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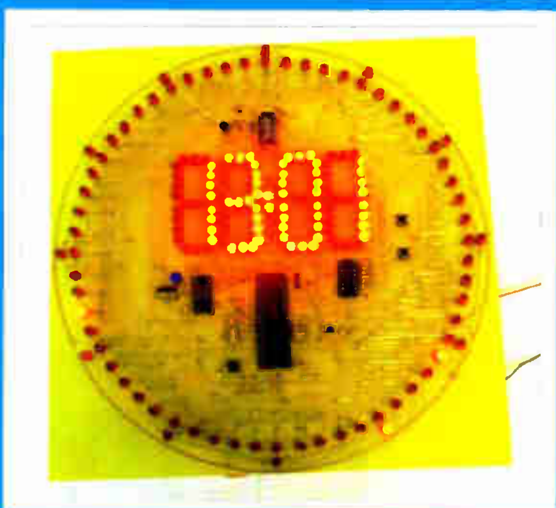

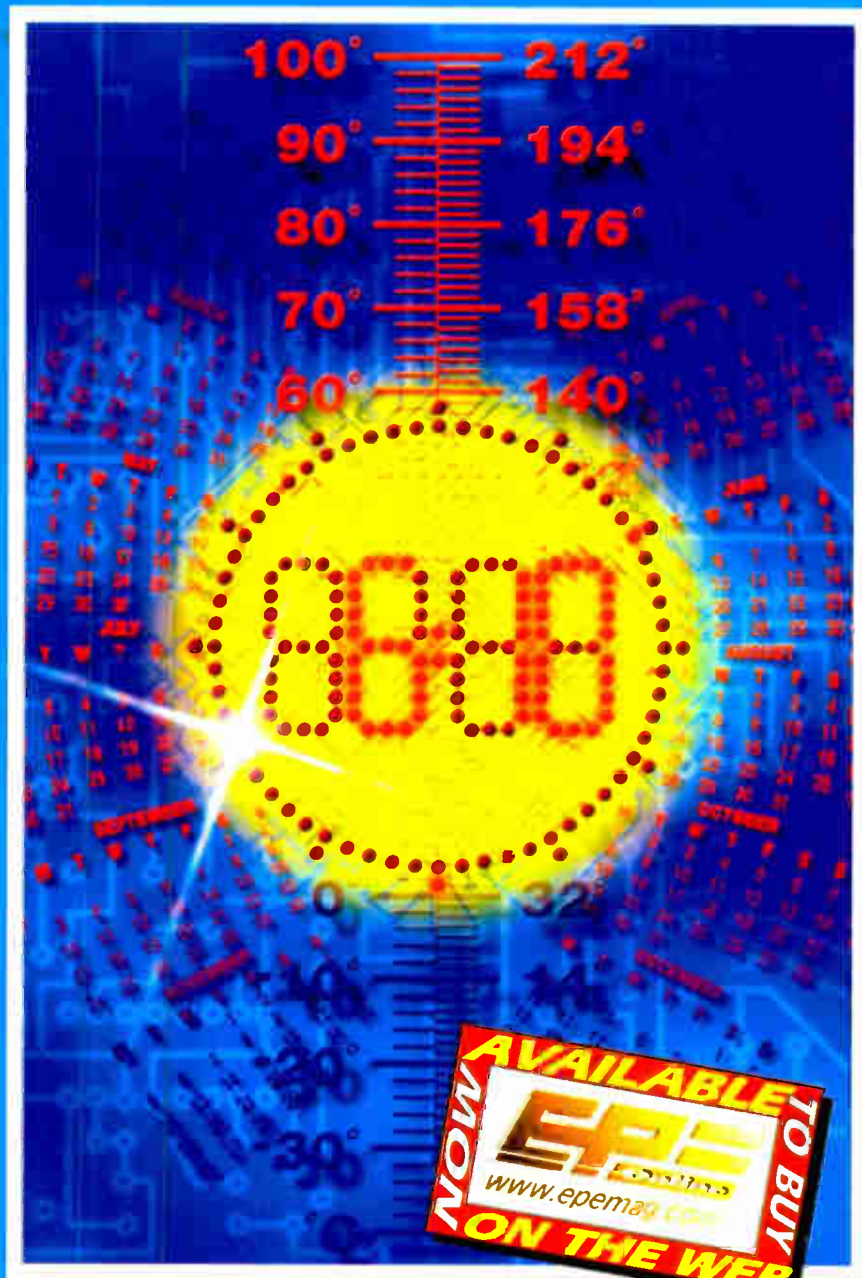

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Colour CCTV camera, 8mm lens, 12V d.c. 200mA 582x628 Resolution 380 lines Automatic aperture lens Mirror function PAL Back Light Compensation MLR, 100x40x40mm. Ref EE2 £69

Built-in Audio .15lux CCD camera 12V d.c. 200mA 480 lines s/n ratio >48db 1v P-P output 110x60x50mm. Ref EE1 £99

Metal CCTV camera housings for internal or external use. Made from aluminium and plastic they are suitable for mounting body cameras in. Available in two sizes 1 – 100x10x170mm and 2 – 100x70x280mm. Ref EE6 £22 EE7 £26 multi-position brackets. Ref EE8 £8

Excellent quality multi-purpose TV/TFT screen, works as just a LCD colour monitor with any of our CCTV cameras or as a conventional TV. Ideal for use in boats and caravans 49.7MHz-91.75MHz VHF channels 1-5,168.25MHz-222.75MHz VHF channels 6-12, 471.25MHz-869.75MHz, Cable channels 112.325MHz-166.75MHz Z1-Z7, Cable channels 224.25MHz-446.75MHz Z8-Z35 5" colour screen. Audio output 150mW. Connections, external aerial, earphone jack, audio/video input, 12V d.c. or mains, Accessories supplied Power supply, Remote control, Cigar lead power supply, Headphone Stand/bracket. 5" model £139 Ref EE9, 6" model £149. Ref EE10

Fully cased IR light source suitable for CCTV applications. The unit measures 10x10x150mm, is mains operated and contains 54 infra-red LEDs. Designed to mount on a standard CCTV camera bracket. The unit also contains a daylight sensor that will only activate the infra red lamp when the light level drops below a preset level. The infrared lamp is suitable for indoor or exterior use, typical useage would be to provide additional IR illumination for CCTV cameras. £49. Ref EE11

This device is mains operated and designed to be used with a standard CCTV camera causing it to scan. The black clips can be moved to adjust the span angle, the motor reversing when it detects a clip. With the clips removed the scanner will rotate constantly at approx 2.3rpm. 75x75x80mm £23. Ref EE12

Colour CCTV Camera measures 60x45mm and has a built in light level detector and 12 IR LEDs .2 lux 12 IR LEDs 12V d.c. Bracket Easy connect leads £69. Ref EE15

A high quality external colour CCTV camera with built in Infra-red LEDs measuring 60x60x60mm Easy connect leads colour Waterproof PAL 1/4" CCD 542x588 pixels 420 lines .05 lux 3.6mm F2 78 deg lens 12V d.c. 400mA Built in light level sensor. £99. Ref EE13

A small compact colour CCTV camera measuring just 35x28x30mm (camera body) Camera is supplied complete with mounting bracket, built in IR, microphone and easy connect leads. Built in audio Built in IR LEDs Colour 380 line resolution PAL 0.2 us +18db sensitivity. Effective pixels 628x582 Power source 6-12V d.c. Power consumption 200mW £36. Ref EE16

Complete wireless CCTV sytem with video. Kit comprises pinhole colour camera with simple battery connection and a receiver with video output. 380 lines colour 2.4GHz 3 lux 6-12V d.c. manual tuning Available in two versions, pinhole and standard. £79 (pinhole) Ref EE17, £79 (standard). Ref EE18

Small transmitter designed to transmit audio and video signals on 2.4GHz. Unit measures 45x35x10mm.Ideal for assembly into covert CCTV systems Easy connect leads Audio and video input 12V d.c. Complete with aerial Selectable channel switch £30. Ref EE19

2.4GHz wireless receiver Fully cased audio and video 2.4GHz wireless receiver 190x140x30mm. metal case, 4 channel, 12V d.c. Adjustable time delay, 4s, 8s, 12s, 16s. £45. Ref EE20

Colour pinhole cctv camera module with audio Compact colour pinhole camera measuring just 20x20x20mm, built-in audio and easy connect leads PAL CMOS sensor 6-9V d.c. Effective Pixels 628x582 Illumination 2 lux Definition >240 Signal/noise ratio >40db Power consumption 200mW £35. Ref £35

