 74LS161. The circuit of Fig.1 could be modified to use a 74LS163 by changing the NAND gate (and inverter) to detect binary 5 (0101). A three input gate is needed, but the capacitor is not required.

When the counter is outputting 5, the $\overline{CLR}$ line will go low causing the counter to reset to 0000 *on the next clock*. Even better would be to connect Y5 to the 74LS163's $\overline{CLR}$. This would avoid the need for a NAND gate and inverter. In this circuit the counter would never go into the unused 6 state, even for a short time. *I.M.B.*



A selection of common circuit symbols.

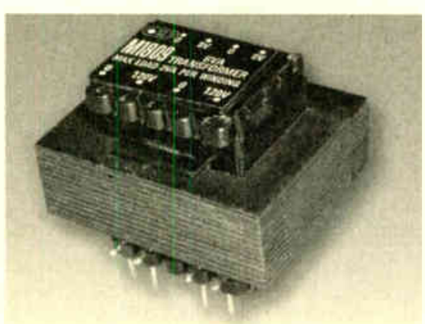
Simple Symbols

In last month's *Circuit Surgery* we described the basic technique of reading a circuit diagram. A circuit schematic is nothing more than a road map, with the towns and cities (electronic components) being interconnected by roads (conductors). We also said that a circuit diagram rarely contains the practical information that may be needed during assembly. Usually we cannot tell from the diagram what type of wire to use nor how to install it: is it handling a sensitive microphone signal or a 3kW heating element?

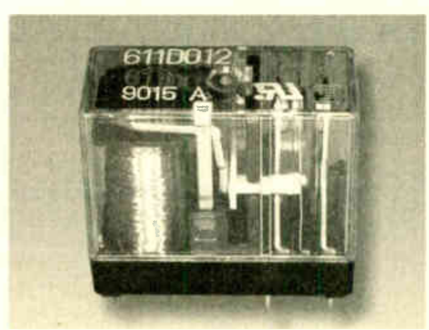
We must "read" the drawing to find out what is going on, and we must then refer to the constructional information provided. A roadway intersection (electrical junction) is represented by a blob on a circuit diagram – see Fig.1 on page 263 of the April 2003 issue for details. The constructional details will offer essential information that relates to cable specification, insulation and pinout information etc., so that you can ensure that parts are connected together properly and components are inserted the right way round.

In Symbol File-1 last month we showed the symbols for resistors and capacitors, including variations of those used in EPE. This month, more basic schematic information is given Symbol File-2 which shows the symbols that depict basic components including switches, fuses, transformers, buzzers, loudspeakers and more

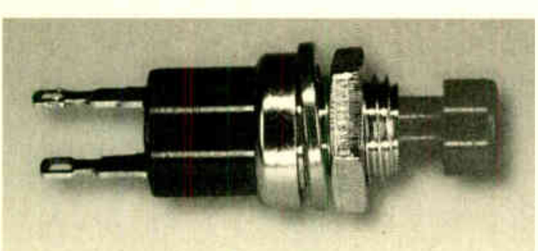
Rotary Switch, 2-pole 6-way



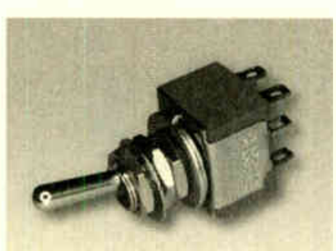
Mains Transformer, p.c.b. mounting



Relay



Pushswitch



Toggle Switch

Piezo sounder disc

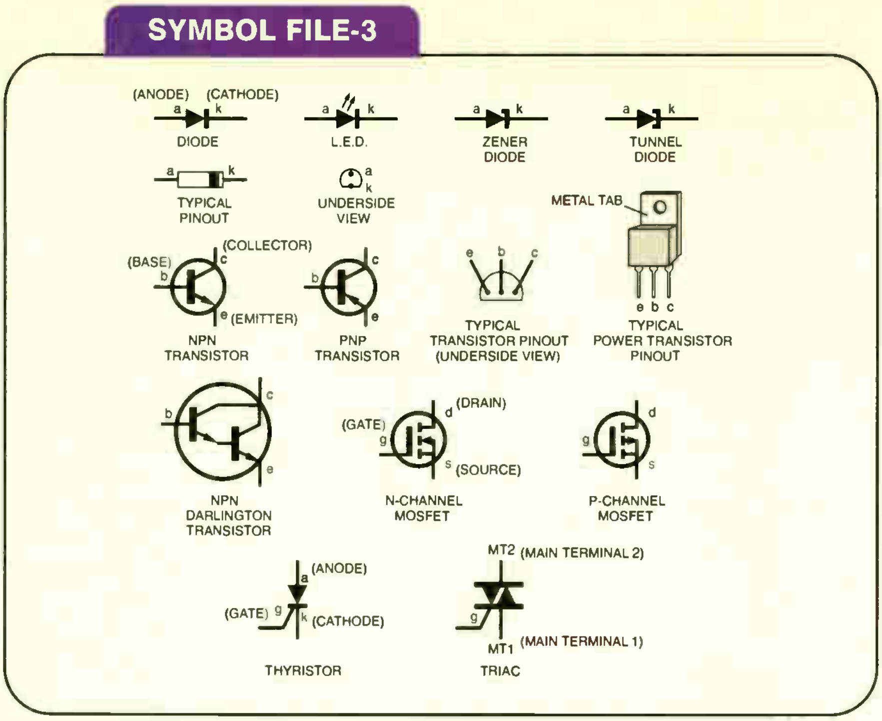


Fig.2. A selection of popular circuit symbols for semiconductors.

besides. With a little practice, you will soon be able to find your way around a circuit diagram and recognise all the major components used by the designer.

A Helping Hand

Devices such as resistors, inductors and capacitors are classed as "passive" components as they have no "electronic intelligence". However, almost every circuit uses "active" semiconductor components including diodes, transistors and integrated circuit chips.

Our experience tells us that the incorrect fitting of semiconductor devices causes a large proportion of circuit construction problems. Almost every semiconductor device requires connecting in a unique way if the circuit is to work successfully, and so in Symbol File-3 we show common semiconductor symbols, which can be compared against their physical pinouts and styles (see photos).

By adding extra information in circuit schematics, *EPE* helps constructors to understand diagrams. Starting with a diode, these have two terminals (anode and cathode), hence the *a* and *k* designations that are shown in our drawings. It is not uncommon to connect these the wrong way round – which may sometimes destroy the device!

Almost always, a stripe on the diode body indicates the cathode (k). (For an example, see the Atmospherics Monitor project last month, and compare the circuit diagram with the stripboard layout). This rule applies to most types of diode, including the Zener voltage reference device also shown.

Light-emitting diodes (l.e.d.s) find their way into many projects and again their terminal arrangement is described in a pinout drawing. Note that in this case the pinout is a worm's eye view of this device, i.e. *as seen looking from underneath the component*. A flat side on the body helps to determine the orientation of the l.e.d. (usually it marks the cathode).

Status Symbols

The symbols for *npn* and *pnp* (hence, "bipolar") transistors, along with a typical specialist "Darlington" transistor (which merely combines two transistors into one package to produce a much higher gain), are also given in Symbol File-3. The use of transistors is often a stumbling block for beginners in electronics, and again *EPE* helps you by labelling the pins *e*, *b*, or *c* for emitter, base or collector respectively in circuit diagrams.

The incorrect connection of transistors is a very common error made by novices, but mistakes can be avoided by comparing the pinout diagrams with the circuit diagram. Smaller low-power bipolar transistors are usually produced in a plastic package whilst power transistors are packaged in TO-3 steel cans or TO-220 plastic tab styles.

In the case of small transistors, pinouts are almost always seen as an **underside** view, but power devices may have a frontal view instead. Either way, identifying the correct polarity of a transistor is essential for successful construction. Fortunately the advent of the Internet means that data sheets can now be downloaded directly from manufacturer's web sites.

On then to MOSFET transistors, and the symbol for the common *n*-channel and *p*-channel devices are given in Symbol File-3. Note how the arrowhead points the other way, when compared with *npn* and *pnp* transistors! As usual, *EPE* designates the terminals (*d*rain, *s*ource and *g*ate) of MOSFETs in circuit diagrams. We described MOSFETs in more detail in the Jan. and Feb. '03 issues of *Circuit Surgery,* and a follow-up is in the pipeline.

Finally, to round off semiconductor circuit symbols, those for a thyristor and triac are shown, along with their terminal designations. It is worth pointing out that triacs are often associated with mains voltage control circuits, and therefore all constructional details must be followed closely, especially concerning the insulation aspects, in order to avoid any possibility of receiving accidental mains electric shock from the triac's metal mounting tab.

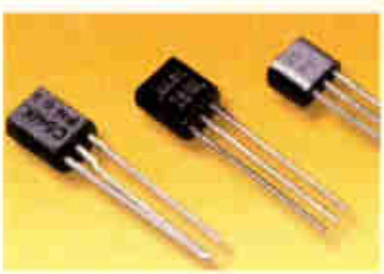
In the third part of our circuit diagram mini-series next month, we look at integrated circuits, followed by power rails and ground (earth) symbols and other considerations. *ARW.*

Diode, glass or plastic package

Power Triac, stud mounted

Red L.E.D.

Power Transistors



Transistors, plastic package

Transistors, metal can

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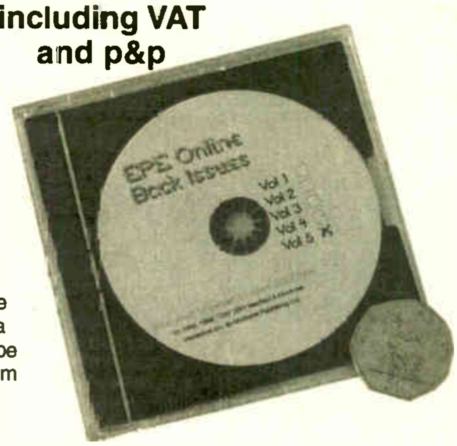

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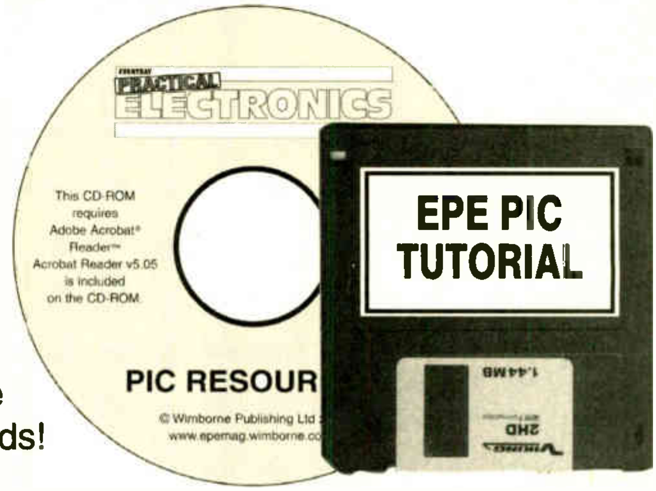

In this part we play with switches, make noises, count times, and generally have fun with some more PIC16F84 commands!

TUTORIAL 7

CONCEPTS EXAMINED

Switch monitoring
Command ANDLW
Command ANDWF
Command ADDWF
Command ADDLW
Nibbles
STATUS bit 1
Digit Carry flag
Bit code DC

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP21 to +5V OUT
CP20 to 0V OUT
Capacitor C7 as 1μF
Preset VR1 set to minimum resistance (fully clockwise)

From hereon we shall usually omit the program initialisation commands that have up to now been shown at the top of each listing. Some will be included where they help to clarify the program. Otherwise, assume that any name used in the listing extracts shown will have been defined or equated in the headings. The commands are included in full on the disk file program listings (source code).

We now turn to looking at how data is input via switches and shall continue to show the results on individual l.e.d.s. In Tutorials 21 and 22 we shall look at 7-segment l.e.d.s and alphanumeric l.c.d.s as the output displays.

First connect TK3's pushbutton switches SW0, SW1, SW2, SW3 (via CP19, CP18, CP17, CP16) to PORTA pins RA0, RA1, RA2, RA3 respectively. Connect the switch power pin CP21 to the +5V OUT pin, and switch power pin CP20 to the 0V OUT pin. Port pins RA0 to RA3 are now connected so that they are normally biased low (to 0V) but will go high (+5V) when their respective switches are pressed.

LISTING 8 – PROGRAM TK3TUT8

```
BEGIN   CLRF COUNT
LOOP    MOVF PORTA,W
        ANDLW B'00000001'
        ADDWF COUNT,F
        MOVF COUNT,W
        MOVWF PORTB
        GOTO LOOP
```

Run TK3TUT8.HEX. Pushing switch SW0 on and off, PORTB's l.e.d.s will be seen to go on and off in a binary sequence when the switch is on (pressed), but will remain in the last condition when the switch is off (released). In this example, the program tests whether the status of switch SW0, which is connected to PORTA RA0 (bit 0), is on or off. If the switch is on then the counter variable, COUNT, is repeatedly added to (by 1 in this example). A value of zero is added to the count if the switch is off. The count value is output to PORTB.

First let's look at two of the commands introduced here, ANDLW and ADDWF. Their counterparts ANDWF and ADDLW will also be examined.

COMMANDS ANDLW AND ANDWF

As no doubt most of you are aware, if one binary number is ANDed with another, then only if the same bits of both numbers are set (1) will the answer also have a 1 in that position. Any zeros on either or both sides for any bit will automatically produce a result of 0, e.g.:

First number:	01110010
Second number:	01011001
ANDed answer:	01010000

This technique is widely used in electronics and computing, the final answer determining the subsequent action to be taken by a circuit or software routine.

There are two ANDing commands available with PICs, ANDLW (AND Literal to W), and ANDWF (AND W with File value). Suppose that the first number in the foregoing examples (01110010) is already contained within W, we then wish to AND it with a fixed number as stated in a program command. Assuming that the fixed number is the second number quoted, the command is:

ANDLW B'01011001'

The PIC ANDs the second (literal) number with that already held in W. The answer (01010000) is retained by W and is available to be further manipulated or copied into any file as specified by the command which follows ANDLW. You could, for example, use the command MOVWF PORTB which will turn on l.e.d.s LD6 and LD4 (01010000).

Any of the three numerical formats may be used with ANDLW, e.g. B'00011111' (binary), H'1F' (hexadecimal), 31 (decimal), are all legitimate and equal. It is also legitimate to use a name that has been equated with a value, e.g. ANDLW PORTB (which would AND 6 with W since we have previously specified that the name PORTB represents the value 6).

The command ANDWF is used to AND an existing value within W to a value within a named file, either retaining the answer in W (ANDWF FILENAME,W) or putting back in the named file (ANDWF FILENAME,F).

It is not possible to directly AND the contents of two files together, the value of one or other file must have already been moved into W before the ANDing can take place. With both commands ANDLW and ANDWF, if the answer is zero, the Zero flag of STATUS is set. If the answer is greater than zero, the Zero flag is cleared. Zero is the only flag affected by an AND command.

COMMANDS ADDLW AND ADDWF

There are two ADDing commands available with PICs, ADDLW (ADD Literal to W), and ADDWF (ADD W to a File value). Command ADDLW is used where a fixed number (literal) within a program is to be added to an existing value within W and which has been obtained by a previous operation. Suppose that W holds the answer produced in the previous ANDing example, 01010000 (decimal 80), and you wish to add a fixed value to it, 53 decimal (00110101), for instance. The command would be:

ADDLW 53 (or ADDLW H'35' hexadecimal, or ADDLW B'00110101' binary).

The answer in this instance is 10000101 (decimal 133) and is retained in W for further use or copying into a file, e.g. MOVWF PORTB.

Command ADDWF adds the contents of W to the value within a stated file. The answer can be held in W (ADDWF PORTB,W) or put back into the named file (ADDWF PORTB,F).

Three flags within STATUS are affected by any ADD command, Carry, Zero and Digit Carry. If the answer to an addition is greater than 255, the Carry flag is set, otherwise it is cleared. If the answer equals zero, the Zero flag is set, otherwise it is cleared. The third flag, Digit Carry, you have not encountered yet. Although the concept is not illustrated until later (Tutorial 19), it is appropriate to describe it now.

If you imagine that an 8-bit binary number (e.g. 10110110) is split into two halves (known as "nibbles"), 1011 and 0110, the righthand nibble is monitored by the PIC as a separate digit and it is served by its own flag, the Digit Carry flag. If an addition takes place which produces a result greater than 15 (binary 1111) for that nibble, the Digit Carry flag is set, otherwise it is cleared.

LISTING 8 FLOW

Having described the new terms, we shall now detail what happens in Listing 8. As said at the start of Tutorial 7, switches SW0 to SW3 are biassed so that their respective PORTA pins are normally at 0V (low) but go high when pressed. In this example program, at the label LOOP the contents of PORTA are copied into W (MOVF PORTA,W), which then holds the status of all five usable bits of that port. We are only interested, though, in the status of the switch on PORTA bit 0, switch SW0. Therefore, in the next command (ANDLW B'00000001') bit 0 is ANDed with 1 to isolate its value, the other seven bits in W being cleared by the respective zeros of the ANDed value.

The answer in W is then added to the contents of the counter (ADDWF COUNT,F). Next, the contents of the counter are brought back into W (MOVF COUNT,W) and then copied into PORTB (MOVWF PORTB), whose l.e.d.s are turned on or off depending on the binary count value. With the command GOTO LOOP, the sequence is repeated.

It will be seen that there is only an increase in the count value if PORTA bit 0 holds a 1, therefore the count will only change if the switch is on (pressed). Pressing any other switch connected to PORTA has no effect. When the counter passes 255, its value rolls over to zero and starts counting upwards again.

EXERCISE 7

7.1. Can you see another way of writing the first two lines using MOVLW and ANDWF?

7.2. Can you see how the BTFSS or BTFSC commands might be used to achieve the same output result; the use of MOVLW 1 or ADDLW 1 could be useful here.

7.3. There is also the opportunity to use INCF in this type of situation. Try rewriting to include this command.

TUTORIAL 8

CONCEPTS EXAMINED

Increasing speed of TK3TUT8
Bit testing for switch status

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP21 to +5V OUT
CP20 to 0V OUT
Capacitor C7 as 1μF
Preset VR1 set to minimum resistance (fully clockwise)

LISTING 9 – PROGRAM TK3TUT9

```
LOOP      BTFSS PORTA,0
          GOTO LOOP
          INCF COUNT,F
          MOVF COUNT,W
          MOVWF PORTB
          GOTO LOOP
```

In TK3TUT8 we saw that the count adding commands etc. were performed even if the count value was zero. This is a waste of processing speed, why bother to add zero to a count? The program in Listing 9 shows a faster alternative. Run TK3TUT9.HEX.

By using the command BTFSS to check the status of a switch (in this case still SW0 on PORTA bit 0), if the switch is not pressed we can avoid the count incrementing procedure, jumping immediately to a further switch status test. Alternatively, in another program, by substituting another destination instead of LOOP, we could jump to a totally different routine and perform some other procedure.

Another choice is to use the command RETURN instead of GOTO LOOP to return to another routine which had called this one. Commands CALL and RETURN will be covered in Tutorial 13.

It is expected that you will recognise from Listing 9 what the program does and how it does it. If you don't, re-read Tutorial 4 and the section on BTFSS.

EXERCISE 8

8.1. What happens if you use BTFSC instead of BTFSS?

8.2. Could one of the Zero flag testing commands be used instead of BTFSS? If so, how, and would an AND command be useful? (Remember that PORTA has more bits than just bit 0).

TUTORIAL 9

CONCEPT EXAMINED

Responding to a switch press only at the moment of pressing

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP21 to +5V OUT
CP20 to 0V OUT
Capacitor C7 as 1μF
Preset VR1 set to minimum resistance (fully clockwise)

LISTING 10 – PROGRAM TK3TUT10

```
BEGIN     CLRF COUNT
          CLRF SWITCH
TESTIT    BTFSC PORTA,0
          GOTO TSTPRV
          BCF SWITCH,0
          GOTO TESTIT
TSTPRV    BTFSC SWITCH,0
          GOTO TESTIT
          INCF COUNT,F
          MOVF COUNT,W
          MOVWF PORTB
          BSF SWITCH,0
          GOTO TESTIT
```

In the switch press examples of Listings 8 and 9, we saw that the counter was incremented for the entire duration of the switch being on. Often, only a single response to a change of switch status might be required. This entails testing the switch status and comparing it with a previous test. Only if the switch is on and if that on condition has not yet been responded to will the next action be performed.

Load TK3TUT10.HEX. You are still monitoring PORTA bit 0 for the switch press (SW0), responding to it via the l.e.d.s on PORTB. Observe the l.e.d.s while pressing SW0 on and off. For each pressing, only one change of the l.e.d. count will occur (but note that low-cost switches may cause switch-bounce, resulting in the count increasing for each bounce – a matter covered later).

Study Listing 10: the entry to the routine is at BEGIN where two variables, COUNT and SWITCH are cleared. At the label TESTIT, the command is BTFSC PORTA,0, testing the status of PORTA bit 0 (is it clear?). Remember that we are only interested in the bit being set. If it is false that bit 0 is clear (i.e. that it is set – the switch is pressed) the command GOTO TSTPRV is performed and then the status of SWITCH bit 0 is tested, BTFSC SWITCH,0. This bit serves as the flag to keep track of the previous status of the switch. At this moment, the bit will be clear because the whole byte was cleared on entry to the routine. Consequently, the GOTO TESTIT command is skipped, the count is incremented and its value output to PORTB.

Now SWITCH bit 0 is set (BSF SWITCH,0) to indicate that the count has been incremented for this switch press (i.e. the flag is set), and the program jumps back to TESTIT. If the switch is still pressed, then at TSTPRV the BTFSC SWITCH,0 command will produce a false answer and the command GOTO TESTIT will be performed, thus preventing the counter from being further incremented at this time.

What is now needed is for the switch to be released so that the two commands BCF SWITCH,0 (clear the flag) and GOTO TESTIT can occur. The stage is then once again set for the next switch press to be responded to by the counter.

EXERCISE 9

9.1. In Listing 10, AND and MOV commands could have been used instead of BTFSC and BCF. How, and with what other command?

9.2. Would using BTFSS instead of BTFSC involve more commands and labels having to be used as well?

9.3. Because low cost switches have probably been used, there is the danger that mechanical switch bounce might occur, causing the count to be incremented undesirably. Another counter could be used to cause a delay in the rate of switch testing to eliminate the effects of switch bounce. How would you implement the delay, and where would you put the commands required. Hint, another label will be needed as well.

TUTORIAL 10

CONCEPTS EXAMINED

Performing different functions depending upon which of two switches is pressed

The use of a common sub-routine serving two other routines

CONNECTIONS NEEDED

All Port B to all l.e.d.s.

Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)

CP21 to +5V OUT

CP20 to 0V OUT

Capacitor C7 as 1μF

Preset VR1 set to minimum resistance (fully clockwise)

Run TK3TUT11.HEX and experiment with the switches on PORTA bits 0 and 2 (SW0 and SW2). You will discover that switch SW0 causes the count displayed on the l.e.d.s to be increased, and that switch SW2 decreases the count. The basic logic flow is the same as that in Listing 10, except that two switches are used and each switch is responsible for a different routine.

Note that whilst each switch could have had its own routine to output to PORTB, the two routines would be the same. Consequently, each switch routine is routed into a common output sub-routine (OUTPUT). At the end of SW0's routine, the command GOTO OUTPUT needs to be given, but at the end of SW2's routine, no GOTO OUTPUT command is needed because OUTPUT follows immediately after it. It is said to reach OUTPUT by *default* because it does not need to be told to go there.

LISTING 11 – PROGRAM TK3TUT11

```
BEGIN    CLRF COUNT
         CLRF SWITCH
TEST1    BTFSC PORTA,0
         GOTO TSTPR1
         BCF SWITCH,0
         GOTO TEST2
TSTPR1   BTFSC SWITCH,0
         GOTO TEST2
         BSF SWITCH,0
         INCF COUNT,F
         GOTO OUTPUT
TEST2    BTFSC PORTA,2
         GOTO TSTPR2
         BCF SWITCH,2
         GOTO TEST1
TSTPR2   BTFSC SWITCH,2
         GOTO TEST1
         BSF SWITCH,2
         DECF COUNT,F
OUTPUT   MOVF COUNT,W
         MOVWF PORTB
         GOTO TEST1
```

EXERCISE 10

10.1. How do you think a single test for *neither* of the switches being pressed could be introduced, shortening the testing time? Could an AND be used with a STATUS check, or can a STATUS check be used on its own without an AND? (Think carefully about the latter.)

10.2. How would you increase the count by more than one, say two, at each press of switch SW0? With the knowledge you've gained so far, three ways should come to mind, one of them including the use of a new named variable.

10.3. If you want to add 255 each time a switch SW0 press occurs, do you need an ADD command, or is there another command which will do the same job? (Think *rollover*.)

TUTORIAL 11

CONCEPTS EXAMINED

The ease of reflecting PORTA's switches on PORTB's l.e.d.s!

Command COMF

Command SWAPF

Inverting a byte's bit logic

Swapping a byte's nibbles

CONNECTIONS NEEDED

All Port B to all l.e.d.s.

Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)

CP21 to +5V OUT

CP20 to 0V OUT

Capacitor C7 as 1μF

Preset VR1 set to minimum resistance (fully clockwise)

Load TUT12.HEX. Experiment with pressing any combination of the four switches on PORTA (SW0 to SW3) while observing the l.e.d.s on PORTB. This routine should need no further comment. Another way of expressing the first two commands is:

```
LOOP     MOVLW B'00001111'
         ANDWF PORTA,W
```

LISTING 12 – PROGRAM TK3TUT12

```
LOOP     MOVF PORTA,W
         ANDLW B'00001111'
         MOVWF PORTB
         GOTO LOOP
```

Now load TUT13.HEX and run it, again experimenting with pressing any combination of the switches on PORTA (SW0 to SW3) and observing the l.e.d.s on PORTB.

LISTING 13 – PROGRAM TK3TUT13

```
LOOP     SWAPF PORTA,W
         ANDLW B'11110000'
         MOVWF PORTB
```

You will see while you press PORTA's four switches, that they are having their status displayed on PORTB's four lefthand l.e.d.s (LD7 to LD4), even though you have not changed the wiring to PORTB and the l.e.d.s. Had there been a fifth switch, on PORTA RA4, it would be affecting the first l.e.d. on the right (LD0) – if a different AND value were used (what value?).

What is happening is that the software has been told to swap and move into W (SWAPF PORTA,W) the left and righthand four bits of PORTA (its nibbles, as introduced in Tutorial 7). The answer is then ANDed with bits that reflect the swapped status in order to remove any possibility of influence by the unused bits of PORTA's register.

The SWAPF command is especially useful if the values of the two nibbles are required separately as values of up to 15 (00001111). A good example of its use will be seen in Tutorial 21. It is illustrated now because of its programming similarity to TK3TUT12 and TK3TUT14.

The F suffix can be used with SWAPF instead of W, as with other files discussed. There is no command which allows nibbles to be swapped once the byte is in W. If a byte within W needs swapping, it must be put out to a file, and then the SWAPF (FILENAME),W command given to bring it back into W.

Let's look now at another command which uses a similar demonstration routine to TK3TUT12 and TK3TUT13. Run TK3TUT14.HEX. Once more, experiment with pressing any combination of switches SW0 to SW3 while watching PORTB's l.e.d.s.

LISTING 14 – PROGRAM TK3TUT14

```
LOOP     COMF PORTA,W
         ANDLW B'00001111'
         MOVWF PORTB
         GOTO LOOP
```

You will now discover that instead of l.e.d.s being turned on when a switch is pressed, they are turned off, and vice versa. This is due to the command COMF, which automatically inverts each bit of a byte, 1s becoming 0s, 0s becoming 1s, i.e. it performs a task known as *complementing*, hence COMF, which means COMplement File.

There are several uses for this command, one of which is the situation when all the switches are biased to the +5V line instead of 0V. In that instance, and using the switch testing techniques shown earlier, pressing the switches would produce the wrong bit levels for the commands shown: switches would need to be held pressed for off, releasing them for on. Not an easy thing to do with push-switches!

Swap over the 0V and +5V connections to pins CP21 and CP20 so that PORTA pins RA0 to RA3 are biassed to +VE, going low when switches SW0 to SW3 are pressed. Run the program again. You will find that the l.e.d.s respond as they did for TK3TUT12. Now run TK3TUT12 again and confirm that the l.e.d. results are the inverse of that previously seen with it.

Another use for COMF is in subtraction. This is a concept for experienced programmers and will not be demonstrated here. In a nutshell, the use of COMF allows addition to be used instead of subtraction while still achieving the desired objective. This technique can be easier in some instances than using the available subtraction commands.

The F suffix can be used with COMF instead of W, as with other files discussed. There is no command which allows the inversion of a byte once it is in W. If a byte within W needs inversion, it must be put out to a file, and then the COMF (FILENAME),W command given to bring it back into W.

EXERCISE 11

With these exercises, reconnect the +5V connection to CP21 and 0V to CP20.

11.1 If SWAPF was not available as a command, how would you write a routine which produced the same result (would RLF or RRF be suitable commands)?

11.2 Rewrite TK3TUT13 and TK3TUT14, putting the contents of W out to a file of any name (which you must equate at the beginning of the program), performing another COMF or SWAPF action, and then bringing it back into W for output to PORTB. Can PORTB be used as the temporary file store in these rewrites?

11.3. Write a routine that allows the nibbles of a byte to be put into separate files and each having a value no greater than H'0F' (decimal 15); there are several ways of doing it.

TUTORIAL 12

CONCEPTS EXAMINED

Generating an output frequency in response to a switch press

The use of two port bits set to different input/output modes

Command NOP

CONNECTIONS NEEDED

All Port B to all l.e.d.s.

Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)

Port A RA4 connected as in Fig.3 (audio connection)

CP21 to +5V OUT

CP20 to 0V OUT

$1\mu F$ capacitor C7 omitted (from hereon)

Preset VR1 set to minimum resistance (fully clockwise)

LISTING 15 – PROGRAM TK3TUT15

```
SOUND     MOVLW 80
          MOVWF NOTE
          MOVWF FREQ
GETKEY    BTFSS PORTA,0
          GOTO GETKEY
          DECFSZ NOTE,F
          GOTO GETKEY
          MOVF FREQ,W
          MOVWF NOTE
          MOVLW B'00010000'
          ADDWF PORTA,F
          GOTO GETKEY
```

So far we have been outputting data to l.e.d.s, and at a comparatively slow rate. We have also been using one port as a switch input and the other port as the output. Here we examine how the same port can be used simultaneously for input and output via different bits. In doing so, we use sound as the medium by which we indicate the status of a switch, generating an audible frequency when it is pressed.