Self-cocking pistol plcr002 crossbow with metal body. Self-cocking for precise string alignment Aluminium alloy construction High tec fibre glass limbs Automatic safety catch Supplied with three bolts Track style for greater accuracy. Adjustable rearsight 50lb drawweight 150ft sec velocity Break action 17" string 30m range £21.65 Ref PLCR002 **INFRA-RED FILM** 6" square piece of flexible infra-red film that will only allow IR light through. Perfect for converting ordinary torches, lights, headlights etc to infra-red output only using standard light bulbs Easily cut to shape. 6" square £15. Ref IRF2 or a 12" sq for £29 IRF2A **NEW 12V 12" SQUARE SOLAR PANEL** Kevlar backed, 3watt output. Copper strips for easy solder connections £14.99. Ref 15P42 **PACK OF 4 JUST £39.95. REF 15P42SP**

Dummy CCTV cameras These motorised cameras will work either on 2 AA batteries or with a standard DC adapter (not supplied) They have a built in movement detector that will activate the camera if movement is detected causing the camera to 'pan' Good deterrent. Camera measures 20cm high, supplied with rawl plugs and fixing screws. Camera also has a flashing red LED built in. £9.95. Ref CAMERAB

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Beltronics BEL550 Euroradarand GATSO detector Claimed Detection Range: GATSO up 400m. Radar & Laser guns up to 3 miles. Detects GATSO speed cameras at least 200 metres away, plenty of time to adjust your speed £319. Ref BEL550

Fully Portable – Use anywhere Six automatic programmer for full body pain relief, shoulder pain, back/neck pain, aching joints, rheumatic pain, sports injuries EFFECTIVE DRUG FREE PAIN RELIEF TENS (Transcutaneous Electrical Nerve Stimulation) units are widely used in hospitals, clinics throughout the United Kingdom for effective drug free pain relief. This compact unit is now approved for home use. TENS works by stimulating nerves close to the skin releasing endorphins (natures anesthetics) and helping to block the pain signals sent to the brain. Relief can begin within minutes, and a 30 minute treatment can give up 12 hours relief or more. TheTENS mini Microprocessors offer six types of automatic programme for shoulder pain, back/neck pain, aching joints, Rheumatic pain, migraines headaches, sports injuries, period pain. In fact all over body treatment. Will not interfere with existing medication. Not suitable for anyone with a heart pacemaker. Batteries supplied. £19.95 Ref TEN327 Spare pack of electrodes £5.99. Ref TEN327X

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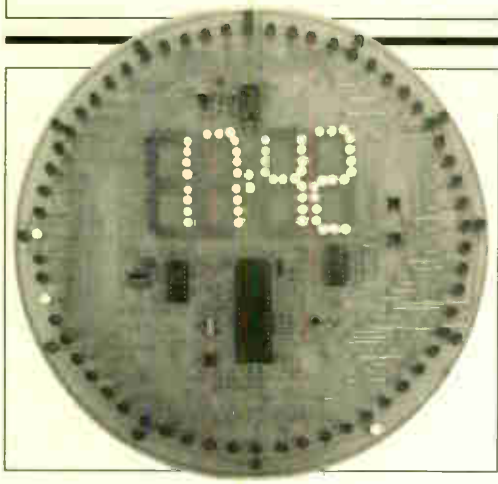

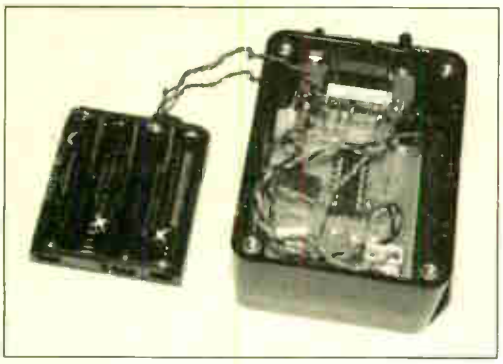

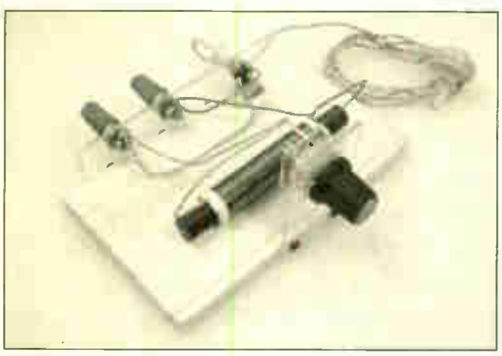

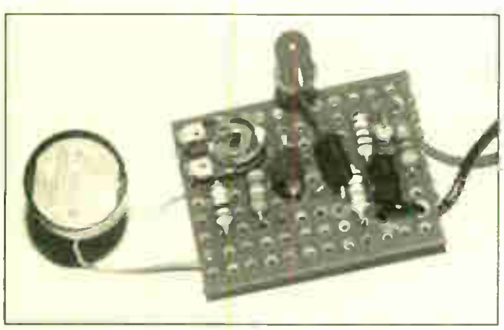

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For overseas PAL versions state 5.5 or 6 mHz sound specification.
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NEW State of the art PAL (UK spec) **UHF TV tuner module** with **composite** 1V pp video & **NICAM** hi fi stereo sound outputs. **Micro electronics** all on one small PCB only 73 x 160 x 52 mm enable full tuning control via **a simple 3 wire link** to an IBM pc type computer. Supplied complete with **simple working program** and documentation. Requires +12V & + 5V DC to operate. ***BRAND NEW - Order as MY00.*** *Only £39.95 code (B)*
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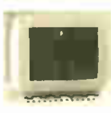

Mitsubishi FA3415ETKL 14" SVGA Multisync colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in **CGA, EGA, VGA & SVGA** modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE.**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

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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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NEXT MONTH

EPE MINI METAL DETECTOR

Beat frequency oscillator (b.f.o.) metal detectors were very popular in the '60s and '70s, soon after the advent of the first commercial transistors. Some models sold thousands of times over. But these quickly went out of fashion as superior induction balance (i.b.) and pulse induction (p.i.) designs appeared on the market.

However, b.f.o. metal detectors still have significant advantages in the areas of cost and ease of construction, and may be better suited to certain applications, such as pipe-finding or probing. Also, they are particularly well suited to miniaturisation. It is this last feature, especially, which is exploited in this design – a miniature b.f.o. metal detector which may be worn on the wrist – and, for good measure, a pinpointer, which is used to pinpoint items found with a larger detector.

While the performance of the EPE Mini *is nothing to write home about, it is sufficiently sensitive to be of genuine use. It will easily detect an old Victorian penny at 55mm, and a tiny 15mm diameter coin at 35mm. It will discriminate between ferrous and non-ferrous metals (e.g. iron and copper), thus giving a good indication as to whether a "noble" metal has been found, or just a rusty piece of iron.*

The EPE Mini *has many potential uses. It may be used for detecting treasure (we hope!) during idle moments in the school grounds or on the beach. It may be used as a pipe-finder or cable locator. It may also be optimised to detect very small items, such as small nails and screws in furniture.*

Besides this, the EPE Mini *may well be the first metal detector to be worn on the wrist. Despite its diminutive size it is easy to build, with just eight standard size components mounted on its miniature printed circuit board.*

PRACTICAL RADIO CIRCUITS

Part 2 of our new radio circuits series looks at regeneration or "Q" multiplication. A simple "Q" multiplier project is described which can be added to the MK484 TRF Receiver featured in Part 1 to improve its performance. This is followed by a design for a classic two transistor medium wave reflex receiver together with full constructional details.

In order to provide these projects with loudspeaker output an easy-to-build speaker amplifier is also fully described, this circuit uses just five components, including the speaker, to give up to 1W r.m.s. output.

Plus three more practical circuits.

LOW RANGE OHMMETER ADAPTOR MK2

Taking measurements of low resistance components and printed circuit board tracks below 10Ω is a common requirement in electronics. However, most multimeters are not able to measure low resistances accurately as their resolution is inadequate.

This article presents an adaptor that can be connected to most multimeters to enable low resistance readings to be taken. The operation of the adaptor is based on the circuit published in EPE *September 1995, but provides improved temperature stability.*

The exact accuracy of the design (i.e. lower limit) depends simply on the quality of the meter used with the adaptor. A normal digital meter should be able to register values down to about 0·01Ω.