The $1\mu F$ capacitor used up till now for C7 should be omitted from hereon.

Connect a 330Ω resistor between RA4 and the +5V connection at CP21. Pin RA4 is an open-collector pin and this resistor biasses it so that an output can be generated on it. Connect a $1\mu F$ capacitor with its positive lead on the junction of RA4 and the resistor. Connect the negative lead of the capacitor to the signal terminal of a jack socket that suits your personal (high-impedance) headphones (see Fig.3).

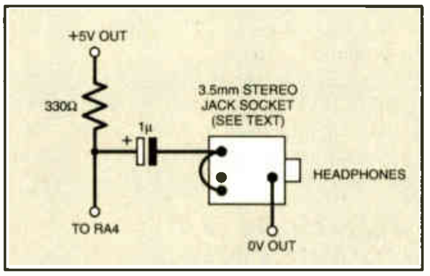

Fig.3. Audio output connections.

Do not connect a loudspeaker directly to this circuit as there is insufficient power to drive it.

Load TK3TUT15.HEX and press switch SW0 on and off. A frequency tone will be heard when the switch is pressed.

In the initialising statements at the head of the full TK3TUT15.ASM program, PORTA has been set with bits 0 to 3 as inputs and bit 4 as an output (MOVLW B'00001111', MOVWF TRISA). You should now recognise all the commands given in the heart of the program shown. Only a general commentary on what happens is now given.

On entry into the routine headed SOUND, a value of 80 is loaded into the files named NOTE and FREQ. The value is arbitrary as far as this demonstration is concerned. You may choose any other from 1 up to 255; the lower the value, the higher the frequency generated.

PORTA's status is monitored at GETKEY and the setting (logic 1) of PORTA bit 0 by switch SW0 is being looked for. Switch testing is repeated until SW0 is pressed, setting RA0 high. When that occurs, file NOTE is decremented and its zero status tested. If it is not yet zero, the routine jumps back to the switch test.

When the switch has been pressed for long enough (mere thousandths of a second), NOTE will eventually reach zero, at which point the command MOVF FREQ,W is reached, followed by the fixed value of FREQ being reset into NOTE. Next, the value in PORTA has 16 (binary 00010000) added to it to increment the count at bit 4 (so alternating the bit between 0 and 1), and then there is a jump back to further switch testing.

For as long as switch SW0 is pressed, PORTA bit 4 will be periodically incremented. The speed at which the routine runs causes this bit to change at the audio frequency rate to which you are listening. If you adjust the rate setting preset, VR1, you will hear the change in the resulting frequency.

In a real-life situation, of course, the operating frequency of the system would normally be fixed. One frequency correction choice then is to change the value of FREQ.

There is, though, another factor that will affect the resulting audio frequency: the number of commands within the controlling loops. To illustrate the point, let's change the number of commands involved.

You may think that to add more commands would be difficult, what would they do which would not interfere in the completion of the loop? Well, there are several options, such as repeating some of the existing commands, MOVF FREQ,W for example, or MOVWF NOTE. Neither of these commands would actually change anything, except for the rate of operation. However, a tailor-made command is already available in the PIC's command codes which is intended for use where minor delay tactics are needed, command NOP.

COMMAND NOP

Command NOP simply stands for No OPeration. Responding to this command takes the PIC just as long as responding to any other single-cycle command but its response is to just do nothing!

This command, then, can be used here to slow down the resulting note frequency. Insert it immediately before DECFSZ NOTE,F. When running the amended program you will notice that a change in the output frequency has occurred.

EXERCISE 12

12.1. Experiment with different values for FREQ. What happens if you set FREQ to zero – does it stop a note being generated? Explain the result.

12.2. Experiment with more than one NOP command in the loop.

12.3. At which other places can you alternatively insert NOP, and is the frequency change still noticeable?

12.4. Are there any places where you cannot use NOP?

12.5. When the audio frequency is not being generated there is the likelihood that RA4 will be set low, so sinking current through the 330Ω resistor. Can the program be modified so that this cannot occur.

TUTORIAL 13

CONCEPTS EXAMINED

Command CALL
Command RETURN
Command RETLW

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP21 to +5V OUT
CP20 to 0V OUT
Preset VR1 set to minimum resistance (fully clockwise)

LISTING 16 – PROGRAM TK3TUT16

```
LOOP    CALL PROG1
        MOVWF PORTB
        GOTO LOOP
PROG1   MOVF PORTA,W
        RETURN
```

Before looking further into sound generation, there are several commands that we should examine. Three of those are associated with calling sub-routines: CALL, RETURN and RETLW.

Load TK3TUT16.HEX and experiment with pressing different combinations of switches SW0 to SW3 while observing PORTB's l.e.d.s.

COMMANDS CALL, RETURN AND RETLW

Programs can be written as a series of sub-routines which can be reached in one of three ways, directly by default (without being told to go there), via a GOTO command, or by a CALL command. (Routing following automatic detection of an interrupt event is another matter and is discussed later.)

We have shown several examples of the first two. Program TK3TUT4 (Tutorial 4) uses them both: the sub-routine LOOP1 is entered directly following the initialisation routine. LOOP2 is also entered directly from the end of LOOP1. Both LOOP1 and LOOP2 are then further accessed by GOTO commands.

However, a CALL command can be used if one routine needs to make use of another and then once that has been completed, for the program to jump back to continue from the command that follows the call. The use of sub-routines allows the same routine to be accessed from many other areas within the overall program, so saving on program space.

A second command always has to be used before the program returns to the calling origin. That command takes one of two forms, RETURN (which is an obvious command – return to where you came from) or RETLW (RETurn to where you came from with a Literal value held in W). There is a third return command, RETFIE, which we shall meet later in connection with interrupts.

A GOTO command can never be used to end a sub-routine call – the PIC will continue to expect a return command and, if repeated calls to a sub-routine are made without a RETURN or RETLW command, it will become confused and unpredictable results could occur. For example, the following is "illegal":

```
PROG1  CALL PROG2
       GOTO PROG1
PROG2  GOTO PROG1
```

This is "legal", though:

```
PROG1  CALL PROG2
       GOTO PROG1
PROG2  RETURN
```

When the program returns from a CALL following a RETURN command, the contents of W are those which were put there by the last command which used W. Consequently, you can perform a complex sub-routine, end up with an answer in W and, using the RETURN command, return to the main program with that result still retained in W.

Command RETLW, though, returns to the main program with W holding the value which RETLW has acquired as part of that command. A literal value is always specified as part of the RETLW command, e.g. RETLW 127 or RETLW 0. That value replaces any other value within W and is the one which is held in W on the return to the calling point. The value may be expressed in decimal, hexadecimal, binary or as a "named" value equated during program initialisation.

To explain Listing 16 then, at LOOP the sub-routine at PROG1 is CALLed from where the value held in PORTA is moved into W. A return is made to the loop where the next command to be performed is MOVWF PORTB, after which the GOTO LOOP command again takes us back to CALL PROG1 again.

It is important to be aware that PICs have a limit to the number of calls that can be nested (calls being made from within calls). This is due to the PIC's Stack (the area that monitors the return addresses when calls are completed) being limited to only eight address values. If the Stack receives more than eight addresses it will over-write the earlier ones, causing a program crash.

There is no way to read or write to the Stack or to determine how full it is. It is therefore imperative that if you are using nested calls then you must keep very careful track of how many you are using. In such cases consider whether you could achieve the same result by using GOTO commands for some of the calls, or by returning to the previous calling routine before making the next call.

Run program TK3TUT16 and confirm that l.e.d.s LD0 to LD3 respond as expected to the pressing of the four switches.

EXERCISE 13

13.1. Rearrange TK3TUT16 so that reading PORTA is in the main loop and outputting data to PORTB is in the called routine.

13.2. Try adding other commands in the subroutine, such as AND or ADD.

13.3. Use RETLW as the final statement in the subroutine, using any literal value of your choice, verifying its operation!

TUTORIAL 14

CONCEPTS EXAMINED

Tables
Register PCL (again)
Register PCLATH

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP21 to +5V OUT
CP20 to 0V OUT
Preset VR1 set to minimum resistance (fully clockwise)

LISTING 17 – PROGRAM TK3TUT17

```
          BANK0
          GOTO LOOP
TABLE     ANDLW B'00001111'      ; AND W with 15
          ADDWF PCL,F            ; ADD to PCL
          RETLW 255              ; 0  11111111
          RETLW 1                ; 1  00000001
          RETLW '5'              ; 2  00110101
          RETLW 0                ; 3  00000000
          RETLW 31               ; 4  00011111
          RETLW 193              ; 5  11000001
          GOTO OTHER             ; 6  00100000
          RETURN                 ; 7  00000111
          RETLW B'10101010'      ; 8  10101010
          RETLW H'C7'            ; 9  11000111
          RETLW 'A'              ; 10 01000001
          RETLW 65               ; 11 01000001
          RETLW 'B'              ; 12 01000010
          RETLW 'x'              ; 13 01111000
          GOTO OTHER1            ; 14 10001110
                                 ; or 10011110
          MOVF STORE,W           ; 15 00000000
          RETURN
LOOP      MOVF PORTA,W
          CALL TABLE
          MOVWF PORTB
          GOTO LOOP
OTHER     RETLW STORE
OTHER1    MOVLW 128
          ADDWF PORTA,W
          RETURN
```

The use of look-up tables, whose tabulated commands or values are determined by a value set elsewhere in a program, is of enormous benefit. Tables depend on the use of the Program Counter (PCL – discussed in Tutorial 4) and the commands CALL, RETLW, RETURN and GOTO. They can be used with other calls within them, but this usually requires making additional commands prior to accessing the table. When a table is accessed, the value already held in W is added to PCL and causes the program to jump forward by the same number of program commands as are in W. The command at the jump address is then performed.

Load TK3TUT17.HEX, run it and experiment by pushing switches SW0 to SW3 in any combination while observing the l.e.d.s. on PORTB. The l.e.d.s should come on according to the binary value shown in the comments column of Listing 17, i.e. all l.e.d.s will be on if no switch is pressed.

In TK3TUT17, the instruction BANK0, although individually stated in the extract shown here, follows the initialisation in the normal way. After initialisation, and before any tables are encountered, the command GOTO LOOP bypasses the table commands. Failure to bypass them would cause confusion to the PIC.

At the first command of LOOP, switch data from PORTA is brought into W. The CALL TABLE command then routes the program to the first command within the table, ANDLW B'00001111' (decimal 15).

The AND command is essential here to limit the possible value which can be added to the Program Counter (PCL). Although only the four switches SW0 to SW3 are in use, in another situation another switch might be connected to pin RA4, and so the binary value at PORTA could be greater than 15 (all five switches on = 11111 binary = 31 decimal) and we also know that the number of "routing" commands within the table is 16 (0 to 15). If the table were to be given a value greater than 15, the additive PCL address jump would cause the program to jump beyond the boundary permitted, with unpredictable results. The ANDing could, alternatively, have been done immediately prior to CALL TABLE.

OMITTING THE AND COMMAND

There are circumstances when the AND statement is not needed. For example, if it is known that the value present in W on the call can never be greater than five, AND would not be needed and the table could be limited to six jump options only (remember that 0 counts as a jump value). However, if in doubt about the maximum value that could be in W, always use a value limiter of some sort (techniques other than AND can be used).

This limiting is especially necessary when a program is being developed since errors in other regions of the program could result in an excessive W value, resulting in a system "crash". When consequential crashes of this type occur, it can be difficult sometimes to establish the primary cause of the problem which is elsewhere.

At the command ADDWF PCL,F the ANDed value remaining in W is added to the Program Counter and the command within the table which corresponds to the new address is performed. For clarity, W's entry value is shown alongside each of the 16 table jumps.

If the W value is 0, then the command performed within the table is the first one (0), RETLW 255. As instructed, the program now returns to the calling point with 255 in W. If the value added to PCL is 5, the command performed is RETLW 193. In all instances of the RETLW command within the table, the stated literal value is copied into W and the return is made. You will see that, as with other xxxLW commands, the literal value can be expressed in decimal, hexadecimal, binary or equated name values.

What you have not encountered yet is the use of characters in single quotes. Any standard ASCII character from the full 0 to 255 set can be entered in this way, numbers, upper or lower case letters, symbols, etc.

During assembly, any character within the quotes is translated into its ASCII value and it is that value which is returned in W. (In reality, a lot of the ASCII codes will not be available on your keyboard.) Note that only the "apostrophe" type of quote is permitted ('), that normally residing on your keyboard between the semicolon (;) and the hash symbol (#). The double-quote symbol (") is not permitted, nor is the "left-hand" single quote (`) found on many keyboards (to the left of numeral 1 and the exclamation mark).

Four examples of "quoted" characters are shown in the table. Quoted '5' will be translated as ASCII 53 (not as the value 5); 'A' and 'B' will become ASCII 65 and 66 respectively; lower case 'x' will be returned as ASCII 120. You will find this conversion technique invaluable when compiling tables of messages for output to an alphanumeric l.c.d. (Tutorial 22).

The simple command RETURN at jump 7 will cause the current value already within W to be returned; i.e. the value on the switches after it has been ANDed with 15. It may not be immediately clear what this action would achieve, but an example is given in Tutorial 15.

TABLED GOTO

There are two examples of a tabled GOTO command in Listing 17, at jumps 6 and 14. These cause the program to jump to the sub-routines named, OTHER and OTHER1. At OTHER, the command MOVLW STORE is executed, after which the program returns to the calling program (not back into the table) with the equated address value of STORE (see full ASM listing).

The routine at OTHER1 shows how a table jump can go to a routine in which more than one action can be performed, in this case adding 128 to the value at PORTA, then returning as usual. Any action can be performed here, on any file, for any purpose, and there is no limit to the number of commands performed before the final RETURN (within the program space available, of course).

The command at table jump 15 is interesting. It looks as though a command other than GOTO, RETURN or RETLW is being performed. However, this jump is the last in the table and so it is perfectly legitimate to perform any other action(s) here since the program will automatically follow them through without interfering with the normal table action.

Here the simple action of getting the value held in STORE is performed, immediately followed by a RETURN. Note that the value returned from jump 15 may not necessarily be zero as shown, since STORE has not been given any value when the program is initialised and so could take any random value between 0 and 255.

What would cause table difficulties is if the command at a mid-table jump did not allow an immediate exit from the table. For example, consider the following mid-table jump commands:

```
RETLW 0          ; 3
MOVF STORE,W     ; 4
RETLW 193        ; 5
```

Jump 3 would be OK, so would jump 5. Jump 4, though, would perform MOVF STORE,W (bringing the value within STORE into W), but the exit route for that command is via the address of jump 5, which is RETLW 193, immediately replacing the value acquired in jump 4 with the value 193. Not very helpful!

Mind you, the commands GOTO or RETURN could be at jump 5, which would be fine for jump 4, but what of the result of actually jumping to jump 5, would you necessarily want to just RETURN or GOTO?

One could, perhaps, envisage a table consisting only of INCF STORE,F commands, for example, in which the number of increments generated would be the equivalent of the entry point value of W. But the use of a loop or an addition would, though, probably be more appropriate to that requirement.

It is legitimate to GOTO a table, or arrive at it from the end of another routine, but in this case it may be necessary to only exit the table by GOTO commands. Unless you are already in the middle of a call, "return" commands will cause a program crash.

Advanced use of Tabled GOTOs is discussed by Malcolm Wiles in his feature *PIC Macros and Computed GOTOs* of *EPE* Jan '03 – this is on the PIC Resources CD-ROM.

TABLE SPAN

There is a significant restriction on tables which must not be overlooked. Because of the way in which the Program Counter handles the calls to and from tables, all of the tabulated data must be contained within the first 256 addresses of the program (0 to 255). Not a single jump address must fall outside this block (except as discussed in a moment).

When writing software, it can sometimes be difficult, depending on program structure, to ascertain from the code editing program (word-processing software) whether or not the tables overlap beyond the block. If this is the case, come out of the WP package and assemble the code. Don't send it to the PIC, but come back into the WP and examine the .LST file that has been generated for the program as it now stands. Look at the address numbers (in the third column as you saw earlier in Listing 3A) and see if any part of the table(s) occurs beyond the H'00FF' hex address (decimal 255). Any overlap beyond (even H'0100' – 256 decimal) is unacceptable.

PCLATH

Advanced programmers do have a way round the table block limit should they need to find one. It is through the use of the PCLATH register which allows additional 256 byte blocks to be used elsewhere in the program. This command will, of course, be useful if the total number of tabulated items is greater than 256. Being an advanced programmer's command, we shall not illustrate PCLATH here. Interested readers are referred to John Waller's *Using the PIC's PCLATH Command* in *EPE* July '02 – again it is on the PIC Resources CD-ROM.

With both the "normal" and PCLATH modified table areas there is no limit to the number of tables within them, and the calling routines can be anywhere within the program, start, middle or end. It is perfectly legitimate to have sub-routines placed between different tables, but remember that their length also consumes part of the 256 byte block.

EXERCISE 14

14.1. Write a routine that calls a table which multiplies a binary number by seven. Use the switches as the source of that number (pressing more than one switch as necessary) and restrict it to between 0 and 7, showing the results on PORTB's l.e.d.s.

14.2. Create a table to convert the binary numbers generated by the switches (multiple pressing again) to a BCD (binary coded decimal) format; tens of units in the left four l.e.d.s, units in right four l.e.d.s. (If you are not familiar with BCD, think about what it might mean and how it might be shown on l.e.d.s. The use of BCD formats is discussed in Tutorial 19.)

TUTORIAL 15

CONCEPTS EXAMINED

Using four switches to create four different notes

Use of a table to selectively route program flow

CONNECTIONS NEEDED

All Port B to all l.e.d.s.

Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)

Port A RA4 connected as in Fig.3 (audio connection)

CP21 to +5V OUT

CP20 to 0V OUT

Preset VR1 set to minimum resistance (fully clockwise)

The program in Listing 18 allows any one of four notes to played by the switches on PORTA RA0 to RA3 (SW0 to SW3). As with Tutorial 12, the audio output is on RA4. Reconnect your audio monitor, load TK3TUT18.HEX and press some switches. You will immediately notice that the "note" frequencies belong to no musical scale known to man. There is nothing we propose to do about that, we are interested in more mundane matters!

The object of this program is to show the use of a table and several sub-routines which allow four notes to be played (singly) depending on the switch presses. Multiple pressing of switches is ignored.

To conserve page space only one note routine is shown. The others are identical except that they process different notes and PLAY4 omits the GOTO OUTPUT command since OUTPUT immediately follows its final command. You will see the now-familiar commands in the GETKEY and PLAY1 routines. The table should seem recognisable as well.

As in Listing 17, when the program first starts, the table is bypassed and the first main command is at PRESET. Here the frequency values for the four notes are set up as NOTE and FREQ variables.

Switches are monitored as before and calls made to the table. There, routing to different notes occurs only if individual switches are pressed (jumps 1, 2, 4, 8). Any other switch setting, including none, results in a return to the calling point.

When the selected note routine has been processed, a jump to OUTPUT occurs from where the output pin RA4 is toggled, causing a note to be heard. A RETURN command follows, returning the program to the calling point.

Even from this cut-down version of the program, it is apparent that a lot of commands are involved and that many of them are similar (PRESET) or even identical (PLAY by four).

You will also see that only five calls to the table achieve useful results. The others are wasted but have to be included because four switches can generate 16 permutations of settings. You can't just say to the musician "never press more than one key at once", you have to allow for human fallibility. If an error can be made by the program user, it will at some time *be* made – Murphy's Law. Programmers must always think about what *might* happen and write the software accordingly (making it "user-friendly" is another way of putting it!).

The programmer must usually also think about program speed and program compactness. Sometimes they can both achieve the same result, but not always. However, for the sake of discussing program options available, in a moment we'll look at how TK3TUT18.ASM could be written in another way. First an exercise for you:

EXERCISE 15

15.1. Try to change the frequency values in TK3TUT18.ASM to produce notes that are somewhat more harmonically related! What problems do you come up against?

TUTORIAL 16

CONCEPTS EXAMINED

Indirect addressing
Using unnamed file locations
Register FSR
Register INDF

LISTING 18 – PROGRAM TK3TUT18

```
TABLE     ANDLW B'00001111'
          ADDWF PCL,F
          RETURN          ; 0
          GOTO PLAY1      ; 1
          GOTO PLAY2      ; 2
          RETURN          ; 3
          GOTO PLAY3      ; 4
          RETURN          ; 5
          RETURN          ; 6
          RETURN          ; 7
          GOTO PLAY4      ; 8
          RETURN          ; 9
          RETURN          ; 10
          RETURN          ; 11
          RETURN          ; 12
          RETURN          ; 13
          RETURN          ; 14
          RETURN          ; 15

PRESET    MOVLW 80
          MOVWF NOTE1
          MOVWF FREQ1
          MOVLW 110
          MOVWF NOTE2
          MOVWF FREQ2
          MOVLW 140
          MOVWF NOTE3
          MOVWF FREQ3
          MOVLW 160
          MOVWF NOTE4
          MOVWF FREQ4
GETKEY    MOVF PORTA,W
          CALL TABLE
          GOTO GETKEY
PLAY1     DECFSZ NOTE1,F
          RETURN
          MOVF FREQ1,W
          MOVWF NOTE1
          GOTO OUTPUT
  (PLAY2 to PLAY4 are similar to
PLAY1)
OUTPUT    MOVLW B'00010000'
          ADDWF PORTA,F
          RETURN
```

LISTING 19 – PROGRAM TK3TUT19

```
TABLE     ANDLW B'00000011'
          ADDWF PCL,F
          RETLW 10
          RETLW 20
          RETLW 40
          RETLW 80

SETUP     MOVLW 4
          MOVWF LOOPA
          CLRF COUNT
          MOVLW NOTE1
          MOVWF FSR
SETUP1    MOVF COUNT,W
          CALL TABLE
          MOVWF INDF
          INCF FSR,F
          INCF COUNT,F
          DECFSZ LOOPA,F
          GOTO SETUP1
GETKEY    MOVF PORTA,W
          ANDLW B'00001111'
          MOVWF STORE
          MOVLW 4
          MOVWF LOOPA
ROTATE    BTFSC STORE,3
          GOTO PLAY
          BCF STATUS,C
          RLF STORE,F
          DECFSZ LOOPA,F
          GOTO ROTATE
          GOTO GETKEY
PLAY      DECF LOOPA,W
          ADDLW NOTE1
          MOVWF FSR
          DECFSZ INDF,F
          GOTO GETKEY
          DECF LOOPA,W
          CALL TABLE
          MOVWF INDF
OUTPUT    MOVLW B'00010000'
          ADDWF PORTA,F
          GOTO GETKEY
```

CONNECTIONS NEEDED

All Port B to all l.e.d.s.

Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)

Port A RA4 connected as in Fig.3 (audio connection)

CP21 to +5V OUT

CP20 to 0V OUT

Preset VR1 set to minimum resistance (fully clockwise)

Time now to examine a concept that allows us to access generalised routines which can manipulate file values without actually specifying the file names within them. This concept is called "Indirect Addressing". It also has profound implications for the ability to minimise the number of sub-routines required by a program. Program TK3TUT19, which uses the technique, will then be discussed and demonstrated.

Indirect Addressing allows the use of generalised routines which do not apply to any specific files. The file which the routine accesses is specified prior to entry into the routine and can be changed at will to suit different aspects of the program.

COMMANDS FSR AND INDF

The two key commands (or, rather, "file registers") in Indirect Addressing are FSR (File Special Register) and INDF (INDirect File). The idea of Indirect Addressing is that you place the address of the file that you wish to access in file FSR. Commands to access the specified file address are then made via file INDF.

Not only does this facility allow the same routine to be applied to different calling routines, it also allows a loop to access a sequence of files without having to specify their individual addresses other than that for one of them in the sequence.

In the following example, assume that we have a sequence of files between addresses H'20' and H'2F' (16 files). Let's call the first file FILE0. Its address will have been equated at the head of the program in the usual way. However, provided we assume the next three addresses to be reserved for 15 files which are consecutive to FILE0, we do not have to give them names unless we actually need to use the names in the body of the program. Even then the names could be anything we like; they do not have to called FILE1, FILE2 etc., unless we wish to.

Suppose, for example, we wished to clear all 16 of these files prior to another routine and that we shall do it in ascending order using a loop. Prior to entering the loop we get the address of the first file, in this case FILE0, copy it into FSR and reset the loop counter, let's call it LOOPA:

```
        MOVLW FILE0
        MOVWF FSR
        CLRF LOOPA
```

Now all we need to do is use the following simple routine:

```
RESET   CLRF INDF,F
        INCF FSR,F
        INCF LOOPA,F
        BTFSS LOOPA,4
        GOTO RESET
```

Command CLRF INDF,F clears the file whose address is held in FSR. Next, INCF FSR,F increments the value held by FSR, in other words FSR is incremented to point to the next file we wish to clear (FILE0 in the first instance of the loop, FILE1 in the next). Next, we increment the loop counter, INCF LOOPA,F, and test its bit 4 (BTFSS LOOPA,4) to see if a count value of 16 (00010000) has been reached (remember we started at 0). If the count is not yet 16, the loop is repeated, GOTO RESET. If the count equals 16, the next command after GOTO RESET is performed, whatever that might be in a full program. Another way of doing it (and there are several ways) is:

```
        MOVLW FILE0
        MOVWF FSR
        MOVLW 16
        MOVWF LOOPA
RESET   CLRF INDF,F
        INCF FSR,F
        DECFSZ LOOPA,F
        GOTO RESET
```

You can also use similar constructions to access a sequence of table values (from anywhere within that table) and add them to the values within a sequence of indirectly addressed files, keeping the maximum resulting addition to less than the maximum number of temporary registers that the PIC provides.

In the following example (nothing directly to do with TK3TUT19), the first address required in the table is at jump 3. This value is first placed into COUNT (MOVLW 3, MOVWF COUNT). We want to start adding the acquired table value to the file starting six bytes beyond FILE0 so the value of 6 is then added to the address of FILE0 and the result placed into FSR (MOVLW 6, ADDLW FILE0, MOVWF FSR). We also want to perform the action five times, once for each note, so a loop (LOOPA) is set up with the initial value of 5 (MOVLW 5, MOVWF LOOPA).

The real action then starts at label GETVAL. The current value held in COUNT is copied into W (MOVF COUNT,W). The table is called (CALL TABLE) and value held in the table at the location indicated by the value in W is retrieved from the table, being automatically placed into W. The value from the table now in W is then added to the value in the file held via INDF and pointed to by FSR, and the result is stored back into the same file (ADDWF INDF,F). File FSR is now incremented (INCF FSR,W), so incrementing the address of the file held via INDF. Count is incremented (INCF COUNT,F), and LOOPA is decremented. If LOOPA is not yet zero the process repeats.

```
        MOVLW 3
        MOVWF COUNT
        MOVLW 6
        ADDLW FILE0
        MOVWF FSR
        MOVLW 5
        MOVWF LOOPA
GETVAL  MOVF COUNT,W
        CALL TABLE
        ADDWF INDF,F
        INCF FSR,F
        INCF COUNT,F
        DECFSZ LOOPA,F
        GOTO GETVAL
```

INDIRECT ADDRESSING DEMONSTRATED

In the following worked example, part of whose program is shown in Listing 19, we demonstrate how Indirect Addressing allows generalised file accessing routines to be used, how a table can help in that process, and how it helps code to be compacted to achieve more actions within the space available. Because only four switches are available, the program is limited to four notes, but if more switches were to be added somehow, the process could readily be extended to suit.

With your audio monitor still connected, load TK3TUT19.HEX and play with the four push-switches on PORTA (SW0 to SW3). You will find that all four switches produce "notes", but not musically tuned, though! The technique used is, in effect, the same as that demonstrated in TK3TUT18. There are, though, some notable (no pun!) differences:

First, if you look at the full listing on your disk, you will see that in the initialisation, we have only equated NOTE1 and there is no mention of FREQ1 etc. Yet, we are actually using four files to behave as NOTE1 to NOTE4 and we use a table instead of FREQ1 to FREQ4.

What we have done (as discussed a moment ago) is to consider a block of consecutive file addresses to be allocated to NOTE1/NOTE4, starting at H'20'. To remind us at some future time, there is a comment alongside NOTE1 to this effect in the full disk listing. The next address which we specify cannot, therefore, occur until the fifth byte later, at H'24', where LOOPA is equated. Any consecutive block of four bytes could have been used.

As seen in the full program and the extract in Listing 19, a table has four values in it and an AND command limits the jump span from zero to three. The values shown are the tuning values which will be accessed periodically throughout the program while it is running.

INDIRECTION

Routines SETUP and SETUP1 make use of the indirect addressing facility to set the initial (FREQ) values into the four notes. Next comes routine GETKEY in which the status of the four switches is obtained in the usual way. There are 16 possible combinations of the switches and we only want four of them, those for any single switches being pressed.

We could, of course, not use a table but simply test each bit of PORTA in turn and use GOTO statements to obtain data about which note should be played and which note reset value is needed. Instead, though, for the sake of demonstration, a different technique is used, converting the 4-bit PORTA value to a 2-bit value, covering four possible combinations rather than 16.

PORTA's value is ANDed with B'00001111' and copied into STORE, and a loop set for a maximum of four operations. Up to four rotate left (RLF) actions can then be called in routine ROTATE, and the value of STORE bit 3 tested. Each bit of STORE corresponds to a separate switch, so the rotation allows all four switches to be tested. If a 1 is found during the rotation, the value of the loop corresponds to the switch in question and a jump is made to the play routine. If a zero is found, then no switches are pressed and no note play action occurs.

In the PLAY routine, the loop value (LOOPA) is decremented while being moved into W (the loop value will be between 4 and 1 but for program ease we need a value between 3 and 0). The value of W is added to the address of NOTE1 and the answer is put into the indirect address register FSR. The note now pointed to by FSR is decremented via INDF and if the result is not zero, a return to GETKEY is made.

A zero result causes the value of LOOPA to again be decremented into W and then the table is called, returning with the reset value for the note in use, which is put into it via INDF. As we have seen before, the output value at PORTA RA4 is then incremented and a jump back to GETKEY occurs.

Had this whole operation been programmed as separate routines for each note, its length would have been considerably greater, as in the previous example of TK3TUT18; indirect addressing, bit rotation and a table have changed that. (Consider the length that would have been required if we were using eight switches for eight notes – a situation that would have also brought up the problem of a table that was greater than 256 commands!) We shall use indirect addressing again later.