QUASAR ELECTRONICS **Number 1 For Kits**

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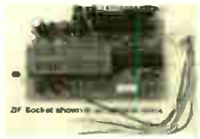
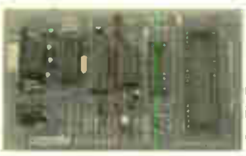
Enhanced 'PICALL' ISP PIC Programmer



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

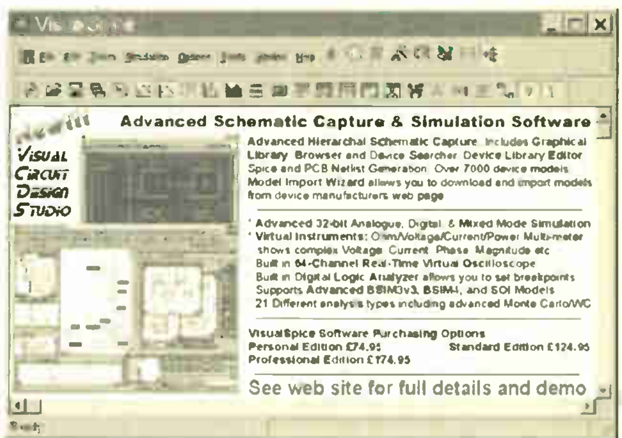
See opposite page for ordering information on these kits

ABC Mini 'Hotchip' Board

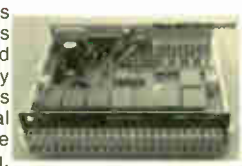
Currently learning about microcontrollers? Need to do something more than flash a LED or sound a buzzer? The ABC Mini 'Hotchip' Board is based on Atmel's AVR 8535 RISC technology and will interest both the beginner and expert alike. Beginners will find that they can write and test a simple program, using 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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Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
15w	75w	162	40	£4.99	£2.49	BC/ES
9w	45w	135	40	£4.99	£2.49	BC/ES

3U

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
24w	120w	178	54	£7.99	£3.99	BC
18w	100w	158	54	£7.99	£3.99	BC

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Type of Fitting: BC = Standard Bayonet, ES = Standard Screw, SBC = small bayonet, SES = small screw

Dim = Dimensions H = Height D = Diameter

4U

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
65w	325w	255	72	£19.99	£9.99	BC
30w	150w	178	54	£9.99	£4.99	BC

FULL SPIRAL

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
25w	125w	145	62	£7.99	£3.99	BC
20w	100w	130	62	£7.99	£3.99	BC
15w	75w	110	49	£7.99	£3.99	BC/ES
11w	60w	110	49	£7.99	£3.99	BC/ES
9w	45w	106	37	£8.99	£4.50	BC/SBC ES/SES

LARGE SPIRAL

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
85w	425w	258	88	£29.99	£15.99	BC

TRADITIONAL BULB

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Each	Type of Fitting
9w	45w	135	60	£5.99	£2.99	BC
13w	65w	150	65	£6.99	£3.49	BC

CANDLE

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
9w	45w	142	41	£5.99	£2.99	BC/SBC ES/SES
7w	35w	142	41	£5.99	£2.99	BC/SBC ES/SES

REFLECTOR

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Price	Type of Fitting
20w	100w	165	97	£9.99	£4.99	BC
13w	65w	112	63	£7.99	£3.99	BC

LARGE GLOBAL

Energy used	Bright -ness	Dim (mm) H	D	RRP	Ultima Each	Type of Fitting
24w	100w	172	120	£8.99	£4.99	BC

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- Full kit with headphones & all hardware

KIT 847 ....£63.95

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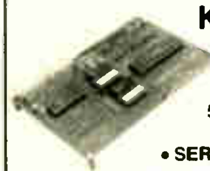
- 12C PORT OPTIONS



KIT 621
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- SIMPLE TO BUILD
- SWEPT FREQUENCY
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Kit includes case, P.C.B., coupling coil and all components.
High coil current ensures maximum effect. L.E.D. monitor.

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

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

- RANDOM PULSES
- HIGH POWER
- DUAL OPTION

Plug-in power supply £4.99

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

WINDICATOR

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

KIT 856.............................£28.00

★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Set of 4 spare electrodes £6.50

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

KIT 866. . Full kit including four electrodes £32.90

1000V & 500V INSULATION TESTER

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

KIT 848. .... £32.95

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

TEACH-IN 2000 -
KIT 879 £44.95
MULTIMETER £14.45

SPACEWRITER

NOW WITH PIC16C84 EEPROM CHIP & SOFTWARE DISK

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

KIT 849 ....£16.99

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KIT 790 ....£29.90

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

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

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

Kit No. 845 ....£64.95

ULTRASONIC PEsT SCARER

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

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

KIT 812.............................£15.00

SIMPLE PIC PROGRAMMER

KIT 857... £12.99

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

Extra 16F84 chips £3.84
Power Supply £3.99

MAGENTA BRAINIBOT I & II

NEW

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

KIT 910 £16.99 KIT 911 £24.99

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

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

Kit 855 £39.95

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

Kit 860 £19.99

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

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

8-CHANNEL DATA LOGGER

NEW

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

KIT 877 £49.95 inc. 8 × 256K EEPROMS

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PIC Real Time In-Circuit Emulator

- Icebreaker uses PIC16F877 in circuit debugger
- Links to Standard PC Serial Port (lead supplied)
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- 16 x 2 L.C.D., Breadboard, Relay, I/O devices and patch leads supplied

As featured in March '00 *EPE*. Ideal for beginners AND advanced users.
Programs can be written, assembled, downloaded into the microcontroller and run at full speed (up to 20MHz), or one step at a time.
Full emulation means that all I/O ports respond exactly and immediately, reading and driving external hardware.
Features include: Reset; Halt on external pulse; Set Breakpoint; Examine and Change registers, EEPROM and program memory; Load program, Single Step with display of Status, W register, Program counter, and user selected 'Watch Window' registers.

KIT 900 . . . £34.99

POWER SUPPLY **£3.99** STEPPING MOTOR 100 STEP **£9.99**

EPE PIC TOOLKIT 3

NEW

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

KIT 880 . . . £34.99 with 16F84 . . . £39.99 with 16F877

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- SUPER UPGRADE FROM V1 • 18, 28 AND 40-PIN CHIPS
- READ, WRITE, ASSEMBLE & DISASSEMBLE PICS
- SIMPLE POWER SUPPLY OPTIONS 5V-20V
- ALL SWITCHING UNDER SOFTWARE CONTROL
- MAGENTA DESIGNED PCB HAS TERMINAL PINS AND OSCILLATOR CONNECTIONS FOR ALL CHIPS
- INCLUDES SOFTWARE AND PIC CHIP

KIT 878 . . . £22.99 with 16F84 . . . £29.99 with 16F877

EPE PIC Tutorial

At last! A Real, Practical, Hands-On Series

- **Learn Programming from scratch using PIC16F84**
- **Start by lighting l.e.d.s and do 30 tutorials to Sound Generation, Data Display, and a Security System.**
- **PIC TUTOR Board with Switches, l.e.d.s, and on board programmer**

PIC TUTOR BOARD KIT

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

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

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

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Kit 862 £29.99

Power Supply £3.99

DISASSEMBLER SOFTWARE £11.75

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

Kit 863 £18.99

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

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MAGENTA

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

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EVERYDAY PRACTICAL ELECTRONICS

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SOMETHING FOR NOTHING . . .

When I was a young lad most enthusiasts' first experience of electronics was to build a radio set. Magazines like *Boys Own* would show constructional projects for crystal sets or one valve radios and later for simple transistor designs. In those days electronics was not the wide ranging hobby it is now, and until *Practical Electronics* was launched in 1964 hobbyists were served only by wireless magazines.

There was always something exciting about building your first radio and receiving stations from around the world – many of the early designs included a short-wave band. I well remember receiving the World Service broadcast from a transmitter near my home on a "set" consisting of a block of wood, a razor blade, lead from a pencil and a pair of ex-army headphones, that was really something for nothing.

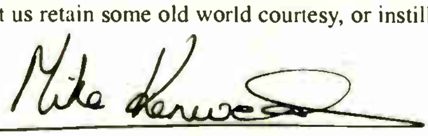
In this issue Raymond Haigh starts a new series on *Radio Circuits* which we hope will recapture the excitement for some readers. There is even a crystal set to build and, over the course of the series, a wide range of other sets building up to a superhet design. Of course, there is no longer the incentive of saving money by making your own receiver that there once was – in those days a number of suppliers advertised kits for a wide range of radio sets – but construction is still very educational and that, teamed with the pride of having built it yourself, is part of what our hobby is all about.

. . . AND YOUR KICKS FOR FREE!

As I write, I note with some satisfaction how helpful our readers are to each other. Requests for information on our *Chat Zone* are quickly met with all sorts of help and advice from around the globe. It is great to see that this freely offered help is still part of our hobby. However, I also note that some people seem to be happy to use that assistance without as much as a "Thank You".

It would be sad if the advice were not so forthcoming in future because a certain section of readers simply take it for granted. A while ago an overseas reader asked about some highly unusual aspect of high power electronics and then started berating the *Chat Zone* because he had received no replies. He seemed to feel that we should have a range of experts in every field to provide instant assistance.

It is, of course, not quite like that, we are a hobbyist magazine run by enthusiasts and helped by fellow enthusiasts who are often willing to give their time and knowledge to help fellow readers. If you receive such help from another reader or even from a freelance *EPE* contributor, it costs nothing to say thanks – let us retain some old world courtesy, or instill it where it has waned.



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

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We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers (see *Shoptalk*). **We advise readers to check that all parts are still available before commencing any project in a back-dated issue.**

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Constructional Project

FIDO PEDOMETER

MIKE BOYDEN

Keeping track of how far you've walked!

TREKKING guidebooks often refer to distances between minor landmarks for navigation purposes. This is not a handicap when navigating across countryside that is full of easily distinguished geographical or man-made features. However, when the author was trekking in the more remote locations of the French Pyrenees, estimating the distance walked was difficult and retracing steps became frustrating.

Fido was developed in an effort to look for navigational signs in roughly the expected location. It can record the distance traversed by a walker or runner and was extended to calculate 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.

WALKING THE WALK

Some background research revealed that estimation of the distance travelled by walkers (or runners) has presented engineers with some difficulty.

Arctic explorers measured movement by towing a "log" in the form of a rotating wheel that made connection with the ground from the rear of a sledge. The turns of the wheel were counted by a gear mechanism, which calculated and displayed the distance covered on a clock face. However, walkers and runners need to move freely, unencumbered with wheels and other contraptions.

Inertial guidance systems have for many years offered a "contactless" means of determining position. The theory is that the distance moved by a body can be determined if the acceleration of the body is accurately known in time. Gyroscopes (looking very much like the toys with which we are familiar) are widely used to detect acceleration. Aeroplanes and ships use these systems extensively.

The problem with using inertial systems is that measuring very small horizontal accelerations when a person is walking (1mg or $1{\cdot}10^{-3}$g) over a long period of time (say 12 hours) leads to an unacceptable level of error (i.e. 25%). Also, the earth's acceleration (g) needs to be removed from the calculations, further increasing the complexity and potential for error. The term *g* refers to the acceleration exerted on an object at the surface of the earth, which is approximately $9{\cdot}81ms^{-2}$.

More recently, a mathematical link between the vertical acceleration of the human hip joint and stride length has been established. By combining microcontrollers and accelerometers using MEMS (Micro Electrical Mechanical Systems) technology – see *Teach-in 2002*, Aug '02 – commercial pedometers started to emerge.

The developments combined to reduce errors to about 8%, which is the sort of accuracy that commercial units now offer. However, the author considered the cost of using an accelerometer as rather excessive, as was purchasing a Global Positioning System (GPS) system.

It was then discovered that Army personnel are trained to take a compass bearing and count the number of steps in a particular direction. Walking the same number of steps on a reciprocal bearing should return them to the same spot. The problem here is that the length of a stride can change, depending upon whether the subject is running, moving up or down a gradient, or simply tired. Some texts suggested that stride length could vary by as much as 40%, which would give unacceptable accumulative errors.

Table 1. Results of Stride Counting

Type of exercise	*Gradient %*	*Strides (1 mile)*
Walk (leisurely 3·5mph)	0	2280
Run (light 5·0mph)	0	1960
Walk (leisurely 3·5mph)	10	2310
Run (light 5·0mph)	10	1982

Nevertheless, in an effort to keep costs low, the literature was reviewed regarding the "stride counting" approach and a number of stride counting tests were made.

GET WALKING

The treadmill machine at the author's local gym was used to count the number of strides to run (and walk) one mile. The results are listed in Table 1. The count was also noted for a variety of gradients (the treadmill incorporated a gradient adjustment) and various stages of tiredness (ranging from mildly hot, to "get a doctor"). Minor gradient changes did not appear to introduce major errors, but the type of motion (i.e. walking or running) had a significant influence on stride length.

It was concluded that providing a person's unique "stride constant" (strides per mile/kilometre) could be estimated and stored, then a microcontroller could use this as a basis of a distance monitor, without the need for complex accelerometers.

Users would have to accept that the readings for steep terrain or excessive tiredness would become increasingly inaccurate, and that each pedometer would need to be calibrated to the type of exercise and individual's stride length. Providing these limitations were accepted, a unit offering about 10% accuracy was considered achievable and acceptable, given the simplicity of design.

DEVELOPMENT

The next problem was to reliably detect and count strides. After a little experimentation it was found that two opposing tilt switches, S1 and S2, pointing downwards by about 10 degrees, could be made to track the cycle of a leg movement.

Referring to the full circuit diagram in Fig.1, the tilt switches are connected respectively to the RA0 and RA1 pins of a PIC16F84A on one side and to the 0V line on the other. The pins are biassed normally-high via resistors R1 and R2, and l.e.d.s D1 and D2.

As illustrated in Fig.2, when the knee is raised the conductive fluid in switch S1 is forced momentarily onto its contacts, closing them, so applying logic 0 to pin RA0. Pin RA1 remains at logic 1. As the foot is placed down, both S1 and S2 open, and both RA0 and RA1 are set at logic 1. As the knee is raised in the last part of the stride then S1 opens and RA0 goes to logic 1, but S2 closes, with RA1 at logic 0.

The prototype was taken to the local gym for testing, where it was found by experimentation that the detection unit operated best when strapped to the left upper calf. Note that the software only allows the unit to function in this position.

The software verifies the correct switch closure sequence and also includes some time delays. These are necessary to reduce the sensitivity of the system and curtail the number of "bad reads" due to the equivalent of contact bounce.

For simplicity and cost effectiveness, a single 7-segment l.e.d. display was used for all of the display and control interfacing, using a cyclic technique to display the various factors. A sounder, WD1, is included to signal each valid step when in the Learn mode – this improved the setting-up procedure. The mode of operation is selected by means of a 3-way toggle switch, S3.

DISTANCE AND TIME

The main computation undertaken by Fido requires distance and elapsed time to be known.

Time: Fido's clock rate is set by a 20ms interrupt generated by a TMR0 overflow. Although this would not be accurate enough for daily time keeping, it is accurate enough for this application. The 20ms "ticks" are counted and eventually used to increment a "6-minute", 16-bit timer-counter (Ttimehi, Ttimelo).

Distance: If Fido is to work in miles then the number of strides recorded to complete one mile is entered into Fido during the Learn mode. Once the calibration distance has been walked, a switch adjustment ensures that the number of strides (the stride constant) is stored in the PIC's non-volatile Data EEPROM. (The software is written to store the stride value for every stride that is taken after the first 255 strides.) The value placed into the EEPROM is calculated from:

Stride Constant = Strides Counted / ten

The Stride Constant is subtracted from the 16-bit stride counter (distlo, disthi) to see if 0·1 of a mile has been walked. If it has, then this is then used to increment a "0·1 mile", 16-bit Total Distance counter (Tdisthi, Tdistlo).

Distance is recorded and displayed by means of a number of incrementing decimal counters.

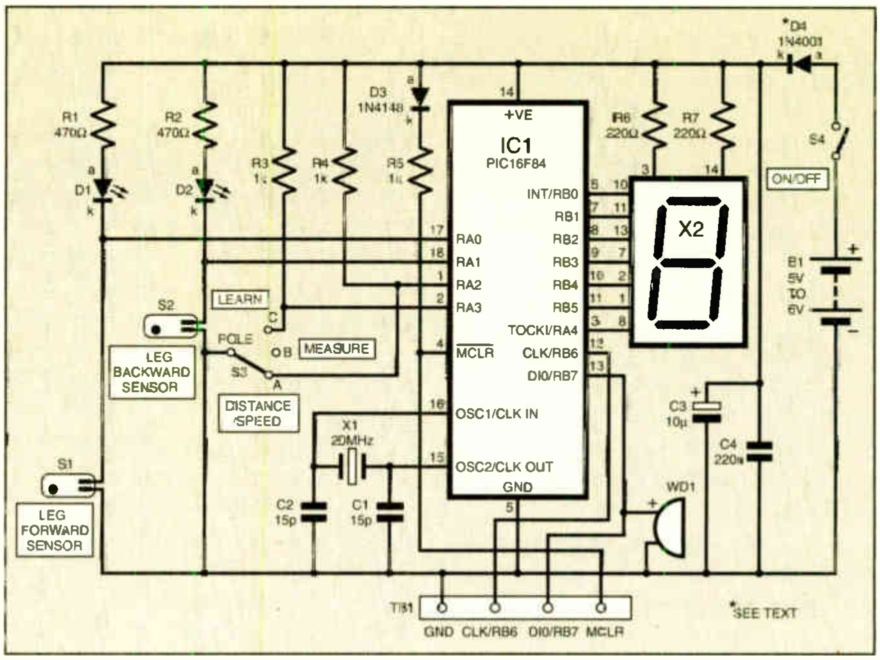


Fig.1. Complete circuit diagram for the Fido Pedometer.