EXERCISE 16

16.1. In Program TK3TUT19, priority has been given to switches in descending order (test bit 3). How would you rewrite to give priority in ascending order?

16.2. If you wanted one of the switches to be ignored, what extra command(s) would be needed, and where? When considering where, think of the number of times the situation has to be checked for between each input of PORTA's value, remembering that each command processed wastes valuable time.

16.3. Is the AND command at the head of the table actually necessary?

16.4. As the program stands, there is one extra file name used than needs to be; which file could be used in two situations?

16.5. Also, with careful thought, parts of the program could be slightly rewritten to save at least seven commands. Can you spot how this could be done? Question all aspects, from initialisation downwards (see also the full listing).

(Whilst the SETUP routine could be heavily rewritten to save four of these commands, in a real programming situation, unless you are short of program space, it is better to concentrate on saving commands in routines that are being called frequently, so significantly increasing the speed of operation. SETUP is only used once, and so has no affect on the loop speed.)

TUTORIAL 17

CONCEPTS EXAMINED

Command XORLW
Command XORWF
Command IORLW
Command IORWF
Tone modulation

LISTING 20 – PROGRAM TK3TUT20

```
GETKEY   MOVF PORTA,W
         ANDLW B'00001111'
         XORLW B'11111010'
         MOVWF PORTB
         GOTO GETKEY
```

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
Port A RA4 connected as in Fig.3 (audio connection)
CP21 to +5V OUT
CP20 to 0V OUT
Preset VR1 set to minimum resistance (fully clockwise)

In a moment, we shall come down to a somewhat simpler audio program, in which we illustrate how two tones can be created, one modulated, the other fixed. Both tones could find use in, for example, a simple intruder alarm. Also to be illustrated is how the combined status of two or more switches on a port can be tested using the XOR (Exclusive-OR) command. This allows us to take one action only if all the specified switches are on simultaneously, otherwise taking another action. First, let's examine the XOR command on its own.

COMMAND XOR

The command XOR checks for "equality" between two numbers. There are two commands, XORLW (XOR Literal with W) and XORWF (XOR W with value in specified File). The latter is followed by the file name, a comma, and the destination (W or F), e.g. XORWF STORE,W and XORWF STORE,F.

Probably you know that in electronics there are XOR gates included in the digital logic chip families, and you will no doubt have read descriptions of truth tables relating to just two inputs of an XOR gate (two bits):

0 XOR 0 = 0
0 XOR 1 = 1
1 XOR 0 = 1
1 XOR 1 = 0

As far as a PIC's XOR function is concerned, the result of XORing two bytes of eight bits is the condition being checked. It is easier here to show the principle by means of switches and l.e.d.s rather than by truth tables. To do this we should really use eight switches on one port and eight l.e.d.s on the other. However, since PORTA has only four switches connected to it, we shall just use a 4-bit number to illustrate the principle, via four l.e.d.s on PORTB.

The basic program we shall use is shown in Listing 20. Run program TK3TUT20.HEX and play with PORTA's switches. You will find that when no switches are pressed, PORTB l.e.d.s LD0 and LD2 are off, and LD1 and LD3 are on, as are LD4 to LD7. When switch SW1 and SW3 are pressed, they turn off their respective l.e.d.s (LD1 and LD3). Switches SW0 and SW2 turn on their l.e.d.s (LD0 and LD2) when pressed.

In this listing, the value on PORTA is input as usual. The next command (ANDLW B'00001111') is necessary to this demonstration since we only want to use the first four bits of PORTA. If PORTA had eight bits that could be used, the AND command would be omitted. The status of each switch is being XORed with the respective bit in the statement XORLW B'11111010'; switch 0 with bit 0, switch 1 with bit 1, etc.

If any bit of PORTA is equal to that of the same bit in the XOR command, the same bit in the W register will be cleared. Thus two zeros will produce a 0, and two 1s will produce a 0. If the bits are dissimilar (1 and 0) the W bit is set (1). The reason that the four lefthand l.e.d.s are on is that bits 4 to 7 from the AND command and bits 4 to 7 from the XOR command have resulted in four non-equalities.

Suppose that the switches produce binary number 0111, the ANDed result in W is 00000111, the sequence of events is:

```
MOVF PORTA,W          answer = xxxx0111
ANDLW B'00001111'     answer = 00000111
XORLW                          11111010
                      answer = 11111101
```

Bits that are equal to their counterparts have their corresponding l.e.d.s turned off, those that are *not* equal have their l.e.d.s turned on. Take another example:

```
MOVF PORTA,W          answer = xxxx0010
ANDLW B'00001111'     answer = 00000010
XORLW                          00000010
                      answer = 00000000
```

Here each bit is equal to its counterpart, therefore all l.e.d.s are turned off, i.e. a zero result has occurred and, importantly, the Zero flag will have been set accordingly. Therefore, we can check for equality by checking the Zero flag following an XOR command. Non-equality clears the flag, equality sets it. Consequently, following an XOR command you simply check STATUS,Z and route accordingly.

LISTING 21 – PROGRAM TK3TUT21

```
GETKEY   MOVF PORTA,W
         ANDLW B'00001111'
         XORLW B'00001010'
         MOVWF PORTB
         BTFSC STATUS,Z
         BSF PORTB,7
         GOTO GETKEY
```

Let's use l.e.d. LD7 to illustrate this, turning it on if equality exists, turning it off if it doesn't. Any bit between 0 and 3 which is equal to the same XOR bit will have its corresponding l.e.d. turned off, otherwise its l.e.d. will be on. Load TK3TUT21.HEX and press PORTA switches SW0 to SW3 to observe this in action. Pressing SW3 and SW1 together causes LB7 to come on. The commands are shown in Listing 21.

COMMAND IOR

Although we shall not meet it until later (Tutorial 21), it is opportune to mention now that there is an "ordinary" OR command available. It is more correctly termed "Inclusive-OR" (as opposed to Exclusive-OR). It has two versions, IORLW

LISTING 22 – PROGRAM TK3TUT22

```
ENTRY     MOVLW 80
          MOVWF NOTE
          MOVWF FREQ
          MOVLW 128
          MOVWF MODLAT
          MOVLW 64
          MOVWF DELAY
GETKEY    MOVF PORTA,W
          ANDLW B'00000011'
          XORLW B'00000011'
          BTFSC STATUS,Z
          GOTO GETKEY
          DECFSZ NOTE,F
          GOTO GETKEY
          MOVF FREQ,W
          BTFSC PORTA,1
          GOTO OUTPUT
          DECFSZ DELAY,F
          GOTO GK2
          BSF DELAY,6
          DECFSZ MODLAT,F
          GOTO GK2
          BSF MODLAT,7
GK2       ADDWF MODLAT,W
OUTPUT    MOVWF NOTE
          MOVLW B'00010000'
          ADDWF PORTA,F
          GOTO GETKEY
```

(Inclusive OR Literal with W) and IORWF (IOR W with value in specified File). The latter is followed by the file name, a comma, and the destination (W or F), e.g. IORWF STORE,W and IORWF STORE,F.

MODULATION

The use of XOR in a practical situation is illustrated in Listing 22. Temporarily swap over the connections to CP20 and CP21 so that RA0 to RA3 are biased normally high, going low when pressed. Reconnect the audio output.

Load TK3TUT22.HEX, press any switches SW0 to SW3, but principally use switches SW0 and SW1 since these are the ones coded to be active.

Listening to the output from PORTA, you will find that switch SW0 controls a static tone and SW1 controls a modulated (ramped) tone. As you will have heard, the tone starts at a low pitch, ascends and then jumps back low again, repeatedly. Adjust VR1 until this fact is more obvious. All other switches are ignored. Look at the program's listing.

As with earlier tone generation examples, a starting value is loaded into NOTE and FREQ, then a modulation starting value is loaded into MODLAT, and a delay value into DELAY, after which the GETKEY loop is entered. Here the switch settings on PORTA are read and ANDed with 00000011 to extract the status of switches SW0 and SW1. The answer is XORed with the same value to check for equality. If neither switch is pressed, no further action is required and the routine jumps back to GETKEY.

We are looking for the situation in which either of the two switches is pressed. We could do it simply by bit testing (indeed, it would be easier!), but part of the aim of this demo is to show a use of XOR. When either switch is pressed, NOTE is decremented and checked for zero and reset as appropriate, as before.

When zero is encountered, if switch SW1 is pressed, the DELAY counter is decremented, if it is zero, DELAY is then reset to 64 (BSF DELAY,6), the value of MODLAT is added to the NOTE reset value and the value of MODLAT itself is then decremented. When MODLAT reaches zero, it is reset to 128 (BSF MODLAT,7). The OUTPUT routine is common to both switch routings.

Note how bit values of MODLAT and DELAY are set to reset these counters to their original values. This works because both values are known to have reached zero.

EXERCISE 17

17.1. Experiment with different settings for FREQ, DELAY and MODLAT

17.2. How would you change the coding to respond to two other switches instead, e.g. SW2 and SW3?

17.3. How would you reverse the ramp to create a rising tone rather than a falling one?

17.4. The addition of a third switch would allow tones to be switched for rising, falling or fixed. Can you write the program for it?

17.5. Can you add another routine which would create a triangular modulation pattern (rising tone, followed by falling, followed by rising, and so on)?

TUTORIAL 18

CONCEPTS EXAMINED

OPTION register
INTCON register
TMR0 register
Command OPTION_REG
Command INTCON
Command TMR0
Use of internal timer

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP20 to +5V OUT
CP21 to 0V OUT
Preset VR1 set to maximum resistance (fully anti-clockwise)

LISTING 23 – PROGRAM TK3TUT23

```
      CLRF PORTA
      CLRF PORTB
      BANK1
      CLRF TRISA
      CLRF TRISB
      MOVLW B'10000000'
      MOVWF OPTION_REG
      BANK0
      CLRF RATE
      MOVLW 8
      MOVWF COUNT
      BCF INTCON,2
MAIN  BTFSS INTCON,2
      GOTO MAIN
      BCF INTCON,2
      MOVLW B'00010000'
      ADDWF PORTB,F
      BTFSS STATUS,C
      GOTO MAIN
      DECFSZ COUNT,F
      GOTO MAIN
      BSF COUNT,3
      INCF RATE,W
      ANDLW 7
      MOVWF RATE
      MOVWF PORTB
      BANK1
      IORLW B'10000000'
      MOVWF OPTION_REG
      BANK0
      GOTO MAIN
```

The PIC16F84 has one special register reserved for use as an 8-bit timer, TMR0 (Timer 0). It divides its input frequency by 256 and can be both written to and read from. In most situations, though, it is unlikely that you will need to use the read/write facility, but note that if TMR0 is written to, the timer is inhibited from counting for two clock cycles.

Probably more useful than writing to TMR0 is to use its output as it occurs naturally at the 1:256 division rate, and then to use the prescaler to subdivide that rate as required. The prescaler divides its input pulses by presettable powers of two. There are eight possible division ratios which are set via bits 0, 1 and 2 of the OPTION register. When used with TMR0, the prescaler division ratios are 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, 1:128 and 1:256.

The prescaler can alternatively be allocated for use with the Watchdog Timer (WDT), in which mode each of these ratios is halved (minimum is thus 1:1 and maximum is 1:128) – more on this later.

OPTION NAMING

Note that the OPTION register should not be equated as such since Microchip previously had a command actually named OPTION and use of this term in an ASM file assembled by MPASM causes an error condition. Consequently it is preferable that the register should be equated as OPTION_REG (Microchip's equated term in their INC files). You may still sometimes come across the equated name OPTION, or even OPSHUN instead.

(It should also be noted that bit 7 of the OPTION register controls the PIC's Light-pullups facility and should be set high to turn it off, as in Listing 23 – this facility is discussed separately later.)

We commented earlier that the PIC effectively runs at one quarter of the input clock frequency at pin 16 (OSC1/CLKIN). When TMR0 is used as an internal timer, the pulses it counts also occur at one quarter of the clock frequency. So, if the clock frequency (set by a crystal oscillator, perhaps) is running at 3·2768MHz, TMR0 will count at 819200Hz and its 1:256 roll-over rate will be 3200Hz. This rate is then divided by the ratio set into the prescaler. If we divide by 32, for example, we obtain the convenient rate of 100Hz.

In TMR0 mode, when the prescaler rolls-over to zero, a flag is set in the INTCON register, at bit 2. The setting of this bit can be used as an interrupt (see Part 3) which automatically routes the program to another specified routine, irrespective of which routine is currently being processed, returning to the same point after the interrupt procedure has been finished. The interrupt can also be turned off and INTCON bit 2 read by the program to establish its status, taking action accordingly.

TIMER SUB-DIVISION

Using the timer and the prescaler, you can specify that some actions will only be performed at specified sub-divided values of the clock frequency. Amongst other things, this allows the PIC to be used as a real-time clock, a function towards which we now progress.

First, let's illustrate the effect of setting different prescaler ratios and, using the l.e.d.s on PORTB, show what happens. Load TK3TUT23.HEX and run it. Set VR1 to full anti-clockwise rotation (slowest rate). In this program we read the status of INTCON bit 2 rather than using the interrupt facility (discussed in Tutorial 27).

Initially, you will see a fairly fast binary count occurring on PORTB's l.e.d.s LD3 to LD7. It is created with the timer "in-circuit" with the prescaler set for a minimum division ratio of 1:2. This is because OPTION_REG bits 0 to 2 are set to 000, a value which is shown on LD0, LD1 and LD2 – all off initially.

This rate of counting continues for eight cycles of 32 increments (incrementing PORTB's count in steps of eight). The ratio is then set at 1:4 (prescaler value 001), and again another eight cycles occur. Similarly, the other ratios are set. The difference in the resulting l.e.d. count rates will be obvious.

Adjust the setting of preset VR1 if the slowness becomes tedious in later ratios. After the eight ratios, the whole cycle restarts from 1:2.

Looking at Listing 23, you will see that the TMR0 rate is set into the OPTION_REG register while in BANK1 mode, along with the port direction registers.

EXERCISE 18

18.1. Study TK3TUT23.ASM, note the comments and see if you understand what is happening at each stage. Note the detection and resetting of the INTCON,2 flag and the need to go via BANK1 when changing the prescaler rate.

TUTORIAL 19

CONCEPT EXAMINED

BCD (Binary Coded Decimal) counting

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP20 to +5V OUT
CP21 to 0V OUT
Preset VR1 set to maximum resistance (fully anti-clockwise)

Having established the use of the timer, we now work towards its use as the pulse source for a real-time clock. There are a few bridges to be crossed yet, though. The first is counting in decimal rather than binary, facilitating the eventual output to a 7-segment l.e.d. or a liquid crystal display. We could keep the counted units in one byte, tens in another, hundreds in another, and so on, but, to conserve precious byte space, it is equally possible to use each byte as two 4-bit nibbles, keeping units in bits 0 to 3, and tens in bits 4 to 7. Hundreds units and tens would be treated similarly in a second byte.

For simplicity now, we concentrate on counting up to 99, first considering the use of two bytes. In 8-bit binary, a value of decimal 9 is expressed as 00001001, decimal 10 is 00001010, decimal 16 is 00010000. It is obvious that with decimal values we have no single symbol for a number greater than nine. When a value one greater than nine occurs, what we do is reset the units digit to 0 and add one to the next digit, i.e. ten is written as 10.

While counting in binary coded decimal (BCD), we can do a similar thing. When the byte holding the units reaches ten, we reset that byte to zero and add one to the next byte. In 8-bit BCD and at a count of nine, the two bytes would read 00000000 (tens) and 00001001 (units). At the count of ten, the bytes become 00000001 (tens) and 00000000 (units).

When using two nibbles of an 8-bit byte (instead of the above two bytes), a BCD value of nine reads as 00001001, but a BCD value of ten reads as 00010000. And, for example, a BCD value of 37 reads as 00110111, i.e. the lefthand nibble (MSN – Most Significant Nibble) holds a value of 3 and the righthand nibble (LSN – Least Significant Nibble) holds 7. A value of 99 is expressed as 10011001. For a value of 100, both nibbles are reset to zero (00000000) and if there is a byte for hundreds and tens of hundreds, its righthand nibble (LSN) would be incremented, and so on.

Thus, when counting in BCD, we have to check the four bits of the LSN on their own and see if their value is greater than nine. If it is, that nibble is reset and the MSN incremented. The MSN is then taken on its own as a 4-bit value and checked if it is greater than nine. If so, this nibble is reset and the LSN of the next byte incremented accordingly.

LISTING 24 – PROGRAM TK3TUT24

```
MAIN      BTFSS INTCON,2
          GOTO MAIN
          BCF INTCON,2
          INCF COUNT,F
          MOVF COUNT,W
          ADDLW 6
          BTFSS STATUS,DC
          GOTO OUTPUT
          MOVWF COUNT
          ADDLW 96
          BTFSC STATUS,C
          CLRF COUNT
OUTPUT    MOVF COUNT,W
          MOVWF PORTB
          GOTO MAIN
```

CHECKING FOR EXCESS VALUES

There are (as in many programming matters) several ways of checking the nibbles for excess values, of which we shall describe one: an additive checking routine. We said earlier (Tutorial 7) that there is a Digit Carry (DC) flag which signals if the binary value of the LSN has become greater than 15 following an addition. We can use this fact by adding a number to the LSN which will make the answer greater than 15 if the basic value of the LSN is greater than 9.

The number to be added is 6, e.g. 10 + 6 = 16 with DC flag set; 9 + 6 = 15 with DC flag clear. Therefore, to check if an LSN value is greater than 9, we temporarily add 6 to it and check the DC flag. If the flag is clear, the LSN is left as it is. If the flag is set, we increment the MSN and clear the LSN.

There is a short cut to doing this, taking advantage of the fact that 10 + 6 = 16, being 00010000 in binary. If you look at this answer, the LSN is now zero, while the MSN has been incremented automatically, thus representing decimal 10 in BCD. Thus, when we add 6 to the byte as a whole, if the DC flag is clear, no further action on that byte is needed (or on any subsequent bytes for that matter). If, though, the DC flag is set, we simply replace the existing value in the byte with the value now stored temporarily. These commands do the job:

```
INCF COUNT,F        ; increment file
                      value
MOVLW 6             ; move 6 into W
ADDWF COUNT,W       ; add it to new file
                      value but keep
                      answer in W
BTFSC STATUS,DC     ; is the Digit
                      Carry flag clear?
MOVWF COUNT         ; no, it's set so
                      move W into file,
                      replacing previ-
                      ous value
(next command)
```

The above check is done in respect of LSN, but when the DC flag is set, the resulting action changes the value of the MSN, which then has to be checked to see if it (as a 4-bit nibble) is greater than 9, i.e. is the BCD value of the whole byte now equal to or greater than decimal 100?

Again there is an easy additive technique. If we translate the binary value of BCD 100 (10100000) the decimal answer is 160. If we temporarily add 96 (256 – 160) to the whole byte, we can then check the Carry flag (C) to see if it has been set, which it will be if the binary answer has rolled over beyond 255. As before, if the flag is clear, the byte can remain as is; if the flag is set, we replace the value with the temporary one.

(Note that the DC and Carry flags are unaffected by an INCF or INCFSZ command.)

Here's the extended routine. Note the inverted logic for checking Digit Carry and Carry flags, BTFSS STATUS,DC in the first instance, BTFSC STATUS,C in the second.

```
        INCF COUNT,F
        MOVLW 6
        ADDWF COUNT,W
        BTFSS STATUS,DC
        GOTO ENDADD
        MOVWF COUNT
        MOVLW 96
        ADDWF COUNT,W
        BTFSC STATUS,C
        MOVWF COUNT
ENDADD  (program continues)
```

Let's look at the BCD additive technique in practice, triggering it from the timer routine. In Listing 24, note the use of CLRF COUNT before OUTPUT at the end. This can be used here since we know that adding 1 to the count is occurring, rather than adding values of 2 or greater. In the latter instance, the resulting temporary answer must be MOVed into COUNT, as in the above examples.

Load TK3TUT24.HEX and observe the count incrementing on the l.e.d.s. The prescaler is now run at a fixed ratio of 1:128. Try adjusting VR1 so that an l.e.d. count rate of one per second (1Hz) occurs. (The tolerance of VR1 and the in-circuit capacitance may not allow you to set the rate quite this slow without also amending the OPTION_REG timing value.)

EXERCISE 19

19.1. Suppose our counting system was not decimal but quinary, i.e. no digit greater than 5, rather than no digit greater than 9. How would you change the additive values in the above examples (you can use decimal, binary or hexadecimal for those!).

19.2. Checking for excess BCD values can be done using an XOR technique which is valid if the count is being incremented rather than added to. Adding to the BCD value cannot be used with XOR since the answer could be to either side of the equality being checked for. Can you write an XORed BCD incrementing program?

TUTORIAL 20

CONCEPTS EXAMINED

Real-time timing at 1/25th second
Counting seconds 0 to 60

LISTING 25 – PROGRAM TK3TUT25

```
          CLRF PORTA
          CLRF PORTB
          BANK1
          CLRF TRISA
          CLRF TRISB
          MOVLW B'10000110'
          MOVWF OPTION_REG
          BANK0
          MOVLW 25
          MOVWF CLKCNT
          CLRF CLKSEC
          BCF INTCON,2

MAIN      BTFSS INTCON,2
          GOTO MAIN
          BCF INTCON,2
          DECFSZ CLKCNT,F
          GOTO MAIN
          MOVLW 25
          MOVWF CLKCNT
          INCF CLKSEC,F
          MOVF CLKSEC,W
          ADDLW 6
          BTFSS STATUS,DC
          GOTO OUTPUT
          MOVWF CLKSEC
          MOVLW B'01100000'
          XORWF CLKSEC,W
          BTFSC STATUS,Z
          CLRF CLKSEC

OUTPUT    MOVF CLKSEC,W
          MOVWF PORTB
          GOTO MAIN
```

CONNECTIONS NEEDED

All Port B to all l.e.d.s.
Port A RA0-RA3 to switches SW0-SW3 (via CP19-CP16)
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

Moving on from decade counting between 0 and 99, it is an easy step to count in BCD from 0 to 59, accurately simulating the seconds count of a real-time clock. In doing so, though, it can be useful to actually increase the count rate available via the prescaler from 1Hz to 25Hz, 50Hz or even 100Hz. Indeed, if a crystal oscillator running at the convenient rate of 3·2768MHz is used, it is actually easier to work with one of these three rates. This is due to the sub-division values available from a crystal of this frequency which can be used in conjunction with the TMR0. Prescaler division ratios of 1:128, 1:64 or 1:32 respectively produce these rates.

So now go over to crystal control on *TK3*'s p.c.b. Go into *TK3*'s PIC Configura-tion option and select crystal XT instead of the previous RC mode. Leave all other settings as they are. Send the configuration to the PIC. Set *TK3*'s switch S2 to crystal mode. It is assumed that the crystal on your p.c.b. is 3·2768MHz. Crystals having a different frequency may be used but the clock timings shown on your l.c.d. will differ accordingly.

All of the programs you have used so far, with the exception of TK3TUT2, can be run under crystal control. Consequently, if you want to go back and look at some of them again, you do not need to reset the PIC for RC mode.

Load TK3TUT25.HEX and observe PORTB's l.e.d.s. You will see them incrementing at a rate of one per second, and the twin-nibble BCD count will be seen to progressively step from zero to BCD 59 (01011001), then restart again at zero, just as would an ordinary seconds clock and, indeed, it should take one minute for the full cycle to occur.

In this program the prescaler rate has been set for 1:128, providing an INTCON,2 pulse rate of 1/25th of second. A counter, CLKCNT, counts down from 25 in response to the pulses. When it reaches zero, it is reset to 25 and a seconds counter, CLKSEC is incremented in BCD.

Checking for the BCD count becoming ten is performed by the additive (+6) technique we have already shown. However, checking for the count being at BCD 60 is done using the XOR equality testing method (XOR 01100000 = BCD 60). If equality exists, the CLKSEC counter is reset to zero.

EXERCISE 20

20.1 There are three commands associated with the XOR check. What XOR coding would be needed to lose one of them?

TUTORIAL 21

CONCEPTS EXAMINED

Using 7-segment l.e.d. displays
Showing hours, minutes and seconds
Command IORLW (usage)

CONNECTIONS NEEDED

7-segment display as in Fig.6
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

LISTING 26 – PROGRAM TK3TUT26

```
COMCATHODE
        ADDWF PCL,F
        RETLW B'00111111'      ;0
        RETLW B'00000110'      ;1
        RETLW B'01011011'      ;2
        RETLW B'01001111'      ;3
        RETLW B'01100110'      ;4
        RETLW B'01101101'      ;5
        RETLW B'01111100'      ;6
        RETLW B'00000111'      ;7
        RETLW B'01111111'      ;8
        RETLW B'01100111'      ;9
        ; common cathode codes

COMANODE
        ADDWF PCL,F
        RETLW B'11000000'      ;0
        RETLW B'11111001'      ;1
        RETLW B'10100100'      ;2
        RETLW B'10110000'      ;3
        RETLW B'10011001'      ;4
        RETLW B'10010010'      ;5
        RETLW B'10000011'      ;6
        RETLW B'11111000'      ;7
        RETLW B'10000000'      ;8
        RETLW B'10011000'      ;9
        ; common anode codes

MAIN
        BTFSS INTCON,2
        GOTO MAIN
        BCF INTCON,2
        DECFSZ CLKCNT,F
        GOTO MAIN
        MOVLW 25
        MOVWF CLKCNT
        INCF CLKSEC,F
        MOVF CLKSEC,W
        ADDLW 6
        BTFSC STATUS,DC
        CLRF CLKSEC

OUTPUT
        MOVF CLKSEC,W
        ANDLW B'00001111'
        CALL COMCATHODE
        MOVWF PORTB
        GOTO MAIN
```

Obviously it is not feasible to show hours, minutes and seconds by just using BCD formatted values on individual l.e.d.s. We need a display which is more suited to being understood. Such a display could be via alphanumeric liquid crystal displays (l.c.d.s) and a typical routine using them will be shown later on.

Another choice is the use of 7-segment l.e.d. displays, and that is the route we now take. First, though, we must examine how the output from PORTB needs to be coded to drive a single 7-segment common cathode l.e.d. display. We shall then extend the principle to multiplexing four such displays to show a full 24-hour clock.

As Tutorial 21 is the only section to use 7-segment displays, you may prefer not to purchase one at this time, and to just read about using them, for future reference. Don't skip reading this section, though, as other concepts are examined.

Each segment of a 7-segment l.e.d. display has to be controlled by individual PIC

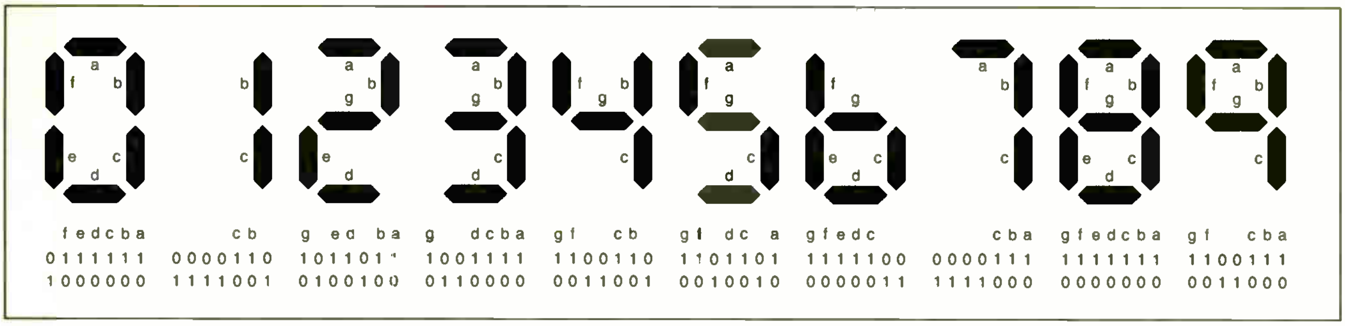

Fig.4. Numerals 0 to 9 on a 7-segment l.e.d. display, plus controlling binary codes for common cathode (middle line) and common anode (bottom line).

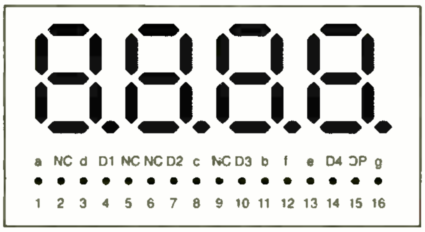

Fig.5. Pinouts for a typical 4-digit multiplexed 7-segment l.e.d. display.

data lines. It does not matter in which order the data lines are connected to the display since the way that they are activated can be set from within the PIC's controlling program. For convenience, here we use PORTB lines RB0 to RB6 connected in their natural order to segments A to G.

In Fig.4 are shown the segments and code letters required to form the ten numerals 0 to 9. Also shown are two lines of binary code. The first one shows the bits which need to be taken high if a common cathode display is used. The second is for a common anode display, each line being taken low to turn on the segment. It is a common cathode display that we use here; its pinouts are shown in Fig.5. Connect it to the p.c.b. as shown in Fig.6, ensuring that the 330Ω resistors do not short between each other. Also connect RA0-RA3 to TR2-TR5 via CP8-CP11. The program keeps transistor TR2 turned on constantly.

Load TK3TUT26.HEX. You will see the individual numerals being shown on the left-hand digit on a cyclic basis from 0 to 9. Using the crystal oscillator selected for the

LISTING 27 – PROGRAM TK3TUT27

```
MAIN      CALL DIGSEL
          BTFSS INTCON,2
          GOTO MAIN
          BCF INTCON,2
          DECFSZ CLKCNT,F
          GOTO MAIN
          MOVLW 25
          MOVWF CLKCNT
          INCF CLKSEC,F
          MOVF CLKSEC,W
          ADDLW 6
          BTFSS STATUS,DC
          GOTO ENDTIM
          MOVWF CLKSEC
          MOVLW B'01100000'
          XORWF CLKSEC,W
          BTFSC STATUS,Z
          CLRF CLKSEC
ENDTIM    GOTO MAIN
SECTEN    SWAPF CLKSEC,W
          GOTO OUTPUT
SECONE    MOVF CLKSEC,W
OUTPUT    ANDLW B'00001111'
          CALL COMCATHODE
          MOVWF PORTB
          INCF DIGIT,W
          MOVWF PORTA
          RETURN
DIGSEL    INCF DIGIT,W
          ANDLW 1
          MOVWF DIGIT
          ADDWF PCL,F
          GOTO SECTEN
          GOTO SECONE
```

previous Tutorial, the rate of display will be at one unit per second. In other words, it can be regarded as being a seconds counter.