CALCULATIONS

Average speed is calculated at each 6-minute interval and a "snapshot" of the Distance Counter is stored in Tdisthi1 and Tdistlo1. The average speed is then derived from:

Average speed (miles/hour)
= 0·1 mile counter/ 6-minute counter
i.e.
(Tdisthi1, Tdistlo1) / (Ttimehi, Ttimelo)

Hence the average speed displayed is the average since the time that Fido was switched on. If the walker stops for lunch, and Fido is left on, the average speed will be seen to steadily fall. If the average speed is required "per leg" of a journey, then simply record the distance together with average speed and turn off Fido, thereby resetting the unit in readiness for the next phase of your walk.

A "standard" library of 16-bit unsigned integer mathematical functions from Microchip's website (**www.microchip.com**) were used in this application. "Invalid" divisions (i.e. 1 / 0 or 2 / 3) are returned as 0, rather than the true mathematical results of infinity or a fraction. Mathematically, Fido has a maximum capability of approximately 6,500 miles and 270 days! A reset of the unit is forced if the distance exceeds 99·9 units, but the time has no restrictions.

INHIBITING ERRORS

Although Fido computes and displays distance immediately, the first computed value of speed is only available for display six minutes after turning Fido on. Distance and average speed values displayed in the first 0·5 miles should be treated with caution as the small reading errors represent a significant proportion of the initial measured values. The errors rapidly diminish as the time and distance measurements increase.

The measurement technique assumes that most of the movement is a genuine walking or running motion, hence the errors contributed by a few "stumbles" are greatly reduced when averaged against the number of strides that equate to a mile for individual walkers.

RESOURCES

Software for this design is available on 3·5-inch disk (Disk 6) from the Editorial Office – a nominal handling charge applies (see the *EPE PCB Service* page. It is also available for *free* download from the *EPE* ftp site. The easiest way into this is via the home page **www.epemag.wimborne.co.uk**. Click the top link saying **ftp site (downloads)**, then take the path **pub/PICS/Fido**.

CONSTRUCTION

Fido is constructed on a single printed circuit board (p.c.b.) whose full-size track layout and component positions are shown

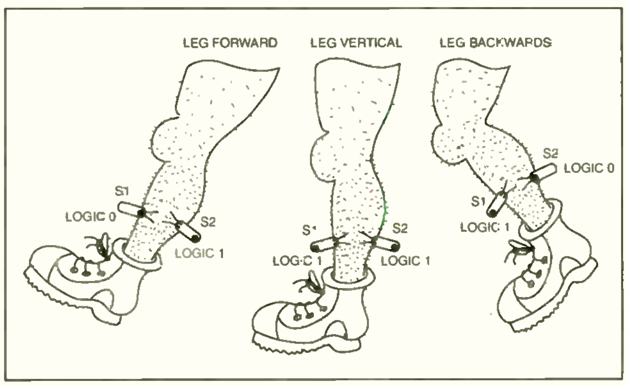
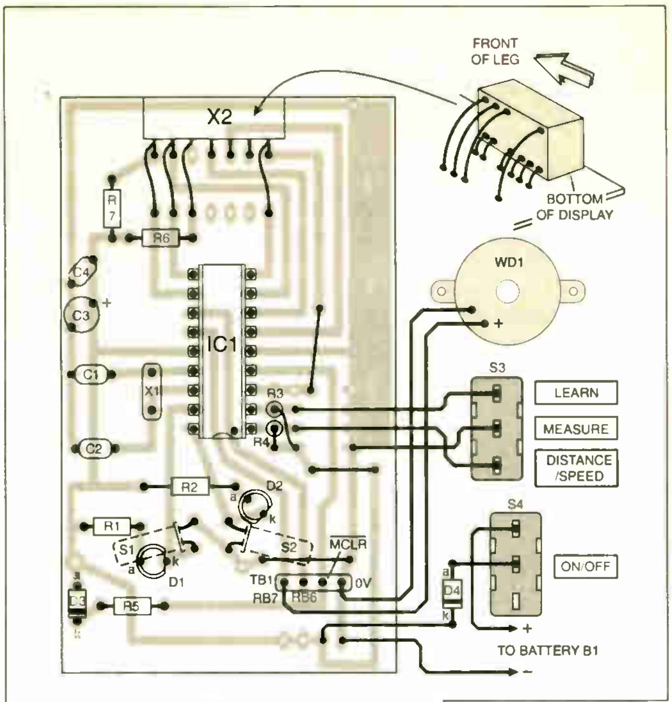
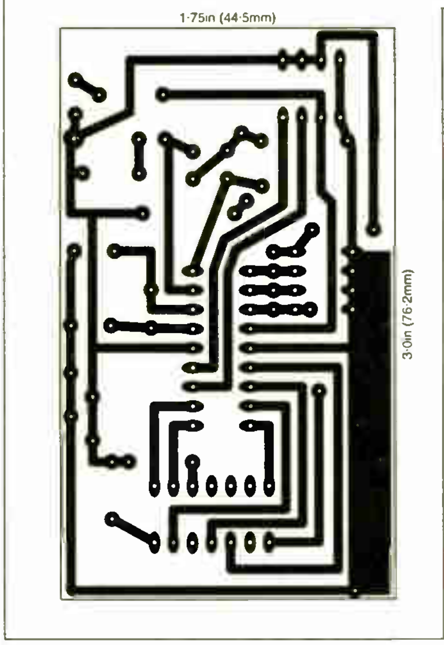


Fig.2. Fido's logic (with or without hairy legs!).





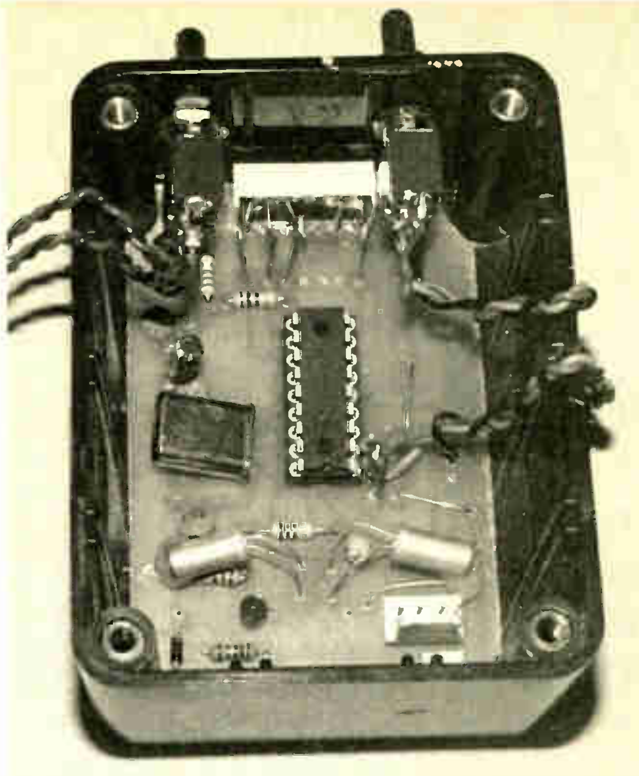


Fig.3. Printed circuit board component layout and full size copper foil master track pattern for the Fido pedometer.

in Fig.3. This board is available from the *EPE PCB Service*, code 394.

Mount the components in order of increasing size. Correctly observe the polarity of the diodes and electrolytic capacitor C3. A socket must be used for IC1. Do not insert the PIC until the board has been completed and fully checked.

The 7-segment l.e.d. is not mounted flush with the board. Rather, to assist viewing when walking, it is mounted on its side. The decimal points are at the lower end of the display and these should point towards the rear of the calf when strapped to the left leg. The lower pins of the display are tightly turned into the p.c.b. Small rigid extension wires link the required upper pins to the p.c.b.. see Fig.3.

Connector TB1 provides the programming connection points for those who wish to program their PIC *in situ*, but note that they are not in John Becker's "standard" TK3 order. Pin RB7 is also the pin to which the sounder WD1 is connected, but the sounder should be disconnected if/when on-board programming is to be performed.

Fido was mounted in a slim-line plastic case, measuring 80mm × 62mm × 39mm, with suitable holes cut for the l.e.d.s, 7-segment display and the switches. Allow room for the battery (see later). It may also be necessary to drill small holes to let the sounder be heard. To protect Fido from rain and mud, rubber dust covers are recommended for the switches and a small piece of clear plastic should cover the 7-segment display.

COMPONENTS

Resistors

R1, R2	470Ω (2 off)
R3 to R5	1k (3 off)
R6, R7	220Ω (2 off)

All 0·25W 5% carbon film

See SHOP TALK page

Capacitors

C1, C2	15p polystyrene or disc ceramic (2 off)
C3	10µ radial elect. 10V
C4	220n disc ceramic

Semiconductors

D1, D2	red l.e.d. (low current) (2 off)
D3	1N4148 signal diode
D4	1N4001 rectifier diode (see text)
IC1	PIC16F84A microcontroller preprogrammed (see text)

Miscellaneous

X1	20MHz crystal
X2	7-segment display, common anode
S1, S2	tilt switch (2 off)
S3	s.p.d.t. centre off toggle switch, spring biassed one direction
S4	s.p.s.t. min. toggle switch
WD1	buzzer
B1	5V to 6V battery (4 x AAA), with holder and clips (see text)

Printed circuit board, available from the *EPE PCB Service*, code 394; slim-line plastic case (80mm x 62mm x 39mm); custom-made cloth pouch (see text); 18-pin d.i.l. socket; 14-pin d.i.l. socket; solder, etc.

Approx. Cost Guidance Only **£16** *excl. case & batts*

SETTING UP

Ensure the tilt switches are angled pointing slightly downwards and both l.e.d.s, D1 and D2, are off. Ensure switch S3 is centred (off). Turn Fido on in the vertical position; the sounder will then signal that the timer function has started.

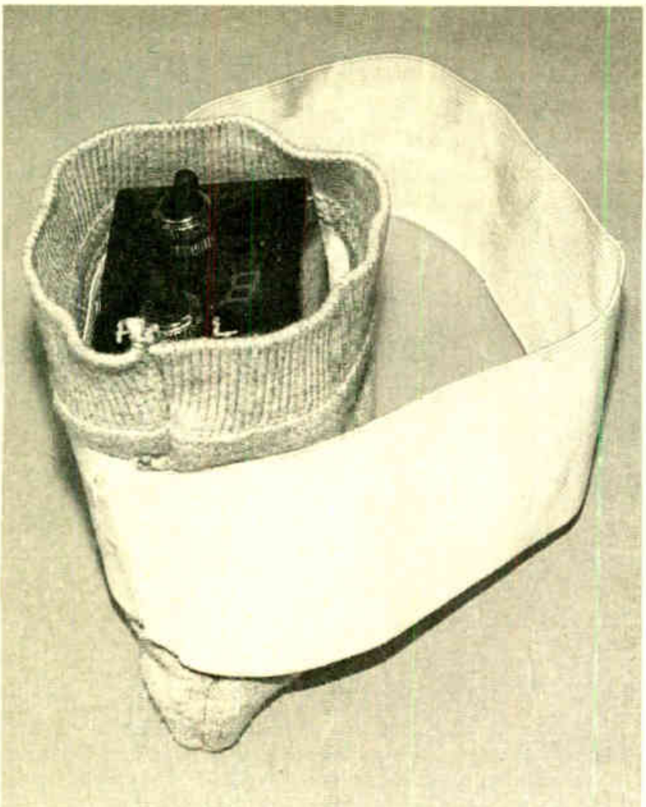
Sway Fido back and forth in a motion as if it were the bob of a pendulum (which effectively is what a leg is, i.e. pivoted at the hip). Each sway will flash, in turn, the horizontal bars of the 7-segment display.

The top, middle and lower bars will not necessarily flash in a perfectly smooth sequence when swayed – this is normal. When vertical, the centre bar will flash. The l.e.d.s. D1 and D2 go on and off as appropriate when the tilt switches make and break their contacts.

Switching to Learn mode will make alignment easier, as each valid stride is signalled by a bleep, but be sure not to exceed 255 "test" steps, otherwise Fido will assume that a new stride constant is to be stored. Reset by turning off and back on again.

Note that the bleep will not always occur in exactly the same leg position. However, only one bleep should be heard per stride cycle. Adjust the tilt switch positions if necessary. Once Fido is "walking" reliably, open the box and secure the location of the tilt switches using hot melt glue.

Turning off power to the unit will reset to zero the distance and speed displays and calculations. If a new stride constant has



Fido's "collar", worn around the left upper calf.

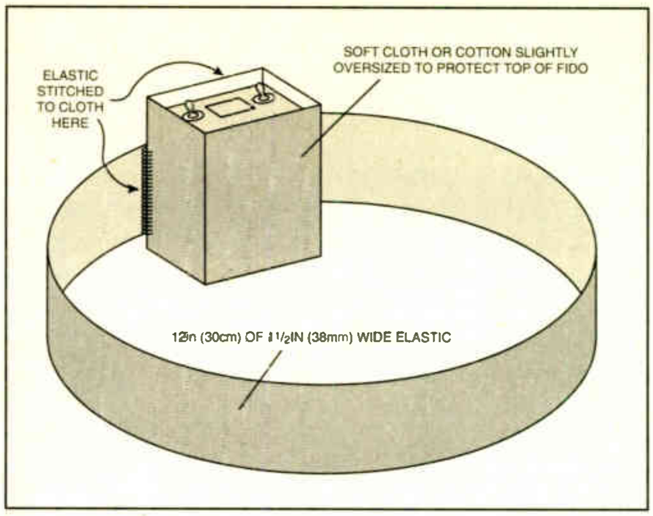


Fig.4. Construction of Fido's "pooch pouch and collar"!

Table 2. Mode Switch S3 Functions

Position	*Mode*	*Function*	*Display*	*Tone*
A	Display	Display distance/ average speed	P0-0 A0-0 ...	Silent
B	Measure	Measure distance speed	Descending bars	Every mile/km
C	Learn	Learn strides per mile/km	L and bars descending	< 255 strides 1 bleep > 255 strides 2 bleeps

been entered using Learn mode then this will be remembered despite power being turned off.

The unit can only be used on the left leg. Changing orientation would require changes to be made to the software, a matter on which no advice is offered.

The 7-segment display will not be readable from a normal standing position, so it is necessary to make a strap-on pouch to allow Fido to be lifted out and read when required. The author's arrangement is shown in Fig.4. The pouch is sewn to a loop of 50mm wide elastic. The walking boot is passed through the elastic hoop and Fido is slipped into the pouch at the top of the calf just below the knee joint.

Note that as the calf muscle is rounded, so Fido points slightly "inward" when viewed from above. This is normal, but check that Fido does not significantly shift from this position, especially when running.

FIDO'S APPETITE

Part of the design criteria for Fido assumed that it might be used in rugged and remote locations, where constant battery changes would not be welcome. When walking, the prototype consumed an average of 27mA, but by using low current l.e.d.s and "flashing" the display whenever possible, this was reduced to an average of 13mA.

The plastic case is sized to house four AAA alkaline batteries rated at 1200mA/hr. No battery duration problems have been experienced in the prototype, despite constant testing over a period of two months.

It should be noted that the PIC16F84A has a maximum supply voltage limit of 5·5V, whereas four AAA cells will nominally deliver 6V. Consequently, it is recommended that a 1N4001 rectifier diode should be inserted in the positive line between switch S4 and the p.c.b. to drop the voltage reaching the PIC by about 0·6V.

TAKING FIDO FOR A WALK

When first switched on, if Fido is not upright the display will remain blank and the timing function will be disabled. When upright, the centre bar of the display will flash and a short bleep from the sounder will indicate that the unit is now functioning.

Slip Fido into its pouch situated on the left calf and walk with Mode switch S3 in position A (centre). As progress is made, each of the horizontal bars of the 7-segment display will flash as each stage of a valid walk cycle is detected. When stationary and vertical, the middle bar will flash at about 1Hz.

Next, Mode switch S3 can be tested. It is a 3-position (centre-off) toggle switch. Position A is "spring return loaded". Its functions are shown in Table 2.

Display Mode (S3-A)

Only when Fido is in the vertical position (middle bar flickering) can switch position S3-A be "pulsed". This will trigger a display cycle on the single digit 7-segment display, showing progress (distance covered) and average speed.

If Fido has been calibrated in miles, the letter P (progress) is displayed first, followed by the miles units, then a decimal point (a dash) followed by tenths of a mile. After a short pause, the letter A (average speed) is displayed and the average speed in miles/hour is shown in the same format as distance. If the distance or speed exceeds 9·9 then the tens of miles digit will automatically appear.

Once a display cycle is completed, the unit will return to measure mode.

Measure Mode (S3-B)

When switch position S3-B is selected (centre), Fido silently counts strides and displays each stage of a valid leg movement by flashing the top, middle and lower bars of the 7-segment display. Every mile (or kilometre) is signalled with a long bleep from the sounder.