Referring to Listing 26, you will see that the counting routine is very similar to that in Listing 25, but only dealing with units of seconds. Now, though, instead of the count being sent to individual l.e.d.s it is converted in the COMCATHODE table to the required 7-segment code for that numeral when used with a common cathode display. Since we know that the value held in W when the table is called can never be greater than nine, an AND command is not needed with this table.

MULTIPLEXING

Obviously, to show the tens of seconds as well we need a second 7-segment display. However, it is not possible, of course, to use the same PORTB data lines to control both displays simultaneously. Nor can we use PORTA for the second display, it hasn't enough lines. What we can do, though, is to connect PORTB to the segments of both display digits and then alternate the data being output between units and tens values, turning on each digit (via their common cathode pins) only when the relevant data is being sent to them. If this is done at a fast enough rate, the eye is fooled into thinking that both displays are on simultaneously – persistence of vision.

This technique is known as multiplexing, and what we do in this instance is to put the common cathode of each display under control of two separate data lines on PORTA, RA0 and RA1. However, the pins cannot supply sufficient current to adequately drive 7-segment displays (PIC pins can handle around 20mA to 25mA – see PIC datasheets). To provide enough current to drive them, the port lines are buffered by transistors TR2 and TR3 configured as current sinks. The emitters are connected to the 0V line and the collectors are connected to the common cathodes of the displays. The displays are turned on when PORTA lines go high.

Note that for this example the active digits are the righthand two (controlled by TR4 and TR5) in Fig.6. The other two digits are ignored.

The program which is now required to drive the two displays is shown in Listing 27. Load TK3TUT27.HEX.

Studying Listing 27, first note that (for the sake of demo) an XOR command is used to check for a count value equal to 60 (BCD). Next, and significantly for two displays, digit-alternating commands have been introduced. At label MAIN the command CALL DIGSEL is given. In DIGSEL, a digit counter (DIGIT) is incremented, ANDed with 1, and the result of this increment is carried by W into the

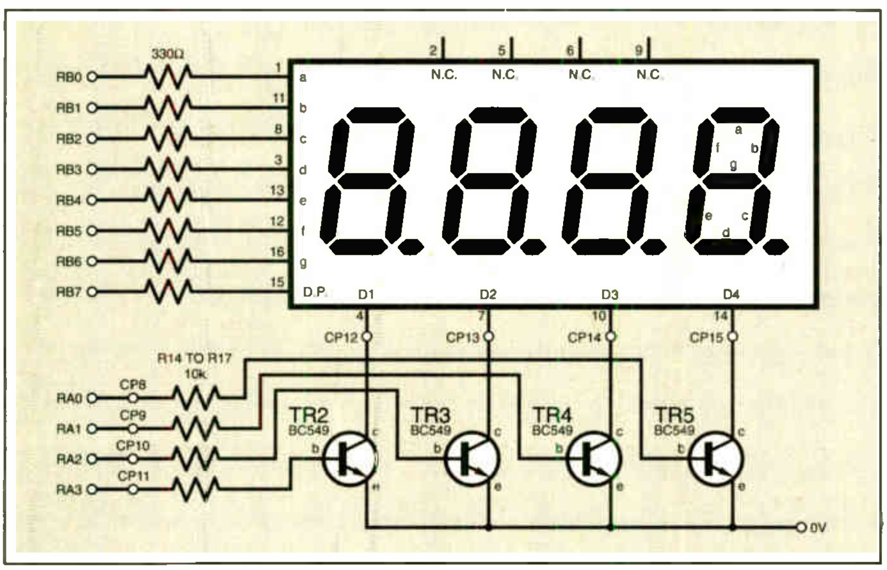

Fig.6. Connections required to drive a 4-digit 7-segment common cathode l.e.d. module.

LISTING 28 – PROGRAM TK3TUT28

```
DIGSEL    INCF DIGIT,W
          ANDLW B'00000011'
          MOVWF DIGIT
          BTFSS PORTA,4
          ADDLW 2
          ADDWF PCL,F
          GOTO HRSTEN
          GOTO HRSONE
          GOTO MINTEN
          GOTO MINONE
          GOTO SECTEN
          GOTO SECONE
DIGSHW    MOVF DIGIT,W
          ADDWF PCL,F
          RETLW 1
          RETLW 2
          RETLW 4
          RETLW 8
MAIN      CALL DIGSEL
          BTFSS INTCON,2
          GOTO MAIN
          BCF INTCON,2
          CALL CLKADD
          GOTO MAIN
CLKADD    DECFSZ CLKCNT,F
          RETURN
          MOVLW 25
          MOVWF CLKCNT
SECCLK    INCF CLKSEC,F
          MOVLW 6
          ADDWF CLKSEC,W
          BTFSS STATUS,DC
          RETURN
          MOVWF CLKSEC
          XORLW B'01100000'
          BTFSS STATUS,Z
          RETURN
          CLRF CLKSEC
```

table that immediately follows. There are only two jumps in this table, GOTO SECTEN and GOTO SECONE.

Note that the table is still within the 256 block permitted for tables. If this were not the case, the table would need to be placed separately within that block.

Routine SECTEN extracts the tens of units value. Command SWAPF CLKSEC,W swaps the nibbles of the seconds and holds the result in W, putting the tens of seconds into the LSN position. The routine then jumps to OUTPUT, where command ANDLW B'00001111' isolates that nibble, zeroing the MSN bits now in W.

Next, the COMCATHODE table (as in Listing 26) is called to obtain the 7-segment code for that number, which is output to PORTB. Now the digit counter value is obtained (INCF DIGIT,W) and output to PORTA to turn on that digit of the display. The INCF command is used because DIGIT only alternates between 0 and 1, whereas PORTA needs to be alternated between 1 and 2 (binary 01 and 10).

Routine SECONE is similar, dealing with the units of seconds. Here we can simply get the LSN by using MOVF CLKSEC,W, ANDing it with B'00001111' at OUTPUT. The rate of alternation between the two digits is several kilohertz, slowing down briefly each time a time-out is detected.

24 HOURS

Whilst one would like to use six digits in order to display a full 24-hour clock showing hours, minutes and seconds simultaneously, this is not convenient since we only have five lines on PORTA which can control individual digits. Therefore, we must compromise and continue to use a 4-digit display but which can now have its data sources changed when a switch is pressed. In this way, we can show either hours and minutes together, or minutes and seconds. The program which does this is TK3TUT28, part of which is shown in Listing 28. Load TK3TUT28.HEX then look at listing 28.

Each time the seconds roll over to zero from 59, the minutes need incrementing; each time they roll over to zero from 59, the hours need incrementing. The hours, though, need to roll over to zero from 23. As far as incrementing each of the three counters is concerned, the easiest thing to do (but not the shortest) is to use three separate BCD routines – as we do in TK3TUT28 (see full listing). The minutes routine is the same as the seconds one, both requiring a count from 0 to 59, with routines to check for 10 and 60. The hours routine, though, requires slight alteration.

With the hours, we need to check when counts of 10 and 20 occur (+6 check), and also when 24 occurs (BCD = 00100100). This check cannot be done in the same way as for the BCD 60 check. With the latter, the check is made at the same time as the tens are incremented. For 24 hours, the simplest test is to check on each hourly digit increment:

```
HRSCLK    INCF CLKHRS,F
          MOVLW 6
          ADDWF CLKHRS,W
          BTFSC STATUS,DC
          MOVWF CLKHRS
          XORLW B'00100100'
          BTFSC STATUS,Z
          CLRF CLKHRS
```

The activating of the decimal point, when required, is done by setting the correct bit in the code once the table has been called (BSF PORTB,7), as seen in the OUTPUT routine:

```
OUTPUT    ANDLW B'00001111'
          CALL COMCATHODE
          CLRF PORTA
          MOVWF PORTB
          CALL DIGSHW
          MOVWF PORTA
          MOVF DIGIT,W
          XORLW 1
          BTFSC STATUS,Z
          BSF PORTB,7
          RETURN
```

Minutes and seconds values are dealt with in the same manner. Minutes units, though, are accompanied by the decimal point bit. Seconds are processed similarly, but without any additional bit setting for colons or points. In Tutorial 24 we shall show how a similar result can be achieved by using fewer commands. A loop plays an active role and a table is used when checking the roll-over values for the time.

In Listing 28, when switch SW4 is not pressed (checked by BTFSS PORTA,4), a value of 2 is added to effective value of DIGIT, to cause the table jumps within DIGSEL to be to the minutes and seconds display routines. Pressing SW3 results in hours and minutes being shown.

You will observe that the brilliance of the display is less than that previously seen, due to the multiplexing. In a real clock situation, the use of a high brightness display would probably be preferable.

Note that ANDing with B'00001111' (as we have done several times in this section)

LISTING 29 – PROGRAM TK3TUT29

```
TABLCD    ADDWF PCL,F
          RETLW B'00110011'
          RETLW B'00110011'
          RETLW B'00110010'
          RETLW B'00101100'
          RETLW B'00000110'
          RETLW B'00001100'
          RETLW B'00000001'
          RETLW B'00000010'
MESSAG    ADDWF PCL,F
          RETLW 'R'
          RETLW 'E'
          RETLW 'A'
          RETLW 'D'
          RETLW ' '
          RETLW 'E'
          RETLW 'P'
          RETLW 'E'

SETUP     CALL PAUSIT
LCDSET    CLRF LOOP
          CLRF RSLINE
LCDST2    MOVF LOOP,W
          CALL TABLCD
          CALL LCDOUT
          INCF LOOP,F
          BTFSS LOOP,3
          GOTO LCDST2
          CALL PAUSIT
LCDMSG    CLRF LOOP
          BSF RSLINE,4
LCDMS2    MOVF LOOP,W
          CALL MESSAG
          CALL LCDOUT
          INCF LOOP,F
          BTFSS LOOP,3
          GOTO LCDMS2
NOMORE    GOTO NOMORE

LCDOUT    MOVWF STORE
          MOVLW 50
          MOVWF LOOPA
DELAY     DECFSZ LOOPA,F
          GOTO DELAY
          CALL SENDIT
          CALL SENDIT
          RETURN
SENDIT    SWAPF STORE,F
          MOVF STORE,W
          ANDLW 15
          IORWF RSLINE,W
          MOVWF PORTB
          BSF PORTA,5
          BCF PORTA,5
          RETURN

PAUSIT    MOVLW 5
          MOVWF CLKCNT
          CLRF INTCON
PAUSE     BTFSS INTCON,2
          GOTO PAUSE
          BCF INTCON,2
          DECFSZ CLKCNT,F
          GOTO PAUSE
          RETURN
```

is a common requirement and it is actually easier to type in using its decimal equivalent of 15, so the ANDLW 15 command could be used instead.

You will see in Listing 26 that a COMANODE table is provided as well. In other applications using common anode displays this table would be called from the OUTPUT routine rather than COMCATHODE. In this instance the transistors would have their collectors connected to the +5V line and their emitters to the anode control pins of the display. Common cathode displays cannot be used with TK3's p.c.b. as the transistor emitters are connected to the 0V line.

EXERCISE 21

21.1. You may have noticed "ghost" images on the "off" segments for the active digits in TK3TUT27, but not in TK3TUT28. Study TK3TUT28's full listing and amend TK3TUT27 similarly to eliminate the "ghosts".

21.2. Create a table that holds all 16 conversions for a hexadecimal count (i.e. 0 to 9 and A to F) to be shown on a 4-digit common anode display. Write a simple counting routine which makes use of it. What compromise might you have to accept?

21.3. Extend the routine from 21.2 so that it blanks the display of any leading zeros (i.e. don't show 0007, but just show 7 on its own).

TUTORIAL 22

CONCEPTS EXAMINED

Using intelligent l.c.d.s
Setting l.c.d. contrast
Initialising the l.c.d.s
Sending a message to the l.c.d.

CONNECTIONS NEEDED

L.C.D. as in Fig.7
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

Having established how 7-segment displays can be driven by the PIC, we now show how an alphanumeric l.c.d. can be used to achieve not only the same result, but one that has additional facilities as well. The coding required is not especially complex, although minimum timing factors for some aspects of sending data to an l.c.d. have to be observed.

The first requirement is to show the basics of how data is output to an l.c.d. from the PIC. We shall not cover the l.c.d. itself in any great detail – you are referred to manufacturer's datasheets for more information.

Here, we first show how the l.c.d. is initialised for 4-bit data transfer from the PIC, using two control lines, RS and E. Line RS sets the l.c.d. for inputting either character data or control data. Line E tells the l.c.d. to act on the data output to it.

Disconnect the l.e.d. module and connect the l.c.d. to the p.c.b. as in Fig.7. Typical l.c.d. pinouts are shown in Fig.8. Load TK3TUT29.HEX and run it. While reading these next paragraphs, refer to Listing 29 as appropriate.

The first time the l.c.d. is used, the Contrast control VR2 should be adjusted until the display is clearly visible.

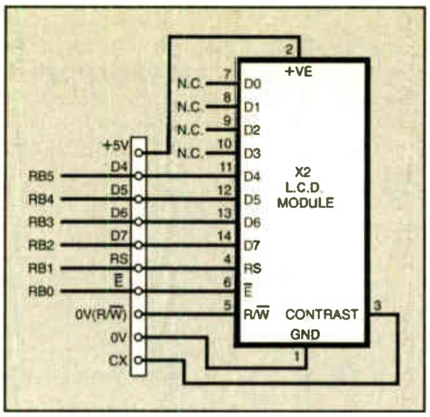

Fig.7. Connection between l.c.d. and TK3 p.c.b.

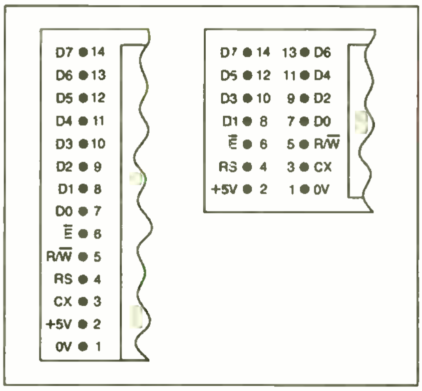

Fig.8. The two "standard" l.c.d. module pinout arrangements.

DELAYED START

When the l.c.d. is under high speed control from a device such as the PIC, it is necessary to allow a minimum of 1/5th of a second between the circuit being switched on and any data being sent to the l.c.d. So, after the PIC's initialisation, the program jumps to the routine at SETUP which, via sub-routine PAUSIT, creates this delay by making use of the prescaler.

The prescaler has been set for an INTCON,2 pulse every 1/25th of a second, so a loop beginning at PAUSE is used to wait for five of these pulses to be completed, i.e. 1/5th of a second. Then a series of commands is sent to set the l.c.d. into the required 4-bit mode. (There are other command routines possible which achieve a similar result.) The commands are held in the table TABLCD, which is accessed from the routine at label LCDSET. The first command here clears the loop counter and the byte (RSLINE) which holds the RS-controlling bit.

Bit 4 of RSLINE is used to inform the l.c.d. what type of data is being sent to it. The bit is cleared for control data, and set for character data. Now, in the manner of table use which was demonstrated earlier, the control commands from TABLCD are sent to the l.c.d. via the LCDST2 routine.

The loop counter is then cleared, RSLINE bit 4 is set and used to inform the l.c.d. that the next commands being sent to it are character data.

Then the message held in the table MESSAG is sent via the routine headed LCDMSG. The l.c.d. displays this message on its first line, starting at the left. Now, for the sake this demo, the perpetual loop at NOMORE is entered and no more actions occur. To replay the routine, use the Reset switch.

In both data sending routines, the l.c.d. output routine is called by the command CALL LCDOUT. The entire block between the start of LCDOUT and the final RETURN at the end of SENDIT is responsible for sending each byte of 8-bit data to the LCD as two 4-bit nibbles, to which control data is then ORed to expand them to a full 8-bit byte. Nibble data is held in the LSN of this byte, control data (in this instance just that for lines RSLINE and E) is held in its MSN.

On entry into LCDOUT, the data brought in on W is copied into a temporary file, STORE. Now a delay loop is entered. The l.c.d. can only handle bytes of data coming to it at a rate which allows previous data received to be processed fully. Details of the delay required are stated in manufacturer's datasheets. In theory, the delay depends on the type of data and command being sent, but on a practical level, a fixed delay of so many PIC commands can be used. In this example, LOOPA is set for 50 and then decremented until zero, as performed by the instructions:

```
        MOVLW 50
        MOVWF LOOPA
DELAY   DECFSZ LOOPA,F
        GOTO DELAY
```

In the author's experience with many programs, this delay is satisfactory for a PIC running at up to about 5MHz. Too short a delay will result in erratic behaviour of the l.c.d., probably accompanied by erroneous display results. The most likely result of this is that the display will not enter 2-line mode, characterised by a line of dark pixels on the upper line, but none on the lower, which will remain blank. If this occurs, the delay loop value should be increased.

Following the delay, there is a call to SENDIT. In SENDIT, the MS nibble of data is retrieved from STORE with the commands:

```
SWAPF STORE,F
MOVF STORE,W
ANDLW 15
```

The first command swaps the two nibbles within STORE, the second copies STORE into W, and then W is ANDed with 15 to isolate bits 0 to 3. The result is ORed with the RSLINE bit and the byte is then output to the l.c.d. via PORTB. The E line is taken high and immediately low again, telling the l.c.d. to process the data on its data inputs. A return to the calling point occurs and then SENDIT is again called. This time, the LSN is extracted from STORE and sent to the l.c.d. in the same way. After two returns, the program returns to the original calling point.

It is important to note that the port bits which are used in these routines to control the Data, RSLINE and E lines reflect the physical connections between the PIC and the l.c.d. as shown in Fig.7. It is permissible to use other PIC port lines for this purpose, but the controlling bits of the software must be changed accordingly.

EXERCISE 22

22.1. There are two commands in the LCDOUT to SENDIT routine which, while being perfectly legitimate, are actually unnecessary. What are they and why are they not needed? (Think "default".)

22.2. When the l.c.d. is first initialised, it is possible (though not definite) that all its character positions (cells) will show as black squares. Sending the message will correct that situation for the first eight cells. How could you ensure that the remaining eight cells on the top line are set to "clear" blanks? There are two methods; try both.

22.3. How would you now set the lower line to all blanks?

TUTORIAL 23

CONCEPTS EXAMINED

Coding hours, minutes and seconds for an alphanumeric l.c.d.
Shortened clock monitoring code
Command SUBLW
Command SUBWF

CONNECTIONS NEEDED

L.C.D. as in Fig.7
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

Having shown how the l.c.d. can have data written to it, we now show how the method can be extended in order to display 24-hour clock data.

Load TK3TUT30.HEX then glance at the display from time to time while you read on here.

COMMANDS SUBLW AND SUBWF

Rather late on perhaps, in the program we are about to display we illustrate the first use of subtraction. PICs have two subtraction commands, SUBLW (Subtract W from Literal) and SUBWF (Subtract W from File). The latter command is used with either the F or the W suffix, e.g. SUBWF (FILE),F and SUBWF (FILE),W.

One might reasonably have expected that SUBLW would actually mean Subtract Literal from W. This is not the case, the subtraction is that of W from the Literal. Consequently, unless you keep your wits about you, this is a command that you could quite easily use incorrectly.

In the following code, the value in the file named DEMO is subtracted from 30 and the result put back into DEMO (the first two lines are just to put an initial value into DEMO):

```
MOVLW 20
MOVWF DEMO
MOVF DEMO,W
SUBLW 30
MOVWF DEMO
```

In this case, the answer is 10 (30 – 20), even though instinctively we might have expected 30 to be subtracted from 20. In this next example, to illustrate SUBWF, again it is the value already in W which is subtracted from the value in file DEMO, the result being returned to DEMO. This is more logical. (Once more the first two commands are just to put an initial value into DEMO.)

LISTING 30 – PROGRAM TK3TUT30

```
MAIN     BTFSS INTCON,2
         GOTO MAIN
         BCF INTCON,2
         CALL CLKADD
         GOTO MAIN
CLKADD   DECFSZ CLKCNT,F
         RETURN
         MOVLW 25
         MOVWF CLKCNT
         MOVLW CLKSEC
         MOVWF FSR
         MOVLW 3
         MOVWF LOOP
         CLRF STORE1
ADDCLK   INCF INDF,F
         MOVLW 6
         ADDWF INDF,W
         BTFSC STATUS,DC
         MOVWF INDF
ADDCL2   MOVF STORE1,W
         CALL CHKVAL
         MOVWF STORE2
         MOVF INDF,W
         SUBWF STORE2,F
         BTFSC STATUS,C
         GOTO CLKSHW
         CLRF INDF
         INCF STORE1,F
         INCF FSR,F
         DECFSZ LOOP,F
         GOTO ADDCLK
CLKSHW   MOVLW B'11000000'
         CALL LCDLIN
         MOVF CLKHRS,W
         CALL LCDFRM
         MOVLW ':'
         CALL LCDOUT
         MOVF CLKMIN,W
         CALL LCDFRM
         MOVLW '.'
         CALL LCDOUT
         MOVF CLKSEC,W
         CALL LCDFRM RETURN
LCDFRM   MOVWF STORE2
         SWAPF STORE2,W
         ANDLW 15
         IORLW 48
         CALL LCDOUT
         MOVF STORE2,W
         ANDLW 15
         IORLW 48
         CALL LCDOUT
         RETURN
LCDLIN   BCF RSLINE,4
         CALL LCDOUT
         BSF RSLINE,4
         RETURN
```

```
MOVLW 20
MOVWF DEMO
MOVLW 5
SUBWF DEMO,F
```

The answer put back into DEMO is, of course, 15 (20 – 5).

In these two examples, the value subtracted is less than the value from which it is being subtracted. What happens if the opposite is true?

For a start, if the value subtracted is greater than the value from which it is being subtracted, the byte simply "rolls-over". We have already shown that decrementing a value of zero results in an answer of 255. Decrementing, of course, is simply a subtraction of 1 from a number and we could, therefore, consider the 0 – 1 situation as being expressed (256 + 0) – 1 = 255.

What we have done by using the addition of 256, is to "borrow" the 256 in order to achieve the correct 8-bit result. The same roll-over situation applies to subtraction of numbers greater than 1. Thus subtracting 20 from 10 produces an answer of 246 (256 + 10 – 20 = 246).

We are quite used to "borrowing" in normal arithmetic, so the concept should be familiar to you, although we express the result of subtracting 20 from 10 as equalling –10.

The difference with PICs (and other digital devices) is that we cannot produce a negative answer as such. What we can do, however, is to use a flag to indicate that a borrow or negative answer situation has occurred. With the PIC, the Carry bit is used for this purpose. In a subtraction operation we simply test the Carry bit to establish whether or not there has been a borrow.

This, though, is where another "inverted" concept has to be applied to SUB commands. Whereas with the ADD commands the Carry bit is Set if a carry result occurs, with the SUB commands the Carry bit is Cleared if a borrow occurs, and it is Set if a borrow does *not* occur.

You could, perhaps, regard the Carry bit as being the bit which is available to be "borrowed" for the subtraction, hence it remaining set if a borrow is not needed, and cleared if it is.

The following are examples of routines which test the Carry bit in a subtraction operation:

```
MOVLW 30
MOVWF DEMO
MOVF DEMO,W
SUBLW 20
MOVWF DEMO
BTFSS STATUS,C
INCF STORE,F
RETURN
```

The above example will cause STORE to be incremented since a borrow will occur when 30 is subtracted from 20. The next example, 30 – 20, does not result in a borrow, so STORE remains at its previous value:

```
MOVLW 20
MOVWF DEMO
MOVF DEMO,W
SUBLW 30
MOVWF DEMO
BTFSS STATUS,C
INCF STORE,F
RETURN
```

You will see the use of SUBWF and the subsequent testing of the Carry bit for the occurrence of a borrow in TK3TUT30.

NEXT MONTH

In the final part of this series we move on to some of a PIC's "sophisticated" operations. You might also care to obtain a PIC16F877 (although this is optional) as we also illustrate some advanced programming techniques that can be used with this device family, as listed on page 3 of Part 1.

READOUT

Email: john.becker@epemag.wimborne.co.uk

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

All letters quoted here have previously been replied to directly.

WIN A DIGITAL MULTIMETER

A 3½ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

Every month we will give a Digital Multimeter to the author of the best *Readout* letter.

★ LETTER OF THE MONTH ★

P.C.B. CAD AND XP

Dear EPE,

Having read Malc Wiles' letter (*Readout* April '03) of concern about using his present p.c.b. CAD package on new PC equipment has forced me to write to you. Reading his comments about using Windows XP, I assume that, like thousands of other PC users, he has been given misguided information about the operating system.

I, too, have tried many types of p.c.b. CAD program (shareware and commercial), some that were written for DOS, Win95, Win98 and XP. I have not found one yet that will not run on Windows XP. The same applies for most other software too. Over the last 12 months I have converted dozens of Win 98 and Win ME users to XP. The operating system is years ahead of its predecessors, being, in my opinion, the most stable system ever. My system has never crashed nor had blue screens since loading it 14 months ago. XP does not allow the use of badly written programs – the type that attempt to write over critical Windows memory locations.

I have some good advice for those who have been misguided. Don't knock it until you've tried it!

On a change of subject I think your mag is great. Its continuing popularity must be due to the constant variety that is covered in it. My favourite at present is PIC programming.

I am interested to know if you have any plans in the future to build an X, Y, Z plotter that will read Gerber or Drill files produced by p.c.b. CAD programs.

Charles Fenton, via email

You are very reassuring about XP, Charles. I've not tried it for myself yet, still variously using 95, 98 and ME.

Years ago I tried to build a plotter but my limited mechanics skills and equipment defeated me. No-one has ever offered us one that I know of. These days I'm sure that it would actually not be appropriate for us to publish one anyway, with the quality of the printers now available, most readers would probably not find any benefit. Admittedly the size of image that could be handled by a decent plotter would find appeal in some quarters, but few readers are likely to need large p.c.b. images.

Even I do not usually require an image larger than A4, although my PICronos L.E.D. Wall Clock *being published next month is wider than A4, but I adequately coped by combining two printout sections.*

GETTING ORG-ANISED

Dear EPE,

I have recently purchased a *PIC Toolkit MK3* board from Magenta and am working through your *PIC Tutorial*. I have typed the first example listing into my WordPerfect program and saved as an ASCII text file. When I try to assemble from ASM to HEX all I can get is a message telling me that an ORG statement has not been found and that the assembly has been aborted. But I have typed in the ORG statements as needed. What am I doing wrong?

Graham Payne, via email

I first pointed out to Graham that he need not type it from the published listing as all the software is available for free download from our ftp site, access through the top of our home page at **www.epemag.wimborne.co.uk** *(and of course it's also available for purchase on disk as described in the article).*

It would also be a mistake to type in all the example programs since as we progress into the Tutorial, *it is only extracts of the listings that are shown. They are on their own and without all the "fixtures and fittings" that must accompany any PIC program, and so cannot stand alone. However, I told Graham I would be interested to see the file that he had created as I could not understand why it would not assemble even though the required ORGs were there.*

Having received Graham's file the answer was simple! Every typed in statement had been placed hard left of the text page. Consequently TK3 was not finding statements in their correct columns, and overlooking the ORGs in column 1 when it was expecting them in column 2. TK3 and other PIC programming assemblers all expect to find commands starting in column 2. Column 1 is reserved for labels. Just putting a space in front of each line was all that was necessary, making TK3 think the commands were in column 2.

The concept of columns is in a sense somewhat arbitrary. TK3 and many other programmers first examine each line of text and split it into sections. The section splits are initially determined by the position at which blank spaces or tab commands (the "separators") are found, with consecutive occurrences of either being ignored. Any text to the left of the first separator is regarded as being in column 1. Any text between separators one and two is in column 2, etc.

Columns are also created by the presence of commas in some commands, as in the case of MOVF PORTB,W for instance. In this statement MOVF is regarded as in column 2, PORTB in col 3, and W in col 4

When you are keying in PIC commands, ideally make column 2 start so there's room for labels in column 1 and to keep things neat and tabulated. Study my listings.

AMPLIFIERS

Dear EPE,

Have you done any projects about amplifier construction, including the tone controls?

Engr. Daniel A. Offiong, Calabar, Nigeria., via email

We have not done much on amplifiers in recent years, but Raymond Haigh's series of four articles, Simple Audio Circuits, *might interest you, published in May-Aug '02.*

Back issues can be bought from HQ, see the Back Issues page, or from our Online shop, accessible via the top of our UK home page at ***http://www.epemag.wimborne.co.uk.***

RAIN MAN

Dear EPE,

With regard to Ferren MacIntyre's letter and your comments to him about rain gauges in *Readout* April '03 – for a long time I worked on the telemetry for a river authority and the classic tipping bucket was about the only accurate method of measuring rain fall and also give a close approximation as to the time the rain started/stopped.

The idea of a gauge with no moving parts is very interesting. We actually had a tipping bucket failure due to ants building their nest under it! However, I feel the method outlined by Ferren of using a V notch weir may present a few problems with regard to calibration. From what I can remember of weirs there are a host of calibration curves depending on the amount of flow over the weir.

The manual type of rain gauge uses a funnel to drain the rain into a long small diameter but calibrated glass jar. I wonder if it would be feasible to bring this device up to date by placing a pressure transducer in the jar? The gauge could be interrogated at 15 minute intervals, as is the norm. There is the small problem, though, of when did the rain start? This would have to be done in software which could sense a change in level/stable-level as being the start or stop time respectively.

May I also draw your attention to April's *Plant Watering Reminder*. If the probe is to be left in the soil, which will obviously be moist, then polarisation will occur around the probes with a build up of gas around them and the device will slowly cease to function thereby giving a false indication.

Peter Mitchell, via email

Years ago, Peter, when I designed my first weather centre, I did consider tipping buckets and the like, but decided the mechanics were probably beyond the tools that I have. These days, on behalf of readers who could be in a similar predicament, I still would not wish to go down the mechanical route (one reason I investigated, and have implemented, solid-state wind speed/direction sensing). An ants problem I'd not even considered, but as a programmer I suppose I should have been prepared to eliminate bugs, though!

Certainly I can see a way in which I could design a pressure sensitive rain gauge, but I think the cost could outweigh its usefulness. First the water level sensor would need to be waterproofed. Secondly, I think it would be necessary to also sense atmospheric pressure with another sensor, to remove that influence from the readings of the first sensor. Using ultrasonics, as I commented in my reply to Ferren, is a technique I've used in the past and am again in the design being worked on.