Learn Mode (S3-C)

Fido has been programed with a default value of stride constant (2280 strides/mile, level ground, walking), but it will probably be necessary to readjust this constant. To make the adjustment, Learn mode needs to be selected by setting the Mode switch to position S3-C.

A distance of one mile, or one kilometre, should now be walked or run. The display will show the normal "descending bars" indicating a valid stride, but this will be accompanied by a bleep and the letter L on the display.

To avoid the accidental selection of Learn mode (and hence entering incorrect data), Fido will only commence remembering the stride count after 255 strides have been completed. When more than 255 strides have been recorded, each stride will be followed by two bleeps to indicate that Fido is now recording a "live" stride constant value.

Once the standard distance has been covered, switch to normal walk mode (Measure – S3-B) and walk a few paces. Check the descending bars are visible again and no bleep is present. Switch Fido off, wait a couple of seconds to let capacitor C3 discharge, and then switch back on. Henceforth only the new stride constant will be used (until such time as you might choose to change it, in the same way as just described).

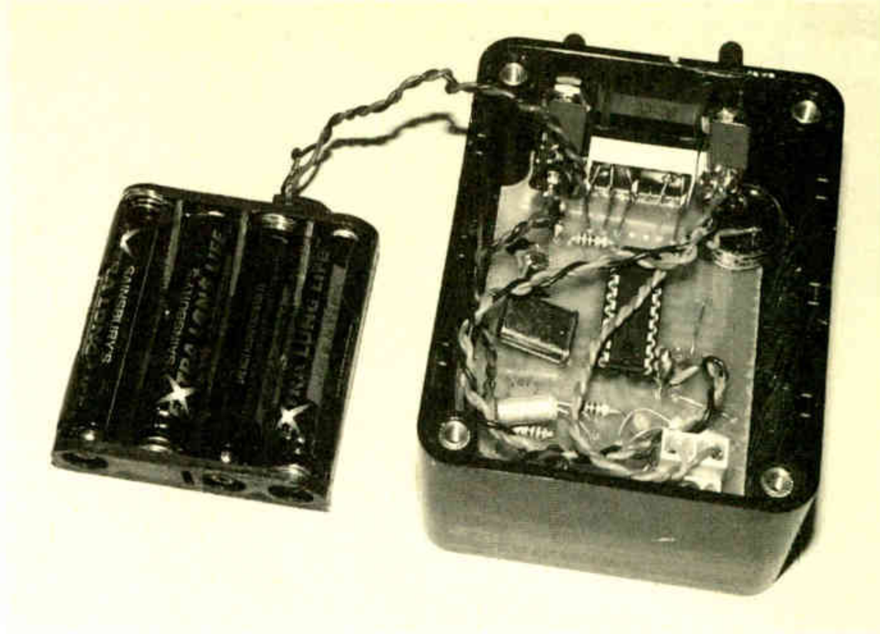
If possible, "train" Fido in the type of terrain in which it will be used. A "standard mile" can be determined by driving a car down a safe road (i.e. also suitable for pedestrians) for one mile (or 0·62 miles for kilometres), as shown on the car's mileometer. Walk back to the start of the mile with Fido set to Learn mode. Save the new stride constant, restart Fido and then walk back to the car.

The display may show 0·9 miles when coincident with the position of the car. Walk until it shows 1·0 miles, which should be an indication of the error and should be no more than 10%, say 170 yards. Getting standard distances in rough country can be more difficult and perhaps ordnance survey maps can be of assistance here.

Both a gym treadmill and the above procedure have been used for calibrating the prototype. Tests showed an accuracy to within 10% for distances greater than 1·0 miles.

The conversion between miles and kilometres is:

Miles to kilometres multiply by 1·609
Kilometres to miles multiply by 0·621



FURTHER IDEAS

Fido can potentially record any repetitive leg movement providing the set-up and calibration are adjusted. Experiments are currently underway to adapt Fido to measure the "stroke rate" and performance profile of club standard rowers.

FURTHER READING

Although this design is simply PIC-based, readers may be interested to read about the ADXL202 accelerometer device, in particular *Using the ADXL202 in Pedometer Applications*, Harvey Weinberg, via **www.Parallex.com**. ADXL202 device information is available from **www.Analog.com**. □

SHOP TALK
with David Barrington

PICronos L.E.D. Wall Clock

The first observation one makes when scanning down the parts list for the *PICronos L.E.D. Wall Clock* is that quite a cash saving can be made if readers approach some of our components advertisers and do a bit of "arm-twisting" and negotiate a special "bulk discount" on the ultrabright l.e.d.s. If you order 200, as the author did, they should certainly be able to offer you a good price, and possibly include different colours as well.

It is important that constructors keep to the specified semiconductor devices for the Clock. The L293DN 16-pin Half-H driver chip (also referred to as a stepper motor driver i.c.) was purchased from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 82-0192. The "D" denotes it is a 16-pin device. Do *not* use other L293 device types as they may not have the same characteristics – for instance, the L293E has 20 pins and cannot be used. (Check out the Texas web site at: **www.ti.com.**)

The 7-stage Darlington line driver type ULN2004A was also ordered from the above company, code 82-0622. It is also listed by **RS Components** (☎ ***01536 444079*** or ***rswww.com***, credit card only – a p&p charge will be made), code 652-825. RS also supplied the rail-to-rail LMC6484 quad op.amp, code 310-925.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-4 microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (Disk 6) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 434). It is also available for free download from the *EPE* ftp site, which is most easily accessed via the click-link option on the home page when you enter the main web site at ***www.epemag.wimborne.co.uk***. On entry to the ftp site take the path **pub/PICS/PICronos**.

The large circular printed circuit board for the Clock is available from the *EPE PCB Service*, code 395 (see page 434).

Fido Pedometer

Apart from the PIC microcontroller and associated software, only the tilt switches called for in the *Fido Pedometer* project are likely to cause any real concern.

Due to the robust treatment of Fido, when taken for "walkies", and the dangerous toxic nature of mercury, we feel readers should make every endeavour to keep well clear of using mercury-filled tilt switches. Instead, we recommend readers use one of the hermetically sealed *non-mercury* types. A suitable switch is "currently listed" by **Maplin** (☎ ***0870 2263 6000*** or ***www.maplin.co.uk***), code DP50E.

The above company also supplied the sub-miniature centre-off, biassed one way, toggle switch (code FH02C) and a suitable waterproof toggle switch cover (two needed – code JR79L). The plastic box is left to individual choice.

For those readers unable to program their own PICs, a ready-programmed PIC16F84A microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £5.90 each (overseas add £1 p&p). The software is available on a 3·5in. PC-compatible disk (Disk 6) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 434). It is also available for free download from the *EPE* ftp site, which is most easily accessed via the click-link option on the home page when you enter the main web site at ***www.epemag.wimborne.co.uk***. On entry to the ftp site take the path **pub/PICS/FidoPed**.

The printed circuit board is available from the *EPE PCB Service*, code 394 (see page 434). The 7-segment common anode display should be in abundant supply, but you will need to check the pinout arrangement before making a purchase.

Back-To-Basics 5 – Mini Theremin/Twilight Switch

The only item that readers will experience problems finding for the *Mini Theremin*, one of this month's *Back-To-Basics* projects, is the specified Toko RD7 i.f. transformer, which is usually used in radio receivers.

Having had problems in the recent past trying to locate sources for Toko coils, it is fortuitous that the author (Raymond Haigh) of the new *Practical Radio Circuits* series has given us the names of two stockists. They are: **JAB Electronic Components, Dept *EPE*, PO Box 5774, Birmingham, B44 8JP** (☎ ***0121 682 7045*** or ***www.jabdog.com*** – they appear to only deal with mail orders) and **Sycom, Dept *EPE*, PO Box 148, Leatherhead, Surrey, KT22 9YW** (☎ ***01372 372587*** or ***www.sycomcomp.co.uk***). We also understand from Raymond that the main UK Toko supplier is **Coils-UK** (☎ ***01753 549502*** or ***www.coils-uk.com***), but that they are only into "bulk orders".

All the semiconductor devices for both of this month's projects should be widely stocked by our components advertisers. They should also carry the ORP12 light-dependent resistor or its derivative used in the concluding *Twilight Switch*.

Practical Radio Circuits – 1

No difficulties should be encountered in obtaining components for the *Practical Radio Circuits* series of projects and any that could possibly cause concern will be highlighted each month.

We "kick-off" the series with a simple *Crystal Set Radio*, a *TRF Receiver* and a single transistor *Headphone Amplifier*. The Crystal Set and TRF Receiver both use the same polythene dielectric tuning capacitor and ferrite rod coil.