Yes, perhaps a note on polarisation should have been added to the Plant Watering Reminder. *It's worth remembering, though, that it is only a simple circuit and by its nature not equipped with the features that would be expected from a more sophisticated design.*

I discussed the problems of polarisation in brief in Part One of my Earth Resistivity Logger *(April '03). The ER's PC program also has a click button that lets you read about experiments that can be carried out into measuring soil conditions and the associated problems.*

WIND TUNNEL

Dear EPE,

Regarding John Becker's *Wind Tunnel* (Feb '03), and the subject of "smoke", model railway enthusiasts use a 12V device, made in Germany under the Seuthe brand name, which takes a few drops of light oil "down the funnel" to give a modest stream of smoke for several minutes. Another, less messy, source is the humble mozzie-coil (they go for ages) or its perfumed relative, incense/joss-sticks available from "new-age"' shops. Used with a perforated tube across the air-path, several streamers may be made from one source of smoke.

Brian Conner,
Newtown, N.S.W., via email

Thanks, Brian. In fact I tried to get joss-sticks, living in a multi-cultural area, I had expected to find them, but failed. Nor could I get model train smoke from my local model shop.

BIG DIGIT DISPLAY

Dear EPE,

Thanks for the *Big Digit Display* project featured in your May '02 issue. A couple of years ago I "procured" four of these 7-segment displays when Shell service stations in Australia refurbished their outlets. There must have been thousands of these devices that were just trashed. However, no-one was able to supply any control devices or info, apart from your Fig.1 and Fig.2 details. So they've sat in the groundsman's hut at my rugby club gathering dust, spiders and wasps. Yes, I know your article was last year, but it was mid-season over here and too late to start on the project, but now that rugby time is here again I needed to get myself into gear.

Have you had any feedback relating to remote control either by infra-red or r.f.? Could you please advise how I go about finding out that info? It's just that it's a long way to dig a trench to run the cables to the other side of the paddock (and needs much amber nectar to encourage us!).

Peter Finch, Australia, via email

*I suggest that you consider using r.f., Peter. It's highly unlikely that infra-red will reach far enough. Browse **www.rfsolutions.co.uk** for r.f. modules.*

And nectar's even more enjoyable if you don't have to work for it!

PIC PATIENCE

Dear EPE,

I have experienced problems with a PIC16F84 when the power is removed and then quickly turned back on. Nearly all of your circuits use a 100nF capacitor between the power pin and ground which I always include.

The problem is most obvious when an l.c.d. is connected to the chip. I can regularly get the chip to start up with the display showing garbage and nothing else seems to function. Am I doing something wrong? Can you offer an alternative.

Simon Smyth, via email

You should always allow time for a circuit's capacitors to discharge fully following switch off and before re-applying power. Intelligent devices like PICs and l.c.d.s require an initialisation procedure when powering up. By switching off and then on again immediately, the device's internals could be caught in mid-stroke, so to speak, through the disruption of partly losing power, but not enough to be triggered into their initialisation procedure when power resumes. They will certainly get confused if you don't allow time for the power supply voltage to drop sufficiently. So yes, Simon, you are doing something wrong, not being patient!

If what you are trying to do is restart the program from the beginning to observe a particular action, there is an alternative to switching off the power. With all of my PIC designs, there is a diode and resistor between the PIC's MCLR pin (pin 4 on a PIC16F84 and the +5V line). There is then a connection point on the board that joins to pin 4, and usually marked as MCLR. Connect a push-to-make switch between that point and the 0V line. Pressing the switch automatically resets the PIC so that it is forced to restart the program from the beginning when the switch is released.

Do not use this technique with any PIC circuit that has its MCLR pin connected directly to the +5V power rail, i.e. without a buffering resistor such as my circuits have (but other people's designs may not). Doing so would short out the power supply.

SOURCING VB

Dear EPE,

I wish to try my hand at programming in Visual Basic. Is this very hard to master? I am ok with Z80, ST6 and PIC but would like get at the PC. What exactly would I need to purchase to get something up and running? If you can point me in the right direction it would be most helpful.

John Ramsey-Brown, via email

Well, John, I found VB6 much easier to learn than I expected, partly helped by some aspects of it being similar to QBasic which I already knew. Problem now though is that VB6 does not seem to be so obviously available – my local PC World for instance no longer has VB6 on its shelves and has not replaced it with the later and more expensive version, VB Net.

However, talking to their manager recently, I was told that although not on the display shelves, VB6 is shown in their latest catalogue. I found it in the books section on page 557, under Visual Basic. It shows the same version that I learned on and continue to use, Visual Basic 6.0 Deluxe Learning Edition Book/CD package, £75.18. Well worth it.

It is a superb tool and I love using it, as much as I do PICs!

TELE-FEEDING (1)

Dear EPE,

After reading Norman Blair's letter about Tele-Feeding in *Readout* March '03, it occurred to me that I had controlled some equipment via the phone using the Velleman K6501 remote control by telephone. This uses DTFM codes which are fairly secure and up to three outputs are possible from memory. I believe Maplin stock this kit, which might help Norman.

David Larner, via email

Thanks David

TELE-FEEDING (2)

Dear EPE,

There is a way that Norman Blair can use the telephone legally to signal his animal feeder – and with the bonus of having the telephone being usable with an answerphone at the same time. If he purchases/has an answerphone that will either ignore an invalid DTMF code for remote retrieval (or simply doesn't have remote access to begin with), then an acoustically coupled microphone (mic plonked near the answerphone speaker) fed into a cheap DTMF decoder i.c. could do the job well.

He would need to dial in, wait for the outgoing message to finish and then press the required key(s) to activate the gadget. So long as the answering machine had call screening – most do – this would work well, offer a degree of immunity from false activation *and* be completely legal.

If security was not an issue, then he wouldn't even need a PIC, just a DTMF decoder, crystal, a few discretes, an op.amp and a microphone, an output via a general-purpose transistor and a relay with back-EMF diode across its coil. I'm not sure if Maplin still stock DTMF decoders, but Farnell do and they *do* supply to private users at trade price. Come to think of it, up to 12 different devices could be controlled in this way – 16 in fact if Norman has access to a keypad with ABCD as well as the usual set of buttons.

Incidentally, if anyone has a spare i-button hybrid module for sale (sold by Maplin's before they discontinued it), I'd appreciate an email, I cannot find another self-contained device that can recognise up to six i-buttons anywhere.

Mark Tibbert, via email
Mark@lineisp.com

Thank you Mark. So, Norman, you are spoilt for choice thanks to David and Mark. And, readers, can you help Mark?

PICTUT V2 PLUS MSCOMM

Dear EPE,

The April issue is a nice edition – I've been awaiting your *PIC Tutorial V2* with some anticipation as I'm hoping to plug most of the significant gaps in my limited PIC knowledge. From the contents page, it looks like it's going to be great.

Secondly, I read Robert Penfold's April *Interface* article and in the State Monitoring section, he states that there is no way to monitor the RI (Ring Indicator) signal. This isn't entirely correct. The OnComm event is raised with ComEvent set to comEvRing. However, not all chip-sets support this signal. More information can be found in the MSCOMM on-line help.

Joe Farr, via email

Thank you, Joe, we look forward to publishing your sophisticated serial interface that we are discussing with you separately.

STACK ENHANCEMENT

Dear EPE,

In the March issue *Readout*, John Waller writes about the 8-level-deep limit on the stack of PICs such as the F877. Microchip have a software solution for the smaller PICs with only a 2-level stack (application note 527), which could be modified to give a bigger stack on the larger PICs.

David Tilch,
Johannesburg, South Africa, via email

Thanks David. In fact a fair bit of correspondence was generated on this subject, but too lengthy and in-depth to publish. Some of the solutions offered though had such an overhead cost in terms of code involved, I became determined that I would find ways round ever needing to use a stack quantity greater than that allowed by the PICs I currently use.

BROWSE THESE

Dear EPE,

Readers could find the following free software on the web to be interesting:

SIMetrix: **www.newburytech.co.uk**.

Quickfield: **www.tera-analysis.com** or **www.quickfield.com**.

The first is SIMetrix' simulation demo. I have the full copy at work, but the free version (which is sort of node limited) has proved quite useful at home. It allows you to save circuits but there is a limit to how many components can be used in the simulation. I've also used it for producing circuit diagrams (bigger than it will allow you to simulate) which is also useful.

The other one is Quickfield's Student edition. It's a finite element analysis package. I've used it for calculating the resistance of odd shapes of polysilicon on ASICs. You can define a geometry and having defined the resistivity, you can see the current distribution – in living colour. You can then get it to calculate resistance. It also does electrostatic and magnetic stuff. That's probably not what most of your readers do, but it can be really educational.

Just got into your *Toolkit TK3*. Very nice. (Is John on the Microchip payroll? I think they owe him!)

Graham Johnston, via email

Thanks for the info and kind comments Graham – I'm waiting for a huge cheque from Microchip (even a little one would do), but it's still not come even after these many years of supporting them! Ah well, I suppose some things one does for love, not money!

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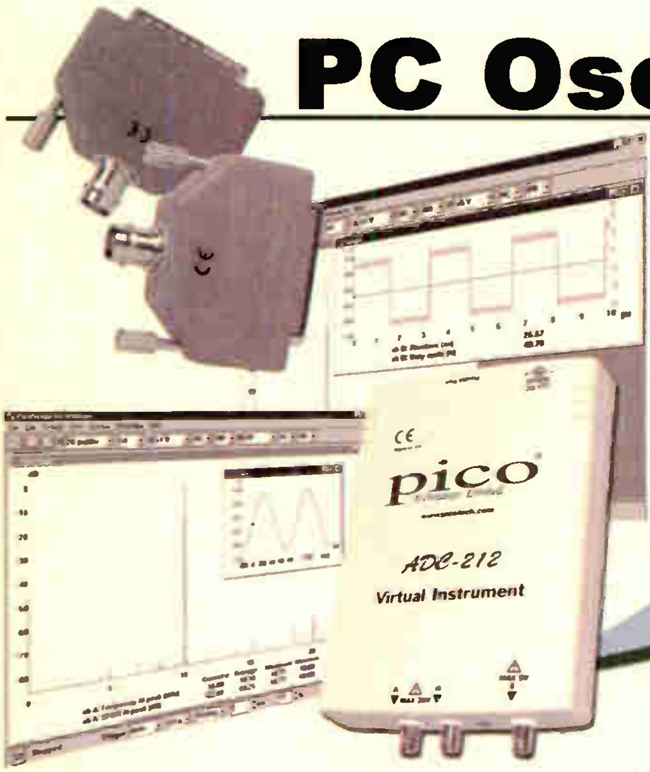

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Constructional Project

BACK TO BASICS

BART TREPAK

Part Four

Illustrating how useful circuits can be designed simply using transistors.

LIVE WIRE DETECTOR

WHEN it comes to useful circuits using very few components, this one takes some beating, as a quick look at the component list will show. Using only three transistors, together with one resistor and a light emitting diode (l.e.d.), it performs a whole series of functions that make it useful for professional electricians and DIY enthusiasts alike.

Despite its extreme simplicity, it can be used to detect if a cable is live, identify the live conductor itself, and to test the fuse in a plug without even dismantling it. It can even be used to locate breaks in a circuit, which makes it ideal, for instance, for finding which lamp in the Christmas decorations has blown or become disconnected, causing the whole chain not to light.

As if this were not enough, it can even be used to test light bulbs, fuses and relay coils for continuity.

CIRCUIT DIAGRAM

The circuit diagram for the Live Wire Detector is shown in Fig.22. It is basically a very high gain amplifier, although no attempt has been made to minimise signal distortion. Indeed, it is not even biased, so it amplifies only the positive part of the sinusoidal mains frequency signal.

The fact that no base bias current is used is an advantage here. It means that when the circuit is not actively being used it draws no significant current, and so an on/off switch is not required.

The electric field, which exists around any conductor connected to an a.c. source, is remotely picked up by a short aerial wire or a small plate (such as a drawing pin) that is connected to the base of transistor TR1. This field, which will exist even if the conductor is not actually carrying a current, will induce a voltage at the transistor base (b) causing it to turn on.

The alternating base current will, of course, be minute as the effective impedance in the base circuit (which consists of the stray capacitance between the conductor and the detector probe) is very high and the collector current is therefore very small.

The collector current, however, provides the base current for transistor TR2. The currents at the emitter (e) of TR1 and the collector (c) of TR2, jointly provide the base current for TR3. In effect, the three transistors form a super transistor, which has a gain equal to the product of their individual gains.

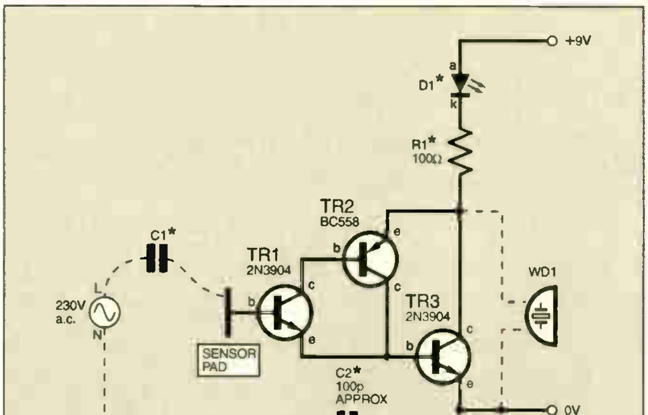


Fig.22. Circuit diagram for the Live Wire Detector.

The resulting current passing through TR3 via resistor R1 and l.e.d. D1, is large enough to light the l.e.d. Resistor R1 is included to limit the current. In fact, the l.e.d. flickers at the frequency of the electrical field source, at 50Hz for the UK mains supply (60Hz for USA). This is because TR1 is only turned on when the voltage on its base goes positive, but this is too fast to be noticeable visually.

The effect can be used to advantage. By connecting a piezo sounder or high-impedance earpiece between the collector and emitter of transistor TR3, an audio indication of the presence of mains fields can be provided, in the form of a 50Hz buzz (60Hz in USA). If this is preferred to a visual indication, then the l.e.d. can be replaced by a link wire and the value of resistor R1 increased to 10k. A louder sound output will also result.

The l.e.d. will only be turned on when the sensor is brought close to the live conductor in a mains cable, enabling it to be easily identified. When the sensor is removed from near the cable, the l.e.d. will be turned off. The circuit's earth is effectively provided by the capacitance of the mains circuit supply to the user's hand, and the user's body capacitance to earth, which is around 100pF (depending on body size!).

Gluing aluminium foil to the inside of the plastic case and connecting it to the battery negative can increase the hand capacitance effect, although this is not usually necessary. These stray capacitances

COMPONENTS

Resistor

R1	100Ω	

See SHOP TALK page

Semiconductors

D1	red l.e.d., 5mm
TR1, TR3	2N3904 *npn* transistor (2 off)
TR2	BC558 *pnp* transistor

Miscellaneous

WD1	piezo sounder or high impedance earpiece

Stripboard, 8 holes x 8 strips; drawing pin (see text); PP3 9V battery; PP3 battery clip; plastic case to suit; connecting wire; solder, etc.

Approx. Cost Guidance Only **£3** *excl. case and battery* are shown in Fig.22 as capacitor C1 and C2, illustrating how stray capacitance, which can be a problem in many high gain and high frequency circuits, can sometimes be used to advantage.

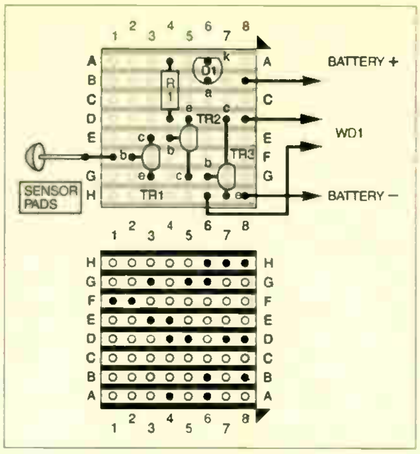
Note that the mains Neutral is approximately at Earth potential, although it is not connected to it.

CONSTRUCTION

The circuit is built on a piece of stripboard, as shown in Fig.23. There are no track cuts required. Ensure that the transistors and l.e.d. are correctly orientated.

The piezo sounder, or earpiece, can be connected directly to the stripboard, or a suitable jack plug and socket arrangement can be used, as has been shown in previous designs in this series.

Mount the circuit inside a small plastic box, size and shape of your choosing, but which should be large enough to house the battery.



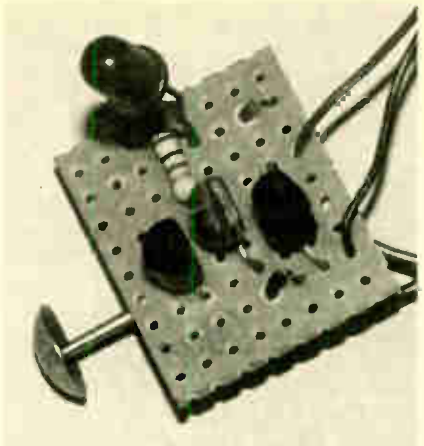


Fig.23. Live Wire Detector stripboard component layout and completed prototype circuit board. Note there are no breaks in the underside copper strips.

USING THE UNIT

The unit will perform many useful functions and can even replace a multimeter in some instances, especially if only a go/no go display is required. Bringing the sensor close to a live conductor will be indicated by the l.e.d. lighting. This can be used to identify the live conductor in a cable without the need for an electrical contact, as is generally the case with a neon type mains tester. **Do not use it close to an uninsulated live mains carrying conductor**.

The live terminal of a mains outlet socket can also be checked to ensure that it has been wired correctly. If the socket is fitted with an on/off switch, this should be switched on. Bringing the unit close to the N or E terminals should not cause the l.e.d. to turn on, but bringing it close to the terminal should.

FUSE CHECKER

The unit is also very useful in checking if the fuse in a mains plug is serviceable, without the bother of dismantling the plug or unplugging the appliance. This should be the first thing that should be checked when confronted by an apparently faulty appliance. It can be done simply by using this Live Wire Detector to check if the cable between the plug and appliance is live when the appliance is plugged in.

A blown fuse will be indicated by the l.e.d. not lighting, as will a disconnected live wire in the plug. Unfortunately, a disconnected neutral wire will not be revealed by this unit so that a visual inspection may be required, although disconnected wires in modern factory fitted moulded plugs are most unlikely.

LIGHTS CHECK

Older style Christmas Tree lights consist of a number of series-connected low voltage lamps (normally 20 × 12V or 40 × 6V) connected across the 230V mains supply. Any one of these failing open circuit or becoming disconnected will cause the whole chain to fail. Discovering the offending bulb can mean disconnecting, checking and reconnecting each bulb in turn. Murphy's Law ensures that it is usually one of the last bulbs checked which will be found to be the cause!

The chain is usually connected (starting at the plug) with a wire from the L terminal to the first bulb, the other end of which is connected by a short wire to the next bulb and so on down the chain with a long wire (twisted around the other wires) from the last bulb back to the N terminal in the plug.

If, say, the fourth bulb is faulty or has become disconnected, bringing the sensor close to the first, second, third and fourth bulbs in turn will cause the l.e.d. to light. But the l.e.d. will not light after the fourth bulb, indicating a fault there.

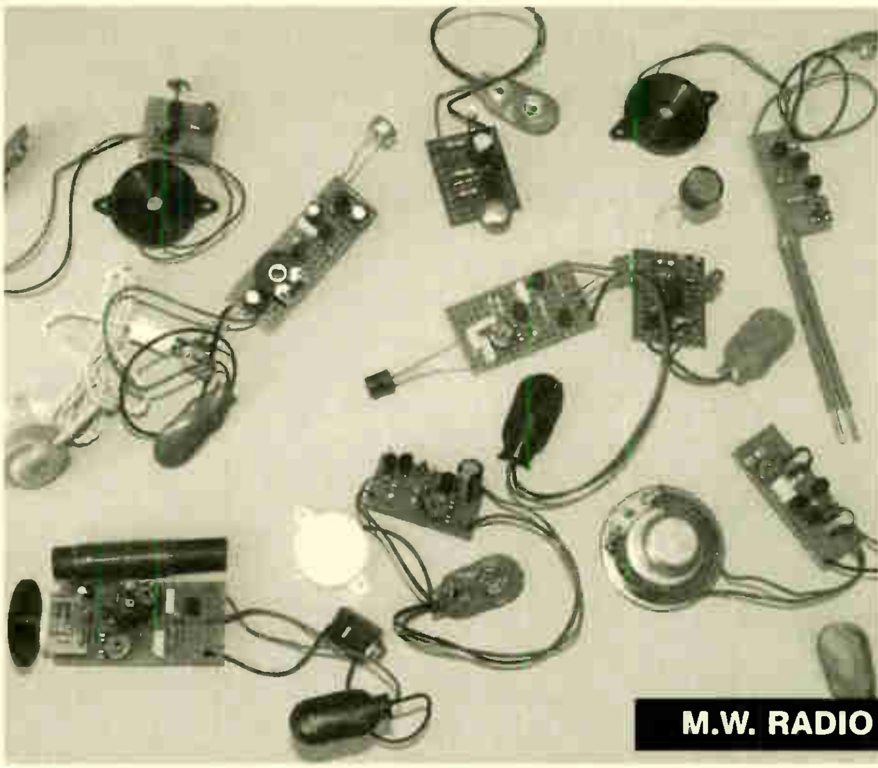
Where the conductors are twisted, it may be found that the circuit only responds along certain sections of the cable. This is because at various places the Live wire will be shielded from the sensor by the other conductor. It is important, therefore, to check along a good length of cable in case this effect gives the impression that a cable is not live when it is.

Bringing the sensor close to an earthed appliance should also not light the l.e.d. unless the earth cable is disconnected or broken so that this unit can also be used to check this.

TAKE CARE

It is clear that a non-lighting l.e.d. does not mean that a cable is safe as this could be due to the above shielding effect, or a poor sensor circuit Earth (if the user is on a ladder for instance). It could even be due to detector's battery being disconnected or exhausted! It is therefore most important that the unit is checked on a known live cable, or by touching the sensor, to ensure that the l.e.d. is operating, before testing an unknown conductor.

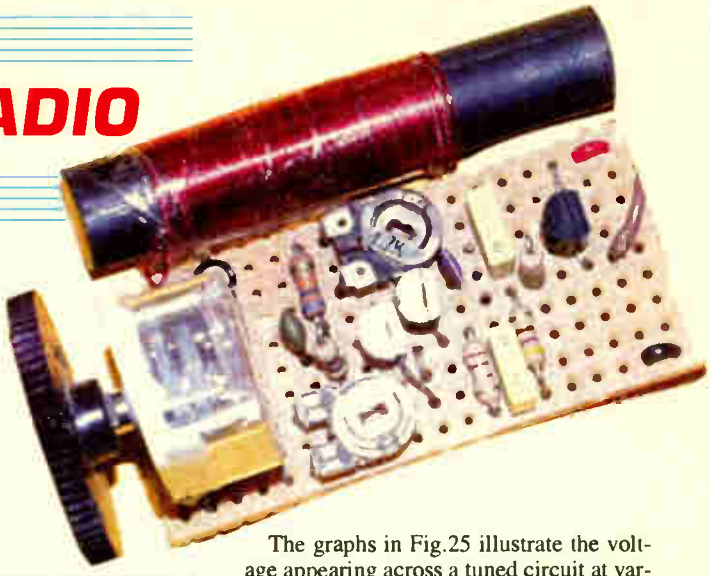
It will be noticed that touching the sensor normally only lights the l.e.d. briefly if the unit is held in the hand. If it is placed on an insulating surface, especially in a region with a high mains field (anywhere near a live conductor), it will glow brightly. This behaviour can be used to test light bulbs, fuses etc., by touching the sensor plate with one terminal of the component while holding the other in your hand. A blown fuse or bulb will not light the l.e.d., allowing continuity to be checked.



M.W. RADIO

Some of the simple transistor-based circuit assemblies described in this series.

MEDIUM WAVE RADIO



No series about transistor circuits would be complete without a simple radio circuit and, although better performance is obtainable using integrated circuits, simple radios are still fun to build and use and have been popular since the first transistors were introduced, well over 50 years ago.

RADIO RULES

Before describing the operation of this circuit, it may be useful to review a few basic principles which govern radio transmission. Aerials (both transmitting and receiving) are much more efficient when their length is comparable to the wavelength of the signal to be used.

Since wavelength is inversely proportional to frequency, it is clear that lower frequencies require longer aerials. It is, therefore, impractical to try to transmit audio signals directly as this would require aerials several hundred kilometres long, so most radio transmissions are restricted to higher frequencies, above a few hundred kilohertz.

CARRY ON

To transmit any useful information (e.g. speech or music) this high frequency, which is called the *carrier frequency* must be modulated and various schemes exist for doing so. Frequency modulation (f.m.), where the frequency of the carrier is varied by the audio signal, is the most widely used for hi-fi transmissions, although amplitude modulation (a.m.) is still popular where lower quality is acceptable.

This is probably due to the ease with which an a.m. radio signal can be *demodulated* and the audio signal recovered. The use of a carrier also has the great advantage of permitting simultaneous transmission by a large number of radio stations, each on a different frequency, while still allowing the listener to tune into one particular station.

In Fig.24 is shown a high frequency carrier which is amplitude modulated by a low frequency signal. In this case it is a sine wave, although it would more likely be a complex speech or music waveform. To receive this, a circuit that responds only to the carrier frequency (or a small range of frequencies around it) is required and here the tuned circuit, which we illustrated in the *Metal Detector* project (Part 2, March '03), can be used.

TUNED CIRCUIT

A tuned circuit has a low impedance at all frequencies except its resonant frequency (which is determined by the value of the inductor and capacitor used) so that all signals appearing at the aerial will be short circuited to earth, except the frequency to which the circuit is tuned.

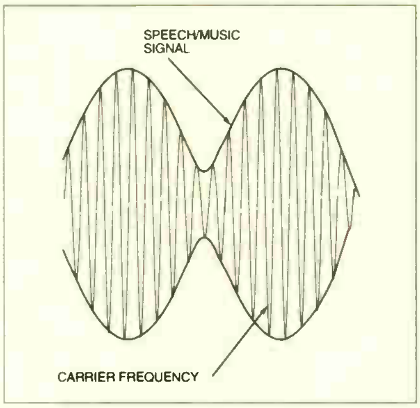


Fig.24. The make-up of an amplitude modulated (a.m.) radio signal.

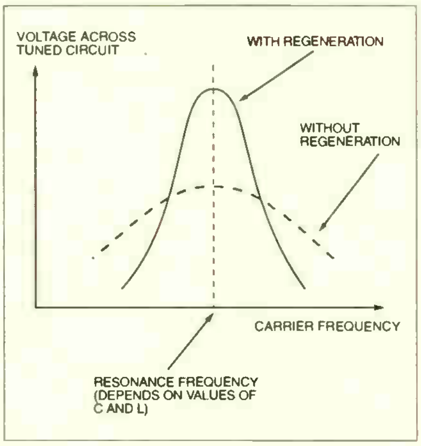


Fig.25. Frequency response of a tuned circuit.

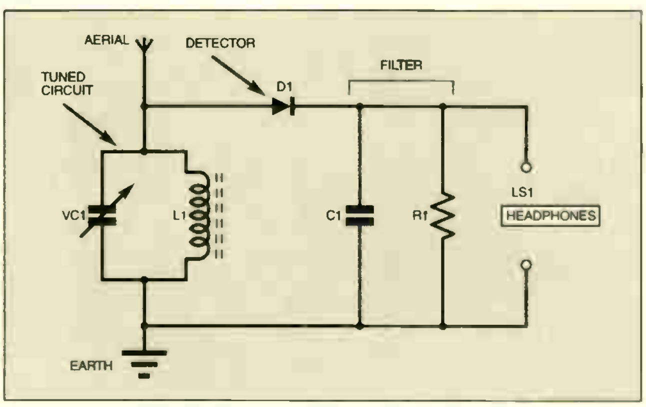


Fig.26. Basic radio receiver circuit.

The graphs in Fig.25 illustrate the voltage appearing across a tuned circuit at various frequencies. It will be seen that the voltage falls away gradually as the applied carrier frequency differs from the resonant frequency of the tuned circuit. Thus if all transmissions on all frequencies had an equal amplitude, the one coinciding with the resonant frequency would produce the largest output.

This is, of course, not the case as some transmitters radiate at lower power or are further away, resulting in a lower voltage at the receiver. For the best results it is clear that the peak response should be as "sharp" as possible to achieve maximum suppression of unwanted signals. This is governed by losses inherent in the tuned circuit and the smaller these are, the sharper will be the response.

BASIC CIRCUIT

A simple radio receiver circuit diagram is shown in Fig.26. The tuned circuit is formed by an inductor, L1, and a variable capacitor, VC1. The latter enables a range of frequencies to be tuned in.

Assuming the transmitted signal is that in Fig.24, the signal appearing across the tuned circuit will be identical. To recover the audio signal, the received signal must be demodulated. This can be done with a single diode, D1, which allows only the positive portion of the signal to pass. It is followed by a simple filter, consisting of capacitor C1 and resistor R1, which removes the high frequency carrier signal, leaving only the audio signal, which can be listened to via suitable headphones.

Given a long aerial and a good earth connection, together with very sensitive headphones, you may just about be able to receive a strong local a.m. station using this circuit. For a portable radio, however, it is useless, but it gives an idea of what is required to make a radio.

IMPROVEMENTS

Aerial signals smaller than the forward voltage of the diode (about 0·6V for a silicon diode) will not be passed to the headphones so the sensitivity of the circuit must be improved to allow weaker stations to be received.

The problem with using only one tuned circuit is that its response is too "flat" and with today's crowded wavebands, it is difficult to select only one station and stronger stations transmitting on an adjacent frequencies to that required can interfere with reception. To improve the selectivity, commercial receivers use many more tuned circuits, but this leads to other problems that need much more complex circuits to resolve.

SENSITIVITY

The sensitivity of the radio can be improved simply by amplifying the aerial signal before it is fed to the detector, while to improve the selectivity, the losses inherent in the tuned circuit must be minimised to sharpen its response. As a first step, any impedance connected across the tuned circuit must be made high to load the tuned circuit as little as possible. Consequently the input impedance of the amplifier must be high.

The tuned circuit is coupled to the base of transistor TR1 by capacitor C1. The latter prevents the d.c. conditions from being upset by the low resistance of L1. The input impedance of this stage is high due to the large value bias resistor R2 and the resistance in the emitter circuit, provided by preset potentiometer VR1, so that the tuned circuit is only lightly loaded.

The circuit around transistor TR1 is very reminiscent of that used in the Metal Detector referred to earlier, in which the first transistor operated as an oscillator. Potentiometer VR1 is adjusted so that there is *just* insufficient positive feedback to sustain oscillation.

As the frequency to which the circuit is tuned increases, this feedback also increases but since the input impedance falls, the losses in the tuned circuit increase so that the circuit remains stable and VR1 should not need to be constantly re-adjusted.

COMPONENTS

Resistors

R1	68k
R2	4M7
R3	2k2
R4	1M5
R5	4k7

See SHOP TALK page

Potentiometers

VR1	1k skeleton preset
VR2	47k skeleton preset

Capacitors

C1	47p ceramic
C2	100p ceramic
C3, C4	100n polyester (2 off)
C5	10µ radial elect. 25V
VC1	15p to 165p variable capacitor

Semiconductors

TR1, TR2	2N3904 *npn* transistor (2 off)
TR3	BC558 *pnp* transistor

Miscellaneous

L1	Ferrite rod, 50mm x 10mm, with coil (see text)
LS1	high impedance earpiece

Stripboard, 19 holes x 9 strips; PP3 9V battery; PP3 battery clip; plastic case to suit; 28swg enamelled copper wire; solder, etc.

Approx. Cost Guidance Only **£5** *excl. case, earpiece and battery*

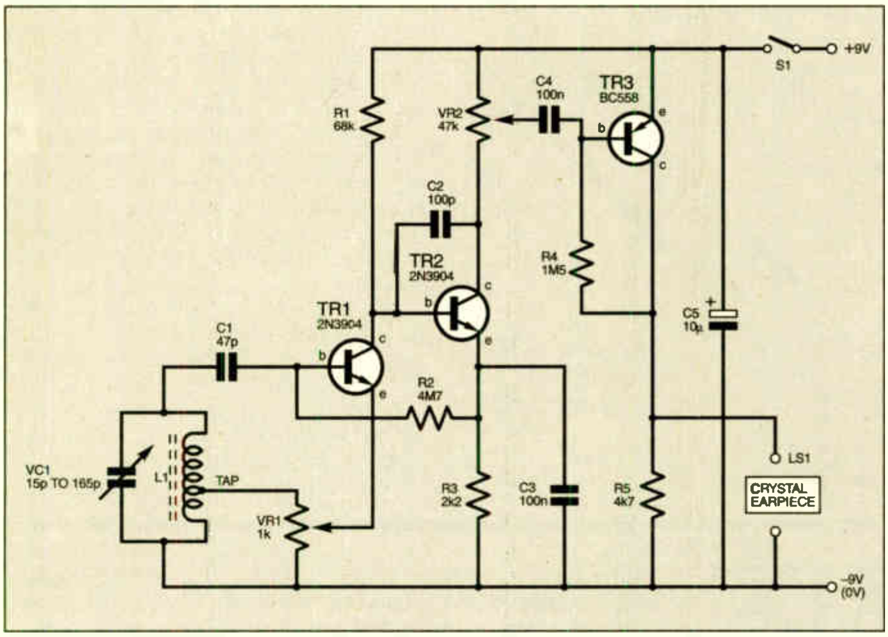


Fig.27. Practical circuit diagram for the Medium Wave Radio.

Another thing that can be done is to try to replace some of the tuned circuit losses by using positive feedback. However, this can lead to oscillation, and so the feedback level must be closely controlled. It is found that the selectivity is greatly improved if the circuit is just on the verge of oscillation.

Most circuits using this technique (which was called *regeneration* in old valve receivers) have a separate control to do this, but which is tricky to use, having to be adjusted for each station and is the reason why no modern commercial radios use it. With careful adjustment, though, it is possible to do away with this control and ensure that once set up, no further adjustment is required.

PRACTICAL CIRCUIT

The circuit diagram for a suitable receiver is shown in Fig.27. As in Fig.26, the tuned circuit is formed by inductor L1 and variable capacitor VC1. The coil acts not only as an inductor but also an aerial and the directional properties of the ferrite rod on which it is wound can also be useful to help eliminate unwanted stations from interfering with reception.

Transistor TR1 amplifies the signal appearing across the tuned circuit, boosting the sensitivity of the circuit and eliminating the need for an earth connection. No separate detector diode is used in this design as this function is carried out by the collector (c) of TR1.

Transistor TR2 further amplifies the signal but the gain at high frequency is very low due to the presence of capacitor C2, so that only the audio signal is amplified while the residual radio frequency carrier signal is suppressed. Using d.c. negative feedback via R2 stabilises the operating point of the two transistors, while capacitor C3 bypasses TR2's emitter resistor, R3, so increasing the gain of this stage at audio frequencies.

The collector load consists of potentiometer VR2, which forms a volume control enabling the signal level to TR3, the earpiece driver, to be varied.

CONSTRUCTION

The circuit is constructed on stripboard, as shown in Fig.28. Care must be taken to ensure that stray capacitance is minimised by keeping component leads as short as possible.

Aerial coil L1 is made by winding 10 turns of 28s.w.g. enamelled wire onto a

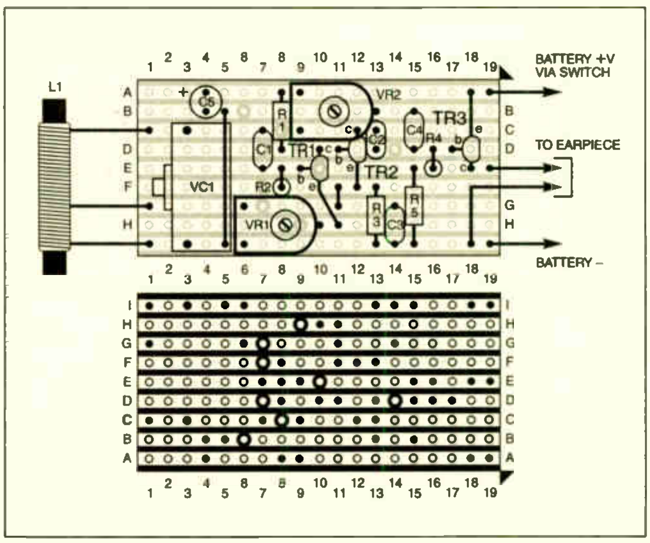
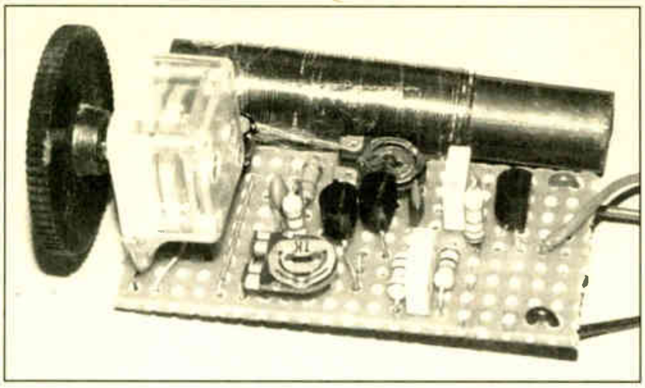


Fig.28. Radio stripboard component layout, wiring and details of breaks required in the underside copper tracks.



Completed radio showing the ferrite rod aerial.

Starting Next Month . . .
. . . RADIO CIRCUITS

Intended** to dispel the mysteries of radio, this **short series** of articles by **Raymond Haigh features** a variety of circuits for the set builder and **experimenter.

This new series will view the technology in an historical perspective and try to dispel its mysteries. The main purpose, however, is to present a variety of practical circuits.

You will be able to build a wide range of receivers, everything from a crystal set to a superhet.

piece of ferrite rod, 50mm long and 10mm in diameter. This forms the feedback winding and should be followed by a further 60 turns to form the main coil.

Each turn should be made adjacent to the previous one and the whole winding should be secured to the ferrite rod with insulation tape. The final number of turns may need to be adjusted (up or down) depending on the actual capacitance range of variable capacitor VC1, which is used to obtain the required medium waveband coverage.

Since it is easier to remove turns than to add them once the wire has been cut to length, it is preferable to initially wind slightly more turns than required.

A miniature tuning capacitor was used in the prototype for VC1, with a value range of 15pF to 165pF. The actual range is not too critical as most values can be accommodated by varying the number of turns on the coil, as just said, and/or connecting fixed capacitors across VC1 to adjust the range span.

TUNING CHECKS

Once construction is finished, VR1 and VR2 should be turned fully clockwise and a battery connected. Adjust VC1 until a station is heard and then adjust the signal amplitude using VR1. If the circuit oscillates (which is heard as a high pitched whistle in the earpiece) turn VR1 back slightly.

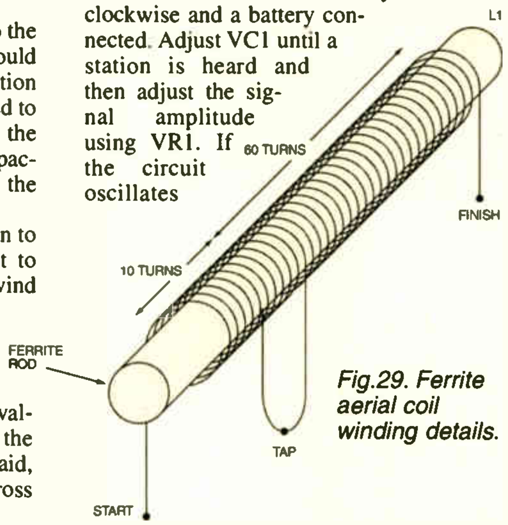


Fig.29. Ferrite aerial coil winding details.

Turn VC1 fully clockwise and check that no oscillation occurs on other stations, re-adjusting VR1 if required. The circuit should now not oscillate, irrespective of which station is tuned in.

The circuit will draw about 2mA, so an on/off switch is required. Alternatively, a 3·5mm stereo jack socket can be fitted for the earpiece with the tip terminal connected to TR3's collector, the centre terminal connected to the circuit's 0V line (marked as Battery –V). The battery negative itself is then connected to the outer terminal.

Inserting the earpiece plug will short out these last two terminals, switching on the power to the circuit. The principle is similar to that in Fig.7 of Part 1, Feb. '03.

In the concluding part of this series, next month, we describe a Twilight Switch, and a simple circuit for that most fascinating of all musical instruments – the Theremin.

SHOP TALK
with David Barrington

Super Motion Sensor

Nearly all of the "miniature" light-dependent resistors we looked up in various components catalogues seem to be within the specification required for the *Super Motion Sensor* project. A suitable l.d.r. should certainly be stocked by many of our components advertisers.

The 12V relay used for this project **must** have switching contacts rated for the appliance it is going to be controlling. This may mean that it will not sit directly on the circuit board so you will have to mount it separately and "hard wire" the relay to the p.c.b.'s appropriate copper pads. The Telecom type, mentioned by the author, should be widely available, but do not forget to check the contact ratings before purchase.

The TL071 low noise, low distortion op.amp is a popular device and should not present any buying problems. It was selected particularly for its high input impedances, which are necessary for this circuit. The 4066 quad bilateral switch i.c. is another popular widely-stocked device.

The Sensor printed circuit board is available from the *EPE PCB Service*, code 391 (see page 359).

Back-To-Basics 4 – Live Wire Detector/M.W. Radio

Some readers may experience problems with a couple of parts for the *Medium Wave Radio*, one of this month's *Back-To-Basics* projects.

Most components suppliers carry a 100mm length by 10mm diameter ferrite rod, which means readers will have to cut it to size. One problem, ferrite is very brittle and great care will be needed when cutting this material. One suggestion is to score around the rod diameter, at the required length, and then give it a "gentle" tap to snap it apart. We see that **WCN Supplies** (☎ ***023 8066 0700***) are currently "advertising" a 140mm x 10mm ferrite rod, with an unwanted tuning coil, at a reasonable price.

The specified tuning capacitor is normally found listed as a miniature "transistor radio" type. However, the favourite value is 20pF to 126pF, which should be OK for this simple radio. One was found listed by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110.

No component problems should be met with the *Live Wire Detector*, the second simple project this month.

Door Chime

The audio amplifier i.c. chosen for the *Door Chime* project is the TDA7052 power amp chip which, in fact, contains two amplifiers in a single 8-pin d.i.l. package. This device is widely held and should not present any buying difficulties. You should certainly give ***Cricklewood Electronics*** (☎ ***020 8452 0161***) a call as we understand they have stocks.

The rest of the components are standard "off-the-shelf" items. Your local DIY superstore should have a suitable front doorbell pushswitch, if you do not already have one, of course. The small printed circuit board is available from the *EPE PCB Service*, code 390 (see page 359).

PLEASE TAKE NOTE

Earth Resistivity Logger *(April '03)*

Page 292. The wrong operating frequency for the crystal X1 is listed in the Components box. This should be 3·6864MHz. The circuit diagram Fig.5 and text are correct.

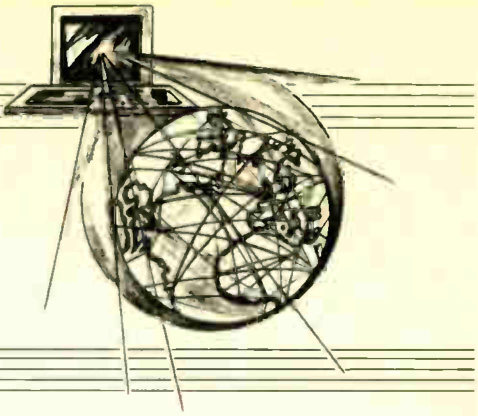
Shoptalk *(April '03)*

We regret that we gave an incorrect telephone number for Farnell and that it should be 0113 263 6311. You can also use 0870 1200 200.

SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



It's a Steal

In last month's column the auction web site eBay (**www.ebay.co.uk** – or select your own country's web site) was described in further detail. eBay enables its members to sell a huge variety of products in its auctions, which run for a preset period that is timed accurately to the second.

When bidding for an item, it can be infuriating to lose the auction when a competing higher bid is entered just a few seconds before the auction closes. This is especially the case when struggling with dial-up access, as it is impossible to refresh the screen more than once or twice within the closing minute of the auction.

One way of clinching a deal is to place an earlier bid that is sufficiently high enough that no-one else will want to beat it; provided that a realistic grip is kept on the likely value of the item and you don't get too carried away with bidding, you can hopefully frustrate any competing bids if you pitch yours sensibly. (As an example of getting carried along with the bidding, the author recently noticed a copy of Adobe Photoshop 7.0 that sold for £460.00, which is fast approaching the maximum full retail price on the High Street, and nearly 40% above a typical eBay price.)

There is no substitute, though, for trumping the deal with your own bid placed only a few seconds before bidding is due to close. This last-moment winning bid is known as "sniping" and to the uninitiated eBayer, losing an auction to a "sniper" can be infuriating! To the sniper though, such a victory can be immensely satisfying!

On the Line

The trick to successful sniping is to use an online bidding service. A search on Google for *auction stealing* or *auction sniping* will highlight a number of web sites that provide this service such as that offered by Auctionstealer (**www.auctionstealer.com** or **www.auctionstealer.co.uk**).

The service places a bid automatically on your behalf during the final few moments of an auction (note that some sniping services appear to use software running on your computer instead). This also relieves you of the onerous task of having to be present at your computer in order to place your bid just before closing time.

The Auctionstealer system is easy to use and works like magic: simply create a username and password, and then enter the number of the eBay item you are interested in, together with your maximum bid. As a free service, Auctionstealer will then enter your own bid ten seconds before the auction closes.

For low value items, this is a great way of having your bids entered automatically, without any need to watch the bidding for yourself. The process is seamless with the eBay auction site, so it appears to eBay that you have placed a bid just as you usually do. However the ten-second period does still offer scope for being outbid by others.

Premium Service

If you are keen to win what might be described as a particularly "juicy-looking" item, then Auctionstealer offers a paid-for premium service starting with a $1 fee per item, that will enter your bid just *three seconds* before closure. This leaves no time for anyone else to respond to your bid (unless another sniper has bid a higher price) and it has resulted in some wonderful deals being struck! The paid-for service also extends to monthly subscriptions for frequent bidders if desired.

Payment is made by Paypal; in fact in the author's case, buying a series of $1 bids by Paypal resulted in the writer's credit card being locked by Visa, who viewed the series of small Internet transactions with suspicion. This became apparent when a major Internet purchase of a new TV was made the next day, because the credit card transaction was declined.

Overall, a combination of eBay's web site and Auctionstealer has produced a number of valuable "finds" and it's worth bookmarking both sites for future use.

Paying the Paypal Way

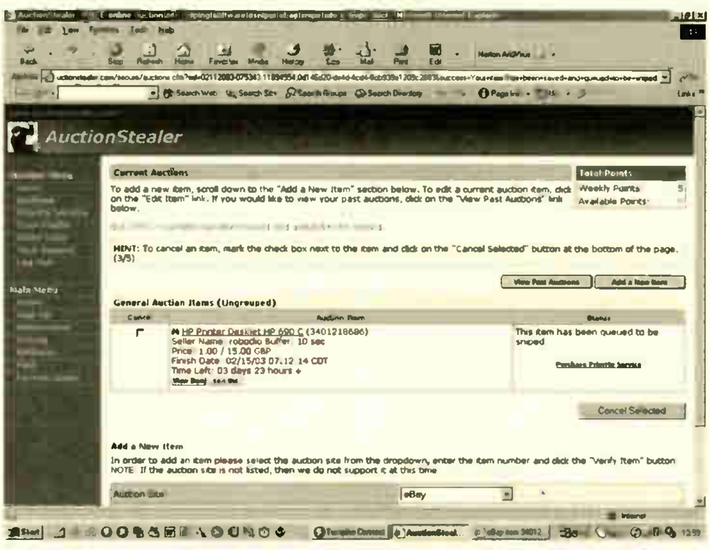
The problem mentioned above regarding credit card processing, which resulted in the writer's credit card being frozen, highlights the fact that trading on the Internet is becoming ever more difficult, mainly due to the increased security measures that the credit card companies and banks have put into place. In the UK it is not easy for new businesses to open an Internet merchant account anyway, so they may not be able to accept CC payments during their start-up phase.

Buyers and consumers should also be aware of the conditions now imposed by the credit card companies concerning the use of their credit card via the Internet. In particular, many CC providers, who demand that only a secure server be used for payments, expressly prohibit customers from sending a credit card number by open email (something that is very unwise to do anyway).

The writer recorded three $1 payments to Paypal, then to make doubly sure that the subsequent Internet purchase of a TV was indeed genuine, the writer had to confirm this to Visa by phone, and they still sent a letter seeking further confirmation that the transaction was indeed genuine. The security of financial systems is being tightened up everywhere, to stamp out fraud and money-laundering.

Paypal (**www.paypal.com**) is the ubiquitous online credit card processing service now owned by eBay, which boasts of having 20 million registered users. The system sounds easy enough but is full of pitfalls for the unwary user or business owner. For example, their web site states "You can pay anyone with an email address . . . even if they don't have a Paypal account." ". . . The money will be sent directly to your recipient . . ."

Sounds easy enough, but is it? Next month we look more closely at Paypal and highlight some of the potential problems that exist when doing business the Paypal way. If you have your own Paypal story to tell or would like to comment, you can email me at **alan@epemag.demon.co.uk**. See you next month.



Auctionstealer allows last-second bids to be made.

PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

ONE of the most common requests for help comes from readers who have gained some experience at building projects, and wish to move on to designing their own circuit boards. As to be expected there is a natural need for a progression from cloning published projects to a more "do your own thing" approach. Some wish to substantially modify existing designs or merge them, but the primary aim of most is to build from published circuits.

There are plenty of circuits published in books, on the Internet, and in *EPE's Ingenuity Unlimited* pages. In order to turn one of these into a working project it is necessary to work out your own circuit layout using stripboard, a custom printed circuit board, or whatever.

A custom printed circuit board certainly gives the neatest results. Designing and building their own printed circuit boards is something that many electronic project builders undertake routinely, but it is not the best place to start. Initially, it is better to use a simpler and more direct method that involves fewer skills and processes.

Stripboard is by far the most popular choice, but it would be a mistake to overlook plain matrix board. This was once a popular construction method, but these days it is mainly used for testing prototype circuits rather than for final construction.

Hole Truth

Plain matrix board is essentially stripboard minus the underside copper strips. There are expensive wiring systems available that utilize this type of board, but again, these are really aimed at the production of commercial prototypes.

Some solder, a plain matrix board and some single strand wire is all that is needed for project building. The general scheme of things is to fit the components onto the board in much the same way as for a custom board or stripboard.

However, instead of the leads being cut short and soldered to copper tracks on the underside of the board, they are bent over at right angles and used to carry the interconnections (see Fig.1). In other words, the leadout wires are used to replace the copper tracks of a normal printed circuit board.

Some modern components, such as integrated circuits and many capacitors, have pins instead of leadout wires. In other cases the component leads may simply be too short. In either case some 22s.w.g. or 24s.w.g. tinned copper wire can be used to bridge any gaps in the wiring.

If necessary, interconnections can be carried on the top side of the board by threading the wire up through one hole in the board and then back down through another. This is the equivalent of a double-side printed circuit board or link-wires used on a stripboard, and it enables wires to cross without touching.

Plainly Speaking

Although no one is ever going to accuse plain matrix construction of looking particularly neat, this method of construction can have definite advantages. When designing any form of board layout it is important to bear in mind that there are stray couplings from one part of a circuit to another.

There can be inductive couplings, but it is coupling through stray capacitance that is the major problem in most cases. For instance, a capacitor is simply two pieces of metal separated by a layer of insulation, so two pieces of wire with air in between constitute a capacitor. Two copper tracks running side by side on a printed circuit board or a stripboard can also act as a capacitor.

The values involved are tiny, but a very small amount of capacitance in the wrong place can be sufficient to produce instability or other problems. The problem is most acute with circuits that involve large amounts of amplification and (or) operate at high frequencies.

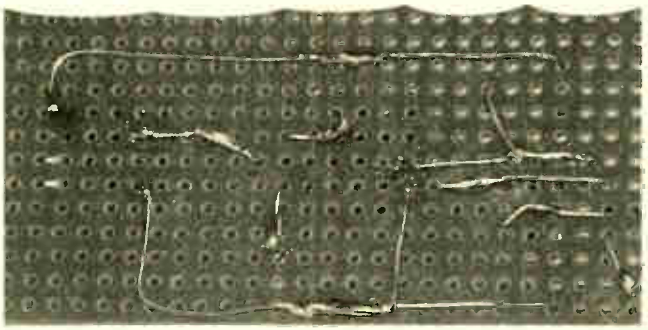


Fig.1. Plain matrix construction is not particularly neat but it is simple and efficient.

Going Astray

The stray capacitance problem is worst with stripboard because it has numerous copper tracks running the full length of the board, which produces a large number of built-in capacitors that are relatively high in value. There are ways of minimising the problem, such as making cuts in the strips to isolate unused pieces, or even peeling away unused bits of copper strip. An earthed strip can act as a screen between parts of a circuit where stray feedback could be a problem.

It can be a struggle to get some H.F. circuits to work on stripboard, and there is no guarantee of success. Plain matrix board does not eliminate these problems, but it keeps them to an absolute minimum. It is the equal of a custom printed circuit board in this respect.

Practically any type of project can be constructed on plain boards, but it can be awkward to use with some types of circuit. The main problem area is digital circuits that use numerous digital chips with huge numbers of interconnections.

This type of thing can be accommodated by plain matrix construction, but it can be very time consuming and difficult to produce neat and reasonably compact layouts. Construction times can also be very long.

The popularity of microcontrollers means that traditional digital circuits of this type are now something of a rarity, so the plain matrix approach is applicable to most modern circuits.

Initial Placements

Probably the most difficult part of designing board layouts is knowing where to start. This is almost certain to be a major sticking point for someone trying their first few board designs.

Initially, try a couple of board layouts for very simple projects. They can be done as pure exercises if there are no simple projects that you wish to build.

The circuit diagram shown in Fig.2 was featured in an *Interface* article, and it is designed to produce a low current +5V output from a PC printer port. This type of single chip circuit is ideal for initial attempts at board design.

A CAD program and a PC are ideal for drawing up this type of thing. All these programs can produce a grid of dots on the screen to aid the placement of lines and shapes, and the dots can be used to represent the holes in the board. Many people use graph paper when drawing up designs on paper, but drawing up your own chunkier version on plain paper using something like a 4H pencil is a better alternative.

Plain matrix board has the holes drilled on the usual 0·1 inch (2·54mm) matrix, but it easier is to see everything clearly if the designs are drawn at double life size. Initially anyway, draw the design as a top view only. Connecting wires can be represented as dashed lines, or drawn using a different colour to the one used for the top layer.

Getting Started

Start with a board outline that is definitely a lot wider than is required so that there is no risk of the design running out of space at one end. The height must have (say) five rows of holes to accommodate mounting holes, two for the supply rails, and sufficient rows between the supply rails for the circuit.

In the case of Fig.2, the 8-pin integrated circuit requires four rows, and three or four rows should be included above and below to allow some room to manoeuvre. Making the board as small as possible is not a consideration, so four holes were used above and below the integrated circuit. This could be reduced to three or even two holes if space was limited.

Next the integrated circuit is drawn into place on its allotted rows of holes, somewhere near the middle of the board. The normal orientation for integrated circuits is with pin one at the top, but in this case the layout is likely to be easier with the chip the other way around (as indicated by the pin numbers).

With a custom printed circuit board it is possible to design a neat component layout and then join everything together with a complex track pattern. With plain matrix and stripboard construction it is better to "go with the flow", and use a component layout that gives simple and reasonably direct interconnections.

First Steps

The obvious first step is to draw the connections from IC1 to the supply rails, and in this case there are two pins that connect to the positive rail (pins 4 and 8). The simplest way of handling this is to add the supply connection for pin 4 and then add a connection between pins 4 and 8. The next step is to start adding the components to the design.

they are readily accessible. In the real thing these connections are made via solder pins on the board. The double-sided variety of pin is better for this method of construction, as these provide more for the wires on the underside of the board to be connected to.

You should end up with a design similar to that shown in Fig.4; without the deliberate mistakes. The unused areas at each end of the board have been erased and the two mounting holes have been added. Two are sufficient for small boards, but for larger boards it is advisable to use one near each corner.

Final Analysis

Even with a simple design it is advisable to put it to one side for half

There are several possible solutions to this, and one of them is simply to leave the design unchanged, but with insulating plastic sleeving added to one of the wires. The solder pin could be moved to just below D1, but this would move it away from the other input connections. Another option is to weave one of the wires onto the top side of the board, over the other wire, and then back down again.

Yet another option is to do some juggling with the basic design. This is quite easy if a CAD program is being used, and a modified design of Fig.4 is shown in Fig.5.

Avoid making numerous changes simply because it is easy to do so. It is easy to end up in a situation where

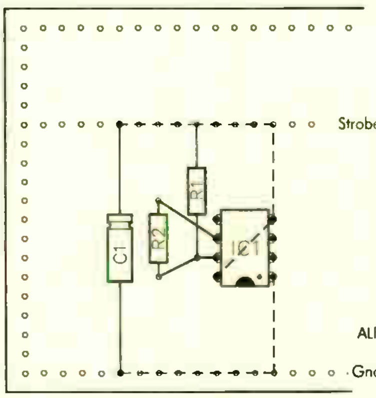


Fig.3. Initial design stages.

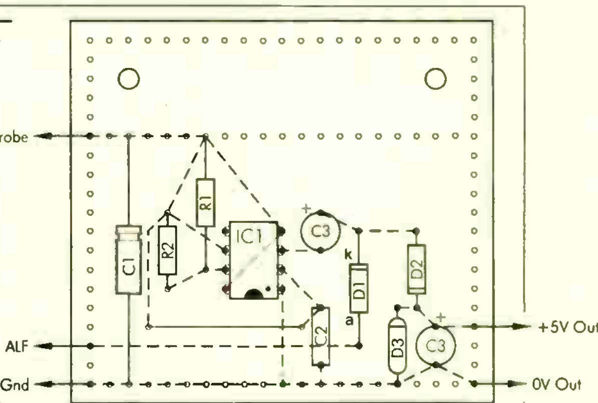


Fig.4. Finished but unchecked design – spot the "deliberate" mistakes.

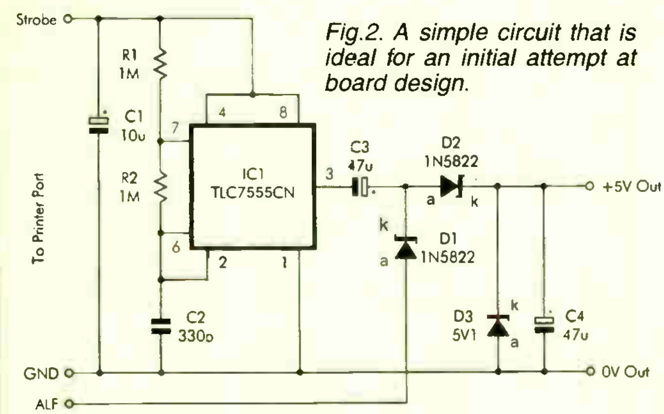


Fig.2. A simple circuit that is ideal for an initial attempt at board design.

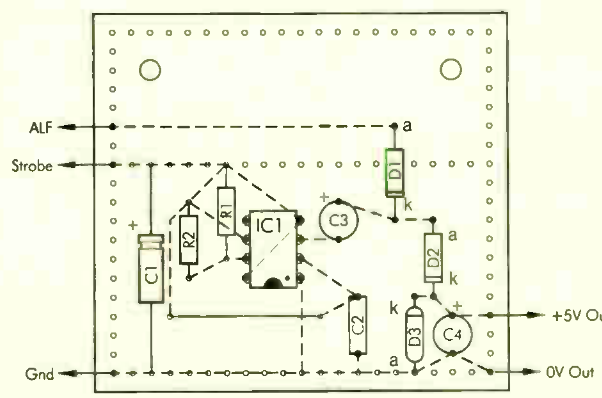


Fig.5. Corrected and, hopefully, working design.

It is best to start by adding the components that connect to the integrated circuit and gradually work outwards. Resistors R1 and R2 can be added to the left of IC1, and capacitor C1 can be added between the supply rails. This gives a layout something like that shown in Fig.3, but there is no single design that is right. There are usually numerous layouts that will give the desired set of interconnections.

The process continues with the components being added one by one, and linked to the rest of the design. The circuit diagram will usually act as a general guide to the physical layout, but it should not be slavishly followed. Have the components and a board handy when designing layouts on "paper". It is then easy to check that sufficient space is being left for each component.

Finally, the off-board connections are added, and they should preferably be at or near an edge of the board where

an hour or so and then give the design a thorough check. An advantage of this method of construction, and stripboard construction, is that any errors that make it through to the finished board can usually be corrected without too much trouble. A major blunder with a custom printed circuit board usually means building the whole thing again.

Even though errors are easily corrected it is better to get it right first time. Incorrect connections can cause expensive damage to the components, and there could be safety issues as well.

In the case of Fig.4, there are a couple of obvious errors. The capacitor labelled C3 near the bottom right-hand corner of the board is actually C4. More importantly, the wire from the anode (a) of diode D1 to the solder pin crosses the 0V supply connection to IC1, and would short-circuit to it.

two errors are added for each one that is corrected. In a similar vein, too much tidying up in an attempt to make the design "pretty" can add errors into what was previously a working layout.

Grand Designs

Producing layouts for larger circuits uses the same basic methods. Larger circuits break down into a number of circuit blocks, and with modern designs there is usually an integrated circuit at the heart of each block. Take things stage-by-stage, gradually building up the design.

Plain matrix board is not well suited to really large projects, but with small and medium sized circuits it represents an easy way of getting started with your own layouts. Unlike stripboard construction, it should work first time with temperamental circuits where stray capacitance can be a problem.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

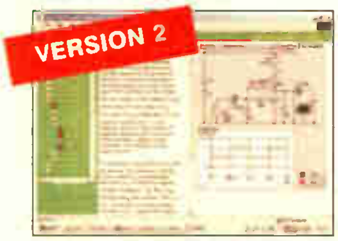
ELECTRONICS CD-ROMS

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.

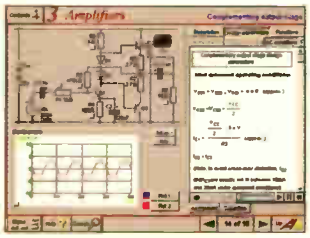
ELECTRONIC CIRCUITS & COMPONENTS V2.0



Circuit simulation screen

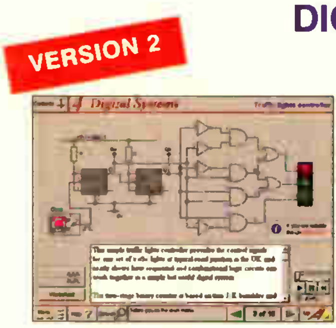
Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 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.

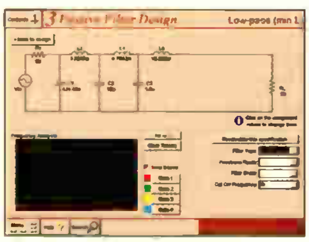
DIGITAL ELECTRONICS V2.0



Virtual laboratory – Traffic Lights

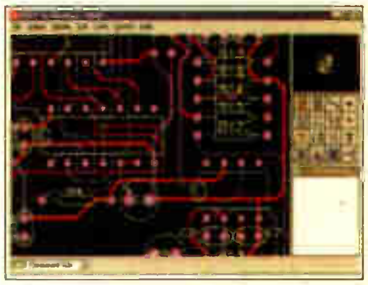
Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.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

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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.

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£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

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

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

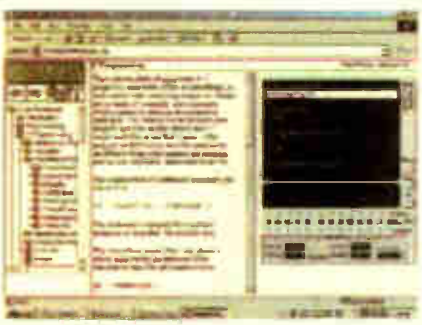
Virtual PICmicro

'C' FOR PICmicro VERSION 2

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

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

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



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

FLOWCODE FOR PICmicro

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

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

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 8, 18, 28 and 40-pin devices ● Institutional versions include virtual systems (burglar alarms, car parks etc.).

Burglar Alarm Simulation

PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

Hobbyist/Student	£45 inc VAT
Institutional (Schools/HE/FE/Industry)	£99 *plus* VAT
Flowcode Institutional	£70 *plus* VAT
Institutional 10 user (Network Licence)	£249 *plus* VAT
Site Licence	£599 *plus* VAT

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Sine wave relationship values

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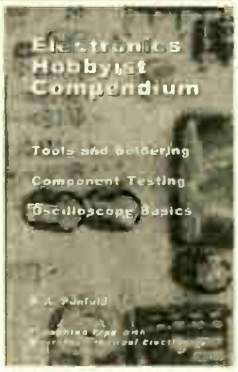

EPE's own *Teach-In* CD-ROM, contains the full 12-part *Teach-In* series by John Becker in PDF form plus the *Teach-In* interactive software covering all aspects of the series. We have also added Alan Winstanley's highly acclaimed *Basic Soldering Guide* which is fully illustrated and which also includes *Desoldering*. The *Teach-In* series covers: Colour Codes and Resistors, Capacitors, Potentiometers, Sensor Resistors, Ohm's Law, Diodes and L.E.D.s, Waveforms, Frequency and Time, Logic Gates, Binary and Hex Logic, Op.amps, Comparators, Mixers, Audio and Sensor Amplifiers, Transistors, Transformers and Rectifiers, Voltage Regulation, Integration, Differentiation, 7-segment Displays, L.C.D.s, Digital-to-Analogue.

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A hands-on approach to electronics with numerous breadboard circuits to try out.

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Counter project

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NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

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Constructional Project

EARTH RESISTIVITY LOGGER

JOHN BECKER

Part Two

Help your local archaeological society to locate and reveal the hidden mysteries of our ancestors.

IN Part One last month we discussed the principles of earth resistivity monitoring and described the construction of a circuit through which this could readily be accomplished and the data stored for computer analysis. This month we detail the software that can help in this analysis, and then examine some of the soil probing techniques. The latest updates to the software are then discussed, followed by briefly considering the ethics of surveying and some practical advice and a list of further reading.

PC SOFTWARE

The Earth Resistivity Logger's PC software is written in Visual Basic 6 (VB6). It has been proved under Windows 95, 98 and ME. It has not been tested with Windows NT, XP or 2000 as the author does not have these systems.

Readers who wish to try running the software under the last three systems may find benefit from reading Mark Jones' article *Running TK3 under Windows XP and 2000*, published in Oct '02.

There are six screens associated with the Logger's VB6 program:

- Main screen as shown below, through which sectional analysis of the survey data is performed
- Full graph screen on which all 128 × 128 download amplitude values are displayed graphically, in oscilloscope fashion (bottom photo on next page)
- Full grid screen on which all 128 × 128 download values are displayed as grid squares having amplitude-related hues or greys (top photo on next page)
- Download screen through which data retrieval from the Logger is initiated
- Directory screen through which previously recorded survey logging files can be loaded for on-screen analysis
- Error Message screen – which hopefully you will never see! This comes into action if the VB6 software detects various types of error (such as trying to load a named file which does not exist). It does not intercept errors which occur outside VB6's specified error interception repertoire as programmed by the author – the PC itself will report any such unlikely events.

MAIN PC SCREEN

The main screen offers several options to enable you to analyse the data received from the Logger. It must be said, though, that the facilities offered through the Windows Excel software supported by most PCs probably exceed what this screen can offer – more on Excel later.

There are two main areas on this screen, as seen in its screen-dump photograph.

To the right is a 20 × 20 grid block of squares, arranged so that the vertical axis represents the survey site columns, and the horizontal axis the site rows. The site data values determine the colour or grey-scale appearance of each of these squares. Two scroll bars are provided which allow the grid data coordinates to be panned vertically and horizontally so that all 16384 values of a 128 × 128 survey grid can be viewed in 400-sample blocks, seamlessly joined.

The range of coordinates from the grid matrix displayed is stated below it. To know the precise coordinate of any square, add the values (numbered 0 to 19) indicated alongside the edges of the matrix.

GRID COLOURING

There is a choice of four options regarding the colour shade range, as shown at the left of the screen. The lefthand bargraph display shows the grey-scale range available, from white to black, 36 shades in all, representing values from 0 (white) to full black (35).

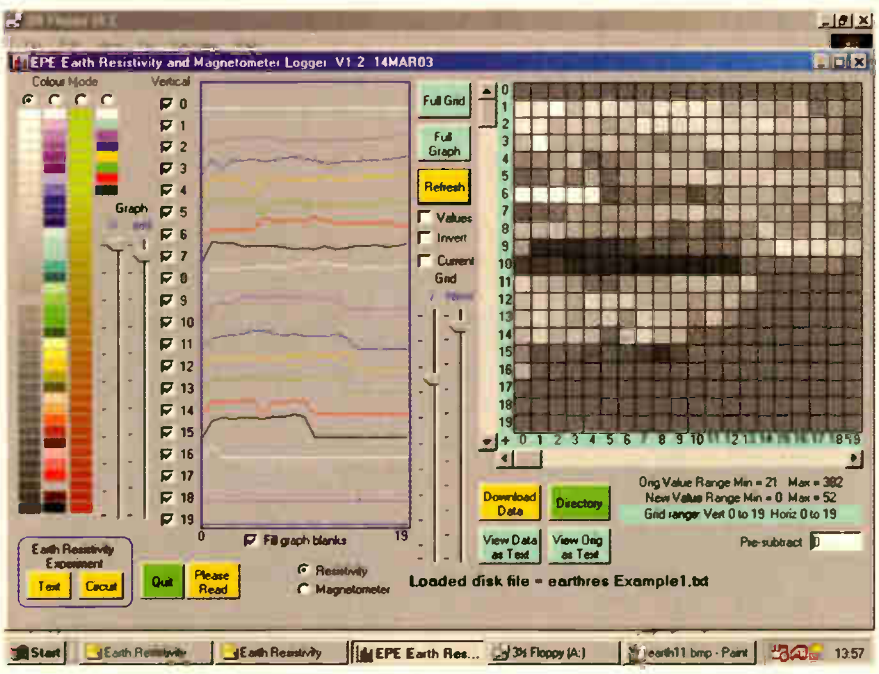
The second bargraph shows a 36-value range of "rainbow" colour shades arranged in the order that VB6 offers them in the system's own (peculiar!) numerical order. They are allocated by the program to represent 0 (top) to 35 (bottom).

Bargraph 3 is a monochrome scale of colours essentially in the green range but with varying intensities of red added. The 36 shades are again numbered from top to bottom as 0 to 35.

The 8-colour bargraph shows the "primary" colours offered by VB6, numbered 0 to 7, top to bottom.

The quality and definition of the scale shades may vary depending on the quality of your VDU.

The scales are selected by clicking on the "radio" buttons above them. In



Example of the prototype's revised main screen displays and facilities.

Example of the full screen grid display, using a zoom value of x9. With zoom at x1 all 16,384 grid squares are shown. The contrast will show more clearly on screen than it may on this printed page.

practice, the greyscale and monochrome bargraph provide the clearest indication of sample value relationships.

The values which are actually obtained from the survey site could, as said previously, fall into the range 0 to 1023. Two slider controls are provided so that the values logged can be suitably displayed as comparative values within the grid squares. They are to the left of the grid squares, jointly captioned Graph, with sub-captions of / (forward slash symbol) and *minus*. Clicking the sub-captions with the mouse cursor toggles them to show *X* (multiply) and *add*, and back again on the next click.

With the lefthand control, moving the slider causes the basic sample values to be either multiplied or divided by the slider's value, according to its sub-caption mode. Similarly with the second slider, adding or subtracting the slider's value. Multiplication/division take place first in the software routine, followed by add/minus.

These two controls allow the optimum shades or colour to be shown that best illustrate the sample value relationships. Even seemingly similar readings can have their values manipulated to increase the contrast.

Above the two sliders is a Show Values tick box. When unticked, just the colour shades are shown. When ticked, the equivalent numerical value of the scale shade, from 0 to 35, or 0 to 7 as appropriate, is displayed within the squares as well. Clicking the box alternates the two modes.

If a particular shade is too dark to read the value, move the mouse cursor over it and a "Tool Tip Text" box will appear, stating the value. Tool Tip Text box messages appear for various functions on screen if you move the cursor over them.

To the bottom of the screen below the grid are two text lines. The first shows the actual range of the sample values, the second shows the range after correction.

Example of the full screen graph display. The zoom is at x9 to emphasise the contour lilnes. The samples cover a maximum area of 16 rows x 26 columns, each sample representing one square metre. The data is the same as in the full grid display and is in eight colours on the screen.

Note that if an original sample value of 0 is found, a dash line (–) is shown in place of a numerical value. This allows recognition of any survey site squares for which a sample has not been taken.

WAVEFORM DISPLAY

The large vertical display area towards the left of the screen shows the sample values plotted as graph waveforms. There are 20 lines (each numbered) representing the numbered grid rows to their right. Horizontally, the lefthand end of each line corresponds with the lefthand side of the grid row.

The two sliders to the left of the graph area allow the plot values to be varied in the same way as with the grid, with the same multiply/divide and add/minus options. Thus the display can again be manipulated to show the survey site features to best degree, in this case as differing amplitude waveforms.

The range of sample graph values is changed at the same time as the grid's coordinate range is set via its scroll and pan sliders.

Below the graph area is another tick box, Fill Graph Blanks. When the box is unticked, any zero values in the original (unmodified) samples are not plotted on screen, indicating any survey site squares that have not been sampled. With the box ticked, the zero values are plotted so that a continuous graph line is shown. Clicking the box alternates the modes.

To the left of the graph display are 20 numbered tick boxes. These allow selected graph lines to be hidden (no tick) to make the viewing of the data in the other lines clearer. As with all tick boxes, clicking them again alternates between on and off.

INVERSION

Below the Show Values tick box is another tick box, Invert Values. When surveying, less-dense soil produces higher values than dense soil. High values produce darker shades on the grid squares and lower troughs on the graph lines.

The Invert Values tick box allows the value relationships to be swapped, high becoming low, low becoming high. This allows denser soil conditions to be displayed more darkly on the grid than for less-dense soil, and the graph lines to show peaks rather than troughs (valleys). Clicking the box alternates between the two modes. The default is for inversion (tick on).

REFRESH BUTTON

The VB6 program allows the main screen to be minimised and shifted in the usual Windows-type fashion. Because VB6 does not regard the graph lines as being "permanent", these can be fully or partially erased by the act of mininising or shifting. To restore the graph lines on-screen, click the Refresh button.

It is also necessary to use the Refresh on the Full Grid and Full Graph screens to action various value selection changes.

FULL DISPLAY SCREENS

There are two buttons, marked Full Grid and Full Graph. They respectively cause the selected full screen mode to be displayed. On both, value manipulation and inversion are available as on the main screen. So too is colour mode selection.

Above and to the left of the grid and graph areas are two sliders. When clicked, these display the survey site grid coordinates to which their arrows point. Their position is also used by the zoom slider facility at the top left.

There are 10 values of zoom selectable according to the ratio Zoom / 2 + 0·5, with a range of ×1 to ×5·5. The slider arrow positions determine the origin point on which the enlargement is made. Intercepts are included in the program to keep the display within the bounds of its frame.

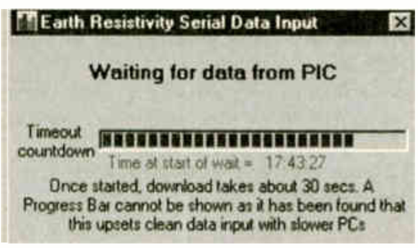
DOWNLOADING DATA

You require a standard serial cable, of the type used with normal modems (D-range 9-way male to female, straight through), for data transfer from the Logger. It should have a connector suited to your PC at one end, and a 9-pin male plug at the other. Adaptors (25-pin to 9-pin) are available if an existing modem lead has a 25-pin male plug.

Download option screen.

To download data serially from the Logger, first click on the Download Data button at the bottom of the main screen. This causes a message screen to be displayed, asking if you want to continue with the download, or cancel the call and re-show the full main screen.

If the OK button is clicked the small Download screen is displayed. As advised on the previous message you now have about 30 seconds in which to press the Logger's Download switch S7. During this 30 seconds or so, a bargraph shows the elapsing time before a time-out error occurs.



Countdown bargraph while waiting for data to start coming from PIC.

Screen displayed in the event of data not received due to COM port failure.

If the time-out occurs before data is received, you are offered the options to cancel the download, for the PC to try downloading via its other COM port address (there are two allowed for, COM1 and COM2, at addresses 2F8h and 3F8h), or to retry downloading from the same COM port address.

If you choose that the other COM port address should be tried, this address is stored to the EarthResSettings.txt file, which resides in the same folder as the rest of the Earth Resistivity software. It is then recalled next time you run the program.

It is permissible to change the COM port address within this file if you wish (via Windows Notepad for instance) – it is the first entry in the file. Take care not to upset the positions of the other lines in the file. These lines set various parameters for the program each time it is loaded and run.

When the Logger starts to send data before the time-out ends, and the PC begins to receive it, the countdown

Screen displayed if synchronisation is not correct.

bargraph halts and a confirmation that data is being received is displayed. The full 32K block of Logger data (16384 samples) is downloaded at 9600 baud, and initially stored into temporary memory locations.

During this process, another time-out countdown of about one second per data byte is monitored. If this period is exceeded the program assumes that the download is complete (the PIC has stopped sending data), or that the serial link has been broken.

Because the download is asynchronous (i.e. no handshaking), an error checking routine has been included. When the PIC starts transmitting, it first sends several zeros followed by the message RESISTY.

When the PC program finds that the one-second serial time-out has occurred, it checks through the first 20 downloaded bytes to see if these values contain the ASCII coded RESISTY message. It also assesses whether the download quantity is correct.

If neither fact is correct, the screen displays a message box stating so, offering the option to try again or cancel the download.

Occasionally, the PC software thinks that data is arriving immediately following the click of OK in the Download message box, even before the Logger's Download switch S7 has been pressed. The reason has not be found. It is a rare situation, though, and in this event the PC software almost immediately experiences a time-out as data does not continue to arrive, and then offers you the option to try again.

It is worth waiting a couple of seconds after OK has been clicked before pressing switch S7, in case this situation is about to occur. Once the Logger has started to send data the process must run its full course and cannot be halted. The same applies to the PC routine, it too cannot be interrupted, and will continue until a time-out has been experienced.

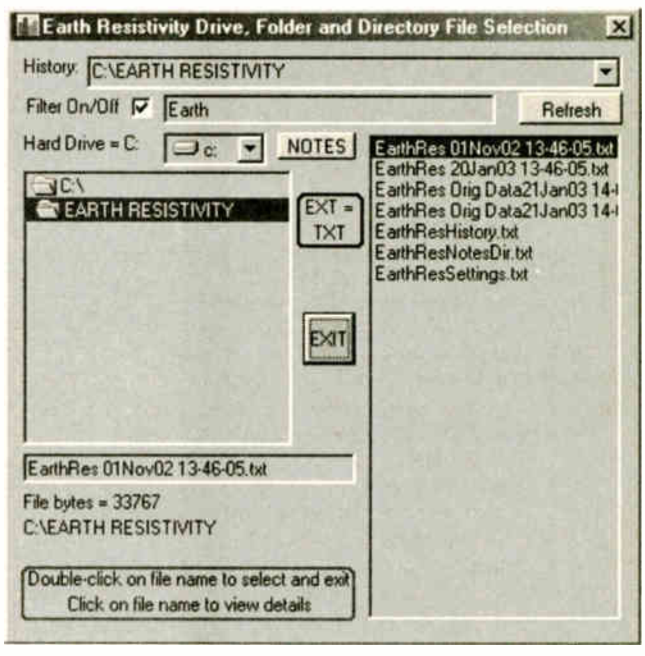
It had been hoped to provide a bargraph to graphically show the progress of the download. Regrettably, it was found that on slower PCs the software is incapable of simultaneously updating the bargraph (or other visual forms of timing) and reliably inputting the serial data. Consequently, this option has not been provided. It takes about 30 seconds to download the full 32768 bytes. A starting time is displayed on screen below the primary time-out bargraph.

When the download has been successfully finished, a routine combines all the double-byte values into single 16-bit binary values. These are converted to decimal and combined into lines of text data, each value separated by a comma. Each line holds the data for one survey site row (128 values). There are 128 lines, representing the number of survey columns.

This data is then output to disk, to a file whose unique name is in the form of the following example:

EarthRes 12JAN03 10-27-35.TXT

in which the date and time (hh-mm-ss) is that applying at the moment that the file is



Example of the folder directory screen through which files from any folder path can be selected according to a filtered prefix option.

created. (The Logger itself has not been provided with date or location recording options – it is up to you to record this information in some other way.) The file is held in the same folder that holds the rest of the Earth Resistivity software.

Having saved the file, the software splits the recombined values into a matrix of registers whose coordinates correspond with those used during the site sampling.

It is these values that are used for display via the main screen's graph and grid areas. They are plotted there immediately the Download screen closes. Simultaneously, the grid matrix location coordinate sliders are reset to zero. The value correction sliders are left as previously set, allowing various sets of file data to be recalled from disk for viewing under the same corrective conditions.

On return to the main screen after the Download, the name of the current file loaded (in this instance that just saved) is displayed in bold towards the screen's bottom right.

LOADING SAVED FILES

To load the program with data from a previously saved file, click on the Directory button. This displays a multi-function screen through which files in any folder on any installed disk can be selected. It is a modified version of the Directory screen originally designed for use with the author's *PIC Toolkit TK3* software (Nov '01), and since used in modified form with other VB6 programs as well.

It will not be discussed in detail here as the screen has a NOTES button which calls up a Windows Notepad text window through which you can read the detail of the Directory screen's use.

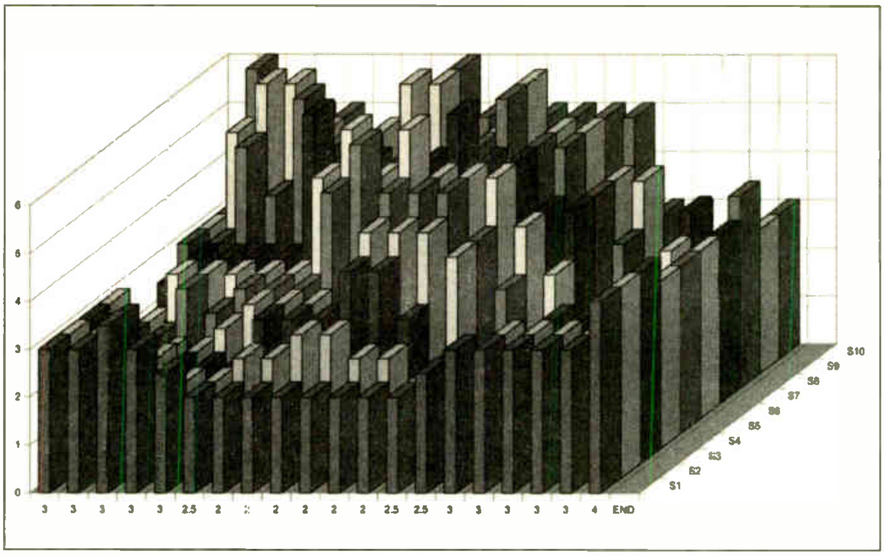
In brief, you can change drives and folder paths, set a "filter" option to only show files having a specified prefix in their name, and recall previously selected paths through a History box. To select a file, double click on its name in the righthand display area. This causes it to be loaded and split for grid matrix allocation in the same way that the downloaded file just discussed was split and displayed.

One of the author's files is included with the software (but with fewer that 400 samples), plus a much longer one produced by Nick during his survey work. Experiment with them and the screen's manipulative controls.

USING WINDOWS EXCEL

When the downloaded survey data is output to disk, it is formatted to suit its analysis and display via Windows Excel, a facility that should be on any PC running Windows 95 and later (search your Windows CD-ROM for it if it is not already on your system).

As well as offering graphing facilities, Excel provides for mathematical expressions to be computed, making it capable of being set-up to calculate true earth resistivity in relation to known resistance and current factors. Study Excel's Help facility, and read Anthony Clark's book. (As said last month, though, Nick's surveys were done in relation to signal amplitude values and not the actual resistance, but see later.)



Example of using Windows Excel to display data graphically.

The formatting simply entails using commas to separate the sample values, which are expressed as normal text characters (e.g. 1234).

Inevitably, there are many versions of Excel and specific use details that apply to all of them cannot be given. The chances are, though, that the use will be similar to that on the author's main PCs. The following is the procedure he uses for Excel 97:

Load Excel, using Windows' Find button to locate it if necessary – on the author's PCs it is at

C:\MSOffice\Excel\EXCEL.EXE

Now follow the path File (in top toolbar), Open, Select folder, set File Type to Text Files, then double click on the required EarthRes file name to load it. A Text Import Wizard – Step 1 of 3 window is now shown, with the first several imported values on display. Select the Delimited option as the active "radio" button.

Click Next to show the Text Import Wizard – Step 2 of 3 window. Click the "Delimited Comma" box to reveal a tick. Click other ticks to become unticked (if necessary). Ignore the "Text Qualifier" box.

Click Next to show the Text Import Wizard – Step 3 of 3 window. Ignore the options offered, but click Finish.

The main Excel screen will now be shown, with the survey values allocated to column and row boxes.

Left click on one of these boxes, say the first one at top left, to select the starting coordinate of the matrix area you wish to show graphically. With the left mouse button still held down, move the mouse downwards and to the right, causing the selected boxes to show white text on a black background as the area is increased. The first box, though, remains as black on white.

EXCEL GRAPHING

Release the mouse button when you've selected the required area. Now click on the Chart Wizard icon on the top tool bar (it looks like several vertical rectangles, with an elongated diagonal shape above them – a chimney falling onto a factory?). The mouse cursor becomes a similar (but not identical) symbol plus a cross, representing that graphing mode has been selected.

Move this cursor anywhere over the darkened area and left click to reveal the Chart Wizard – Step 1 of 5 window. The darkened area reverts to normal black on white, surrounded by a dotted box, possibly "shimmering".

Ignore the options offered and just click Next, to show the Chart Wizard – Step 2 of 5 window. Select (left click) one of the graph type options offered, the "3-D Column" option is suggested.

Click Next to show the Chart Wizard – Step 3 of 5 window. Select one of the chart type variants on offer, the one numbered 6, perhaps.

Click Next to show the Chart Wizard – Step 4 of 5 window, and an illustration of the Sample Chart selected will be seen. Ignore the right hand option boxes and click Next, to show the Chart Wizard – Step 5 of 5 window. Now just click on Finish.

The graph type selected will now be displayed on the main Excel screen, with the value boxes still visible behind it. It can be moved around the screen and sized in the usual Windows style. A small (mobile) Chart selection window will also be displayed, allowing different options of display to be selected and manipulated.

Save the file and its graphical displays (more than one can be generated on the screen at any time and placed at different positions) as an Excel-type file with any name of your choosing. Alternatively, simply Exit unsaved if you prefer.

It is now up to you to experiment with Excel's numerous options, calling up its Help files for more information. It is an amazing package with many uses, and seemingly ideal for the sort of analysis that archaeological survey data calls for. In a word – experiment!

PROBING METHODS

The construction of the probe assemblies will be discussed once some of the probing techniques have been examined.

There are several probing methods available through which to obtain grid data about a survey site. The author makes no attempt to recommend any one in particular. You must do your own research into that, through the references given later, and by chatting to those in archaeological societies who know about such things.

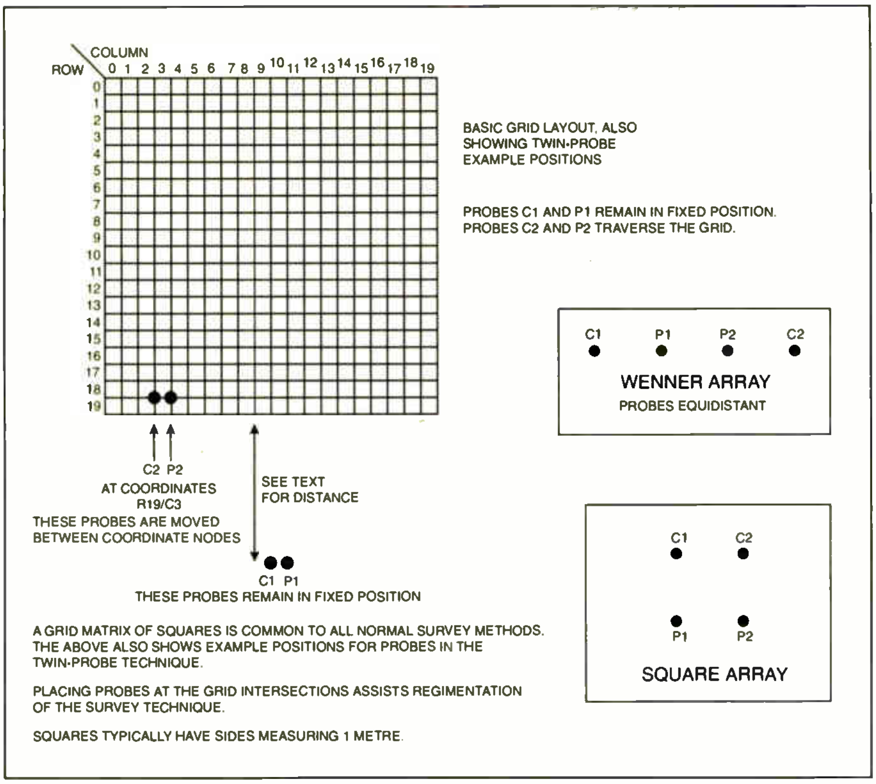


Fig.8. A 20 x 20 grid layout with Twin-Probe example positions, and the positioning of the probes in Wenner and Square arrays.

There are numerous archaeological web sites with bulletin boards and "chat-zones" on-line if you search through the excellent **www.google.com**, or other quality internet search engines. It is worth noting, though, that Anthony Clark considers the Twin-Probe technique to be that most suitable to archaeological work, and is the one used by Nick with his surveys.

With all techniques, the area to be surveyed is first marked out as a grid with tapes or similar, to form squares having sides of, say, one metre in length (this is a commonly quoted distance in this context), and probably forming a 20 × 20 matrixed area, see Fig.8.

Anthony Clark comments that plastic covered clothes line is also useful for setting out a grid matrix. He cautions, though, that it can be difficult to untangle and on one site he knows of, it had to be "guarded in the presence of sheep, by whom it was regarded as a rare delicacy"!

TWIN-PROBE

The Twin-Probe technique is apparently more suited to initial surveying of a site, establishing whether or not it is worth carrying out a more detailed survey.

With this method, the two probes C1 and P1 are inserted into the ground, sufficient to make electrical contact with it (see earlier), centrally to and somewhat outside the area to be surveyed. Anthony Clark discusses the best distance in his book.

Probe C1 is the transmitting probe connected to the comparator IC3, via switch S2. Probe P1 is one of the receiving probes, connected to the input of op.amp IC4a.

Probes C2 and P2 are inserted into the ground, to a similar depth, at the far corners of the first square to be monitored, say top left, coordinate R0/C0 (row 0, column 0). Probe C2 is the 0V reference probe, and P2 is connected to the input of op.amp IC4b. The respective leads from the Logger are then connected to the probes, using heavy duty crocodile clips seems the easiest method.

The Logger's storage coordinates are set to suit the square number, i.e. to R0/C0 in this case, and a reading saved to the Logger's serial EEPROM by pressing switch S8.

The C2/P2 probes are then moved to the top corners of the next square, to the right for example, to be monitored and its coordinates set into the Logger, in this case R0/C1. Again a reading is stored to the EEPROM.

The process continues fully across horizontally for the width of the marked survey area, e.g. R0/C19 (the final column of this row in a 20 × 20 grid). The probes are then moved down by one row, and the process repeated, to the left this time, back to R1/C0. And then down by another row, and so on for all 400 squares.

WELL ORDERED

Note that the relative order of all probe connections must be maintained during the survey. Differences in reading can result if the order is changed, hence the earlier recommendation that the plugs and crocodile clips should be colour-coded.

In practice, it does not matter in which direction you move the probes, or whether you start the survey from the top of the grid or the bottom. Note that the PC screen regards location 0,0 as being at top left of the screen.

"Be methodical and consistent" seems to be the key phrase, though – this helps you to establish a routine that becomes second nature, which the author soon found when starting his own mini surveys!

It was also soon found that it is not necessary to move both probes on each occasion. Since one is already at the corner of the next square, it is only necessary to move the probe from the corner now finished with, putting it in the next square's opposite top corner, and swap the probe leads to retain the correct order.

The author surveyed his garden several times in different ways during design development, and on each occasion became faster at doing so. On the final survey, on an 11 × 7 grid (77 samples) it took about an hour and half.

Of course, during the process of doing the test surveys, several methods for speeding it were imagined. For a solitary surveyor, perhaps the most efficient in terms of speed would be to insert separate probes at each corner of the matrix prior to taking readings. It would then only be required to repeatedly change the lead connections – a seemingly much faster "conveyor belt" system. No doubt, though, having an assistant would probably make the moving of just two probes a speedy alternative.

A perhaps less practical method was (bizarrely?) thought up too – using a motorised vehicle like a golf buggy with probes attached to the wheels in Boadicea fashion. This would then be driven back and forth across the grid, the probes automatically inserting themselves, and triggering the storing of each reading at the correct coordinates! (Well – a chap can dream, can't he?!)

WENNER PROBING

Another seemingly useful technique is known as the Wenner configuration. In this method the four probes are arranged in a straight line, equally spaced apart, say a metre between them. Fig.8b shows the order of arrangement.

This method is apparently better suited to doing a more detailed survey of the matrixed grid site. The principle is that the TX probes are the outer two. The RX probes are in line between them. The current flows across the TX pair and is picked up across the RX pair, the received signal value varying with the resistance in series with the probes in a more direct fashion than with the twin-probe technique.

A variant of this technique, the Schlumberger, in which the probes are not equally spaced, is discussed in Anthony Clark's book. But he regards it as not ideally suited to archaeological surveying.

SQUARE ARRAY

Another method is known as the Square Array in Anthony Clark's book. With this method, the TX and RX pairs are placed at the corners of the one metre squares, as shown in Fig.8c. The four probes are moved as a set from square to square.

The transmission signal flows between the TX pair as before. This time the RX pair pick up the radiated signal at the same distance from the TX probes. If the soil resistance between the TX and RX pairs is uniform, so too will be the amplitude of the signal received by both RX probes.

Tests showed that because the probes are connected to a differential amplifier, if the two input amplitudes are the same, they will cancel each other out at the final combining stage (IC4c).

If, on the other hand, the amplitudes are not the same, the difference between them is that which will be finally output from IC4c. In this case, what would be looked for is any difference values, indicating the edge of a subterranean feature.

It is evident, however, that balanced (zero) readings, when the two input values are equal, would only indicate the uniformity of the terrain in that grid. It would not indicate whether that uniformity was due to a highly resistive feature or a highly conductive one. Nonetheless, the detection of only outlines might in itself be a desirable situation.

A variant of this technique would be to place the two TX probes at one end of a column, and the RX pair at the other, taking a reading and moving both pairs to the next column, still at the top and bottom points. This could perhaps yield initial information about whether or not a site is worth examining more closely. Not being an archaeologist, though, the author cannot comment on the validity of this.

Anthony Clark discusses the above named probing techniques in more detail, and describes others.

PROBE CONSTRUCTION

During garden tests with the prototype Logger, individual metal rods measuring about one metre long by 5mm diameter, and with a right-angled bend at the top were used as the probes. These were purchased inexpensively from a garden centre, their intended use being to support plants.

A recently observed, but not tried, possibility was in the form of long inexpensive barbecue skewers – seen in a local supermarket.

If you wish to construct purpose-built probe structures of more durability, and perhaps greater ease of use, the probe assemblies described by Robert Beck should be considered. Schematics of the original figures illustrating these probes have been redrawn and are repeated here. Other than the following details, no additional information can be offered.

Robert's rigid frame assembly for two probes is shown in Fig.9. Details of his single probe are given in Fig.10.

His original text states that the Twin-Probe assembly was specially developed and that its top member is a wooden batten, 30mm × 50mm × 1050mm, the ends of which are bound with self-amalgamating tape to form hand grips.

An aluminium platform is attached to the centre of this batten to carry the case that holds the electronics, secured by rubber bands. The bottom member is a similar wooden batten, but this piece must have good insulating properties (to prevent current leakage between the probes). He suggests that you either dry and coat the batten with varnish, or devise insulating collars of Tuffnol or similar material, and fit them where the probes go through the batten.

The top and bottom battens are held together by metal conduit pipes, threaded at each end and secured by lock-nuts.

In describing the construction of the other probes, he says that none of their dimensions are critical and may be dictated by what is to hand. In Fig.10a is shown a substantial probe made out of stainless steel tubing with a brazed on T-handle and tip which assist soil penetration. This probe is designed to be used by the operator in the standing position.

A smaller version of Fig.10a is shown in Fig.10b. This has a 4mm screw terminal added, an alternative method of wire connection.

Probes may be constructed of material other than stainless steel, which is expensive and a little difficult to obtain, he says (provided it is corrosion resistant of course).

An extremely simple probe is shown in Fig.10c and which may be constructed from 6mm diameter metal rod, i.e. brazing or uncoated welding rod, mild steel, silver steel, etc. A depth guide consisting of a band of paint or insulating tape is added and connections are made to the top using a crocodile clip.

The depth stop in Fig.10d is adjustable by means of an Allen key. The material need not be insulating, and could be of metal if desired.

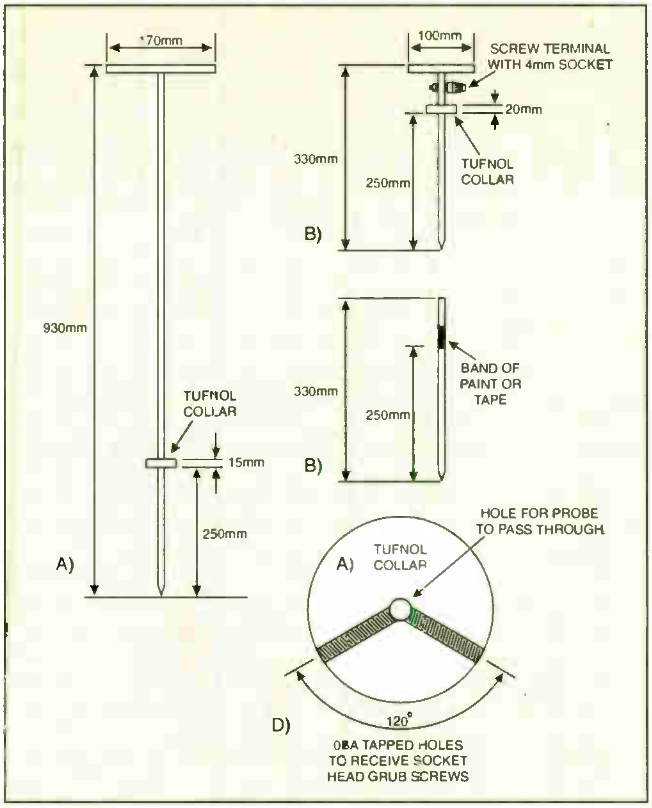


Fig.10. Construction details of Robert Beck's probes.

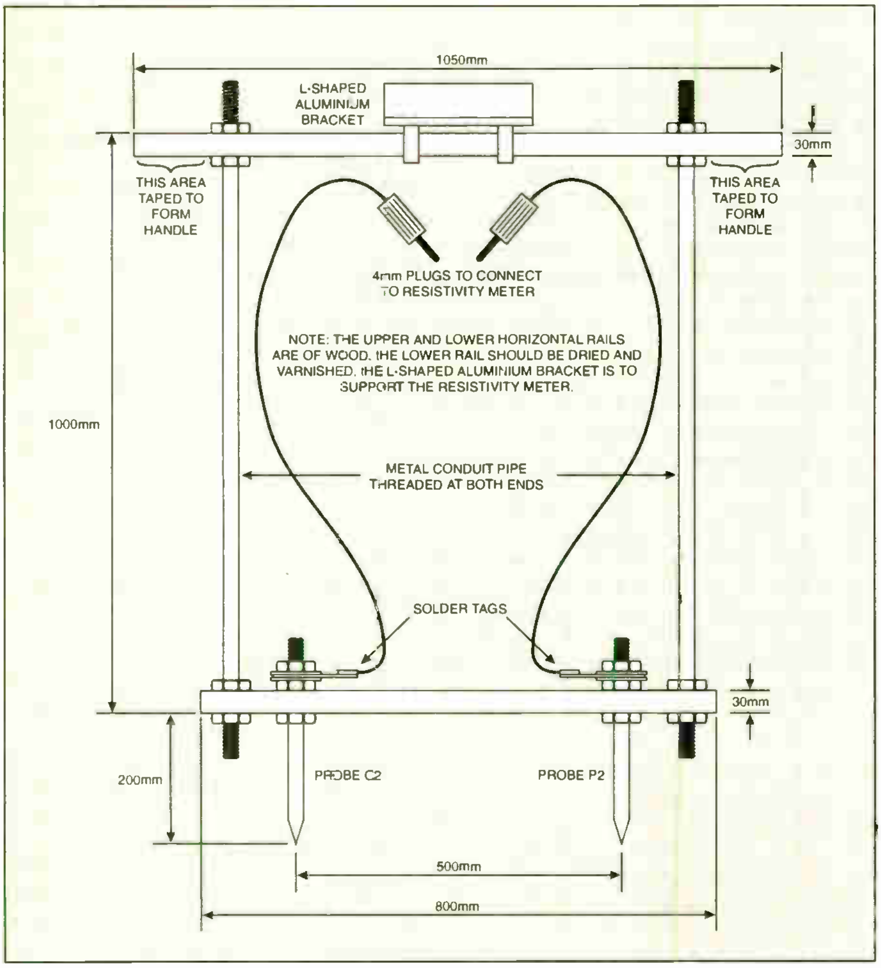


Fig.9. Support frame for the Twin Probe configuration used by Robert Beck.

SERIAL OCX

Since finalising the *Earth Resistivity Logger* Part One for publication last month, reader Joe Farr has provided *EPE* with a specially written SerialIO.OCX program that allows legal access to Visual Basic's own serial control I/O facilities.

This option has previously only been available to readers who have a registered version of MSCOMM (as Robert Penfold has discussed many times through his *Interface* series).

Joe's serial OCX facility will be published in full at a later date – probably the September issue. However, a section of Joe's program has been built into this Earth Resistivity (ER) program and is available to readers who are using the EarthResist.EXE standalone version.

To use Joe's option, though, several changes need to be made to ER's p.c.b., without which the facility cannot function. They are:

1. Cut the track (0V) connecting to IC7 (MAX232) pin 13.

2. Connect IC7 (MAX232) pin 13 to 9-pin serial socket SK3 pin 3.

3. Connect IC7 (MAX232) pin 12 to IC5 (PIC) pin 18 (RC7).

This action allows the PIC to receive handshake data from the PC.

To set the PIC program to respond to the correct serial data transmission routine, initiate the following procedure:

1. Before switching on power, press and hold down the Mode switch, S6.

2. The screen will go into serial path change mode, alternating at about one-second intervals between a display saying "SERIAL PORT NORM" (original version) and "SERIAL PORT OCX " (Joe's OCX).

3. Release switch S6 when the mode you require is shown. This mode becomes the active path mode and is also stored into the PIC's data EEPROM, to be recalled next time the program is run.

4. On release of switch S6, normal running of the PIC program resumes. The serial path mode may be changed whenever you choose.

PC OCX SETTING

Ensure that the PC is also set for the chosen mode, as follows:

Click the on-screen button labelled Please Read. Accept the option that then follows to read the text. Having read it, exit the text reading screen to reveal another options screen. This allows you to choose between the new OCX option and the original (normal) serial mode. Click YES for Joe's OCX, NO if you want to use the normal serial download as originally written into the ER program, or CANCEL to exit without making a change to the serial path used.

Your choice is recorded to disk and recalled next time the program is run. You may change your mind at another time if you wish, re-entering via the Special Note button to do so.

Note that the same mode **must** be selected for the PIC and the PC.

The advantage of Joe's program is that it allows a bargraph to display the progress of the data input procedure. It is also likely to be better at detecting input data problems as it uses a handshake procedure to communicate with the PIC, inputting the 32768 bytes of data in blocks of 256 bytes.

Whilst the original program inputs data that is usually 100% accurate, there is the occasional loss of synchronisation, which is reported on screen, allowing you to re-download if you prefer, although minor "first aid" is provided by the program to regain sync after that point. It is rare, though, for more than one loss of sync to occur. Such loss should not occur with Joe's OCX program.

It should be noted that readers who wish to make their own changes to the ER source code cannot make use of Joe's OCX input option. For that to be used, the installation of Joe's full OCX facility is required. For copyright reasons this will not become available to readers until its publication. Attempting to examine the ER source code will generate an error condition because of the presence of Joe's program. Until Joe's full serial program becomes available, the ER program can only be recompiled if Joe's sub-program (EarthResOCX) and all references to it in the main program are removed.

Also be aware that this version of ER with Joe's OCX has not yet been proved on a wide variety machines. If it will not work on your PC, revert to using the normal serial download option on PIC and PC. Please advise us at HQ if this is necessary, telling us the PC and its operating system type.

SURVEY CURRENT MONITORING

Another feature added to this version is the ability to monitor the current flowing between the transmission (TX) probes. It too requires a small change to the PCB:

1. Cut the track between resistor R16 and pin 7 of IC4.

2. Connect the now-open end of R16 to the pole of switch S2.

With switch S2 in the R5 (1k resistor) position, current flows from the switch pole through the 1k resistor and to 0V via the resistance of the soil. These two resistances form a potential divider. The square wave voltage at their junction is buffered by R16 and half-wave rectified by diode D2. The resulting peak positive voltage is monitored via PIC pin RA0 operating in analogue (ADC mode). The peak voltage depends on the resistance of the soil, and from this voltage value the equivalent relative current through the resistance path can be calculated.

To establish an initial reference value prior to any survey, switch on the unit. Then set switch S2 to the setting that directly connects the pole to IC3 output pin 6. Do not connect transmission probe C1 to socket SK2 at this time. Press switch S6 (Mode) and hold it pressed, then press switch S8 (Save) and hold it pressed until the message REF SAVED appears, preceded by a value. Release S8, then release S6. The value shown is now stored to the PIC's EEPROM for present and future use. Then switch S2 to the 1k resistor (R5) path.

During active surveying, the voltage at the pole of S2 is subtracted from the reference value and stored as a 6-bit number into bits 1 to 6 of the MSB of the survey value recorded to the external serial EEPROM IC6. The range of current values acceptable is from 0 to 63, and the actual value is displayed as the second value on l.c.d. line 1 when in Test Mode (S9 on). It is followed by the letter A. The first value shown (followed by B) is that monitored from IC4b pin 8, as described in Part One. The output from IC4a is no longer monitored via the l.c.d.

If current values greater than 62 are encountered, they are limited to 63, and the word MAX is displayed on the l.c.d. Switch S2 may be used to select one of the other resistors (R3 to R6) in the event that the site being surveyed has greater or lesser resistance than appropriate to a 1k fixed resistor value. Do not change the resistor value during a survey.

The PC program stores the full 2-byte survey value to disk. On re-input the current value is extracted from the MSB, and the MSB is then limited to one active bit (bit 0). The range of survey values is then from 0 to 511. During surveying, the gain setting via switch S3 should be chosen to keep the values below 511, favouring a middle range centred on 256. If a value greater than 511 is encountered by the PIC, it is limited to 511 and the word MAX is shown on the l.c.d.

CURRENT ON/OFF OPTION

All three display screens of the PC program now have an extra tick box marked Current. When it is ticked, each survey value is multiplied by its associated current value divided by 10. The theory is that slight differences in the transmission current value at each survey grid square affect the actual value of the received voltage signal from the receiving probes. By relating these voltages to their prevailing transmission current, compensation is made for variations in the latter. The current values are not actual milliamp values, but simply numbers representing the relative current flowing.

It is suspected, however, that in practice the variations make little difference to the interpretation of the displayed results. To repeat the statement made in Part One, the aim of this Logger is to show relative differences in signal amplitude across a site being surveyed. It is the differences that then indicate different sub-soil features.

If there are significant differences they are worth physical investigation. If there are no significant differences, then the site is probably not worth examining further, unless such techniques as magnetometry or ground-penetrating radar reveal differently. A magnetometer design is currently being worked on and will be published in *EPE* at some time in the future, but not yet scheduled.

We shall be interested to learn if you find that the current-monitoring feature enhances the results of your survey. Let us know via EPE HQ.

DOT MATRIX

A further option added to the PC program since Part One is the dot-matrix display facility, operative when the Matrix tick-box on the Full Grid screen is ticked. This draws small squares on the display whose dimensions are relative to the signal amplitude.

The principle is a bit like the dots that make up a B&W photograph in a newspaper (known as half-tone). It will be more useful with a large amount of survey data on screen than with a small quantity.

MISCELLANY

A few other "tweaks" have also been added since Part One.

The text and demo circuit for some experiments referred to on Part One page 1 are now accessible via buttons at the bottom left of the screen.

Two other buttons allow you to examine the survey data as text files, one showing the twin-byte values separately, the other as the full combined value. These values include the current values as well.

All three display screens have also been given a "pre-subtract" box, allowing you to subtract, say, the minimum value received from all other values, enabling relevant data to be extracted from any overall bias levels.

Because this PC software will be used with the Magnetometer currently under development, two "radio" buttons allow selection of whether Earth Resistivity or Magnetometer data will be processed. Ensure that the Resistivity button is the one selected.

ETHICS

It was said in the opening paragraph in Part One that the original *Earth Resistivity Meter* published in *EPE* was an electronic tool to assist amateur archaeological societies. So too is this Logger design.

Whilst there is nothing to stop anyone from carrying out surveys on their own property, there are considerable ethical issues regarding the surveying of other land.

First, other land is not *your* land, and so any surveying of it requires the permission of those who own it. Remember that **all land in the British Isles is owned by someone.** Find out who it is and gain their permission before you proceed.

Secondly, **do not dig without an archaeologist's involvement.** If you have located through your earth resistivity survey something that proves to be a site of any importance, your unsupervised digging will certainly destroy information that is necessary to fully interpret the site.

Earth resistivity surveying is essentially non-invasive except for the slight intrusion made by the probes just into the surface. Many landowners could well be as interested as an archaeological society in knowing what history might lie beneath their land, especially if they are approached in a polite manner and it is explained to them that the resistivity surveying is just a matter of sticking some shallow probes in the soil.

Remember that some locations are designated as Scheduled Ancient Monuments and that permission to carry out any form of research on them requires official approval. Experienced local archaeological societies will know where these sites are and whether or not surveying permission is likely to be granted, and if so, by whom. If such information is not already known to a society, enquiries at the local town hall should provide answers.

JOIN A SOCIETY

It really is in your interests to join an archaeological society if you are not already a member. It is also in the society's interests if you join them and they then have the use of your Logger!

Nick's survey was done not far from where John Constable painted this Boat Building Near Flatford Mill *scene. The contours in the full graph screen shown earlier clearly indicate a trench comparable to that in this painting.* Illustration courtesy of www.excelsiordirect.com/constable.htm.

To find a local society, look in the telephone directory, or ask at the library. The author's local library building even has a display of the artefacts found by the society in his area. It is a region once heavily populated by the Romans, with many artifacts that have been found on display, and even the ruins of two Roman villas (but left where they were found!).

Only a few hundred yards from the author's house a Roman corn drier was recently found by his local society. 400 yards further on are the ruins of a Roman bath house. It is quite probable that his garden is on a site where Roman's once trod.

Although his survey graphics did not show anything other than known modern features, and probably including builder's rubble of recent decades, perhaps he'll one day do a more detailed survey and then call in the archaeologists to uncover an amazing find – one way to get the garden dug for him!

NICK'S SURVEY

Nick was fortunate enough to be permitted to survey a site made famous by English artist Constable (before he was promoted to Sergeant says reader and friend John Waller – quoting an old Goon Show line!).

Constable painted several pictures of sites at and around Flatford Mill in Essex. One of them is his *Boat Building Near Flatford Mill*, which is reproduced here. It is near that site that Nick surveyed and his results are those illustrated earlier in the full graph and full screen illustrations. They reveal very clearly the sub-surface features that could have been bays cut into the ground where boats might well have been tied up. Much of the site, though, is now overgrown with trees, preventing adequate survey.

The primary area covered in the survey is approximately 16m × 26m at maximum dimensions. Most of it was covered in one day, but then rain "stopped play" for several weeks.

PRACTICAL ADVICE

From his experience with the prototype of this Logger, and from his general surveying activity, Nick offers the following advice:

- For extensive survey work the battery needs to be bigger than PP3 size
- The case should be larger than in the prototype and a better shape to carry about
- Do not use small plugs and sockets
- The sockets need to be solidly mounted, possibly on a metal base of some description, and include strain relief, it's surprising how hard you have to pull 50m of cable laying on wet grass!
- Lay the survey out accurately, based on a 3, 4, 5 triangle to get the lines perpendicular. Bamboo canes make good markers for the 1-metre grid intersections. If using clothes line with metre marks, beware that rope stretches. Survey tapes (typically 30m) need to be carefully cleaned after use, or they get full of dirt and can jam
- Keep perfect track of what you have surveyed, it is horribly easy to lose track of the grid section that you have just recorded
- Probe around the site at random before you start to make sure that you are set up to keep the Logger's values roughly around 250
- Try and get it all done in a day – a shower overnight throws in a step function because you are then working in the area that the rain will have penetrated
- Coil everything neatly – controlling 50 metres of cable across a plot is tricky

- Buy high visibility cable in case someone tries to trip over it!
- Colour code the probes – you need to be consistent
- Ask permission, most people will be chuffed to bits that you want to do the survey – but not everybody, and make sure that you are not somewhere where you should not be
- Make contact with your local archeology group, they will be very helpful and interested, and may well bite your arm off to get you helping them
- Be prepared to talk to people, you will cause interest if you are somewhere public, and they will be surprisingly knowledgeable – and probably have all been watching *Time Team*
- Keep your ears open for local stories of old ruins, you might be the one that re-discovers something lost to history because you happened to take the time to listen to the ramblings of the old guy in the pub
- You can do a survey on your own, but it is much easier with two of you
- Keep a note book that notes the time, place, date, etc of the survey and things like weather conditions which could explain odd results, for example if it started to rain half way through the work
- Any survey must have a repeatable base point, or base line so that if you do find something interesting, you can be sure where it was without having to repeat the survey!
- Use compass bearings, fixed physical features, corners of buildings, drain covers etc, or triangulate from fixed points if the survey is in an open area. Most archaeologists work north to south.

ACKNOWLEDGEMENTS

The author offers very grateful and appreciative thanks to Nick Tile for carrying out extensive field tests with the prototype, for discussing at length many aspects of its use, for lending *Seeing Beneath the Soil* and vetting the script.

The author also thanks those *EPE* readers who provided him with information during the development of this design (in alphabetical order!):

Dave Allen for sending an ancient issue of *ETI* containing a rudimentary ER circuit using d.c. probing (and yes Dave, this design could be used for monitoring relative impurity content levels in water).

Peter Barnes, for vetting the script and for several useful email exchanges of thoughts and circuits, plus comments from his archaeologist acquaintance Derek about using Robert Beck's design.

Robert Beck, for the original inspiration.

Aubrey Scoon, for comments about stray electrical currents in the soil.

ODAS, the Orpington and District Archaeological Society, and Alan Hart in particular.

FURTHER READING

Applied Geophysics, W.M. Telford, L.P. Geldart, K.E. Sheriff, D.A. Keys. Cambridge University Press. ISBN 0521-20670-7.

Applied Geophysics, Griffiths and King, Pergamon Press. 1965. (ISBN unknown).

Seeing Beneath the Soil, Prospecting Methods in Archaeology. Anthony Clark. Routledge. 2000. ISBN 0-415-21440-8. This is a revised edition of the title referenced in *EPE* Feb '97, and having a different ISBN and publisher. It is the most informative source used by the author during the design of this Logger.

It additionally covers other earth surveying techniques, including magnetometry, and provides several further reference sources. It is known to be available for on-line ordering from **www.Amazon.com** and **www.BOL.com**, current price around £25.

USEFUL WEB SITES

www.archaeology.co.uk. Various aspects of the subject, including further links, access to the magazine *Current Archaeology*, and to the Council for Independent Archaeology.

www.geop.ubc.ca. Source of semi-mathematical tutorial on earth resistivity and a link to a site called Introduction to Exploration Geophysics.

www.google.com. Excellent search engine.

LOGGING OFF

The ER software placed on the *EPE* ftp site on 17 March '03, was version V1.2. Look in on the site occasionally to see if any further updates have been introduced. ☐

CORRECTION

Crystal X1 should be 3·6864MHz (as in Fig.5), *not* 3·2768MHz as in the components list.

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Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

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The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

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Topics covered include: The equipment that is needed; Setting up the shack; Which aerials to use; Methods of construction; Preparing for the licence.

An essential addition to the library of all those taking their first steps in amateur radio.

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Although nearly a century has passed since Marconi's first demonstration or radio communication, there is still research and experiment to be carried out in the field of antenna design and behaviour.

The aim of the experimenter will be to make a measurement or confirm a principle, and this can be done with relatively fragile, short-life apparatus. Because of this, devices described in this book make liberal use of cardboard, cooking foil, plastic bottles, cat food tins, etc. These materials are, in general, cheap to obtain and easily worked with simple tools, encouraging the trial-and-error philosophy which leads to innovation and discovery.

Although primarily a practical book with text closely supported by diagrams, some formulae which can be used by straightforward substitution and some simple graphs have also been included.

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This concise book tells the story, and shows the reader how to construct and use 25 indoor and window aerials that the author has proven to be sure performers. Much information is also given on shortwave bands, aerial directivity, time zones, dimensions etc.

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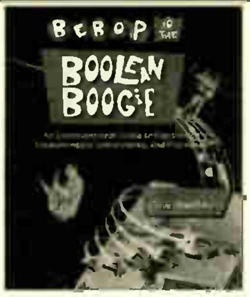
THEORY AND REFERENCE

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

Specially imported by *EPE – Excellent value*

An Unconventional Guide to Electronics Fundamentals, Components and Processes



This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!). Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day. . . .

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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.

199 pages Order code NE23 £13.99

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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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In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

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

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

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

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If you want to take your synthesiser – of the hardware or software variety – past the presets, and program your own sounds and effects, this practical and well-illustrated book tells you what you need to know.

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Ian Waugh

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R. A. Penfold

Whether you wish to save money, boldly go where no musician has gone before, rekindle the pioneering spirit, or simply have fun building some electronic music gadgets, the designs featured in this book should suit your needs. The projects are all easy to build, and some are so simple that even complete beginners at electronic project construction can tackle them with ease. Stripboard layouts are provided for every project, together with a wiring diagram. The mechanical side of construction has largely been left to individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing in this respect.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

124 pages Order code PC116 £10.95

THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN

Robert Charles Alexander

This book is the definitive study of the life and works of one of Britain's most important inventors who, due to a cruel set of circumstances, has all but been overlooked by history.

Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first eleconic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

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VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical 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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Just a few of the questions you've probably asked. Well, you'll find the answers to all these questions, and many more, in this book. It will show you what can be done, what it all means, and what you will need to start creating your own music on your PC. It's an easy read, it's fully illustrated and it will help you understand how a computer can be used as a creative music tool.

It covers soundcards, sequencers, hard disk digital audio recording and editing, plug-ins, printing scores with notation software, using your PC as a synthesiser, getting music onto and off the Internet, using Windows, sample PC music setups, FAQs, a glossary, advice on hardware and software, and a list of industry contacts.

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HIGH POWER AUDIO AMPLIFIER CONSTRUCTION

R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

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CIRCUITS AND DESIGN

AN INTRODUCTION TO PIC MICROCONTROLLERS
Robert Penfold
Designing your own PIC based projects may seem a daunting task, but it is really not too difficult providing you have some previous experience of electronics.

The PIC processors have plenty of useful features, but they are still reasonably simple and straightforward to use. This book should contain everything you need to know.

Topics covered include: the PIC register set; numbering systems; bitwise operations and rotation; the PIC instruction set; using interrupts; using the analogue to digital converter; clock circuits; using the real time clock counter (RTCC); using subroutines; driving seven segment displays.

166 pages — **Temporarily out of print**

PRACTICAL OSCILLATOR CIRCUITS
A. Flind
Extensive coverage is given to circuits using capacitors and resistors to control frequency. Designs using CMOS, timer i.c.s and op.amps are all described in detail, with a special chapter on "waveform generator" i.c.s. Reliable "white" and "pink" noise generator circuits are also included.

Various circuits using inductors and capacitors are covered, with emphasis on stable low frequency generation. Some of these are amazingly simple, but are still very useful signal sources.

Crystal oscillators have their own chapter. Many of the circuits shown are readily available special i.c.s for simplicity and reliability, and offer several output frequencies. Finally, complete constructional details are given for an audio sinewave generator.

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Contains all of the everyday information that anyone working in electronics will need.

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