The tuning capacitor will normally be found listed as a miniature "transistor radio" type and is currently stocked by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110 and **Sherwood Electronics** (see ad. on page 440), code CT9. The ferrite rod for the aerial/tuning coil should be easy to come by, it is certainly listed by Sherwood (code FR1) and we note **WCN Supplies** (☎ ***023 8066 0700***) are offering a 140mm x 10mm rod, with a coil (unwanted).

For the 26s.w.g. enamelled copper wire, the author obtained a 50g (2oz) reel from **JAB Electronic Components** (☎ ***0121 682 7045*** or ***www.jabdog.com***). We also understand **J. Birkett Supplies** (☎ ***01522 520767***) stock 50g reels. Most suppliers only sell "large" reels.

The MK484 radio i.c. is stocked by ESR Components (see above) and **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), code 82-1026. Any point-contact germanium diode should prove suitable for the detector in the Crystal Set; e.g. the OA47, OA90 and OA91, and any silicon signal diode can be used for D1 and D2 in the TRF Receiver, e.g. 1N4148, 1N914, 1N916.

The two small printed circuit boards are obtainable from the *EPE PCB Service*, codes 392 (TRF Rec.) and 393 (Headphone), see page 434.

PLEASE TAKE NOTE

Toolkit TK3 *(Oct/Nov '01)*

Version V1.42 of the TK3 programming software is now on our ftp site. It has had the following facilities added:

- Recognition of Macro functions
- Use of LOCAL in the context of Macro addresses in relation to HIGH and LOW functions
- Recognition of IFDEF and ENDIF functions
- Calculator for PIC Baud rate register values

Powerline Comms – Boon or Bogey?

Broadband delivered over mains wiring? Andy Emmerson investigates

If you thought PLC stands for public limited company, you'd be right. But to some it means power line communications as well, also known as PLT (power line telecommunications). Although some electricity companies see PLC as an ideal way of providing Internet service down your power feed (and making mega money at the same time), others consider the idea nothing short of abominable. So what's all the fuss about?

The notion is very simple. The copper cables that supply mains electricity to your home could deliver bandwidth by the bucketload as well to provide low cost broadband connections for Internetters frustrated by its lacking availability in their neck of the woods. With governments banging the broadband drum and users yearning for low-cost bandwidth, it's hardly surprising that power companies scent money in this opportunity.

Hardware vendors are equally keen to assist the electricity industry apply leverage to its existing assets and proclaim the effectiveness of their solutions most eloquently. The technology is cost-effective, it needs no new wires and everyone wants it. Or so you might believe.

WHAT IS PLC?

Communicating over electricity mains uses the existing supply (110V, 230V, etc.) wiring to carry information as well as energy. This concept can be applied to local area networking (using internal wiring within the home or workplace) or for access to the public network (over the feeders that connect consumers' premises to the local substation).

As a commercial proposition, it is the latter opportunity that is exercising the minds of the power companies. With the delays and uncertainties of unbundling the European and US local loops and the stagnation surrounding broadband fixed wireless access, powerline technology is attracting considerable attention as a local access technology.

Before detailing the underlying technology, first we need to see what's fuelling this feeding frenzy. Power generation and distribution is a highly competitive business and utilities would dearly like to tap into new revenue streams.

A key imponderable remains, however, and it could prove a major stumbling block. The issue is electromagnetic compatibility (EMC); power lines carrying data signals are likely to radiate, interfering with broadcast signals. Bean counters make little of the issue and vendors argue that interference problems can be overcome. Others are less confident and are putting their faith in existing regulations against undesirable transmissions.

Debate has been mainly theoretical but with tests underway now, many bodies will be observing the results. If these are successful and interference can be contained, major deployment of the technology is forecast to follow.

WHAT'S ON OFFER

Commercial applications for powerline communication include high-speed Internet access, entertainment distribution, voice telephony and fax using Voice over Internet Protocol (VoIP), building automation, meter reading and remote surveillance for building security and healthcare.

Data rates are not spectacular, however. Although products available currently work at up to 2Mbit/s, once several users are sharing the same data stream these speeds will drop significantly. Higher speeds are promised in future, though, and the vendor that spoke of individual network connections of 2·5Gbit/s has still not provided substantiation of this claim after 18 months.

A data concentrator installed at the neighbourhood substation is the transfer point for data streams between the local supply mains and the main telecommunications trunk network. The mains-voltage distribution network carries the data between here and consumers' homes or offices, where an adapter breaks out the voice and data signals and feeds them by coaxial cable to the user's PC, telephone and other applications. In general the maximum distance between transformer and consumer is up to half a mile.

Carrier frequencies for transmitting this data lie in the region 9kHz to 30MHz, the same part of the spectrum as used for a variety of radio communications. Implementations use a variety of spread spectrum and fast frequency hopping techniques, with either frequency division or amplitude modulation.

Power lines are a harsh environment for data transmission; impulsive noise and voltage spikes from electrical appliances, switching operations and distant lightning strikes can wipe out low-level signals. Modulation levels can be increased but then signals begin to leak out; radiation from street lamps during trials in Manchester gave rise to concerns over data security as well as fuelling opposition to further pollution of the airwaves. Powerline communications are anathema to broadcasters and listeners, not to mention government, amateur and CB users of the radio spectrum.

But is it legal? Or better stated, does it matter? Legitimate users of the radio spectrum think so. Radio Netherlands has warned that interference levels, even to reception of strong domestic signals, will be so high that the whole concept will have to be re-thought. Otherwise many urban dwellers will lose the opportunity to listen to foreign radio stations on AM radio.

The Radio Society of Great Britain has also voiced its concern, noting that German approval for powerline communication systems, strongly opposed by radio users in that country, allow higher levels of emission than those cited in the UK as a "worst case" for acceptable interference. It concludes there is a European agenda to provide cheap wideband data systems and that the technical arguments for preservation of the h.f. spectrum appear to be ignored.

However, given the recent success of legal appeals under human rights legislation, it is likely that any significant interference to citizens' ability to listen to authorised broadcast stations would be found unconstitutional and would lead to effective action against the "jammers".

Just think back to the early 1980s and the hijacking of the airwaves for citizens' band radio, the largest manifestation of mass lawbreaking the country has ever seen. Rather than prosecute the malefactors, the supine government of the day saw fit to legalise the use of the 27MHz band for CB use, forcing the existing users of the frequency to swallow the cost of buying new equipment on different frequencies. If the British government gives in that easily to individuals, how likely is it to resist private companies with vested interests?

STILL INTERESTED?

Scottish Hydro-Electric is due to begin full-scale commercial trials this summer of its broadband service over power lines, naming Stonehaven in Scotland and "a town in Hampshire". Pricing for triallists is stated to be around £25-£30 a month, although this was not finalised at the time of writing.

Don't hold your breath for powerline communications to reach your home by the end of the year though; the company may have legal action on its hands if the system causes interference. It cannot be forgotten either that high-profile trials in Britain and Germany by suppliers such as Nortel/Norweb, Siemens and Rhine-Westphalian Electricity have failed on account of regulatory issues and slow sales.

The truth is that powerline communication faces an uncertain future. Superficially attractive, its deployment may turn out to be unviable and technically problematic. A report from UBS Warburg and the Smith Group argues that it will come so late that it will "miss the boat" and by the time manufacturers have equipment that meets EMC regulations, the rollout of ADSL will be at an advanced stage. This may be unduly optimistic for ADSL but only time can tell.

News . . .

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

FOUNDER OF TI DIES

THE British-born founder of Texas Instruments, Sir Cecil Green, died on 11 April 2003 aged 102 in a hospital at La Jolla, California. He had pneumonia.

He was the last of the four founders and a philanthropist who donated more than $200 million to education and medical institutions around the world.

On 6 Dec 1941 he joined Eugene McDermott, J. Erik Jonsson and H. Bates Peacock to purchase Dallas-based Geophysical Service Inc., which performed seismic explorations for petroleum. During WW2, GSI branched into other areas, including the manufacture of submarine-detection devices and airborne radar systems.

In 1951 the company changed its name to Texas Instruments. In 1952 TI entered the semiconductor business by licensing Shockley's work at Bell Labs, putting it at the front of the chip business. Green discovered that foreign competitors were far smarter at adopting TI's innovations than US competitors. He is quoted as having said "Our aggressiveness, in effect, set the Japanese up in business".

Cecil Howard Green was born near Manchester, England, emigrated as a child to Canada, then San Francisco. He was awarded an honorary knighthood in 1991. He leaves no immediate survivors.

For more information browse **www.theregister.co.uk/content/3/30282.html** and **www.washingtonpost.com/wp-dyn/articles/A1993-2003Apr13.html**.

RACE FOR EPSOM

SUNDAY 22 June 2003 is the starting dateline for the Radio and Electronics Fair to be held at Epsom Grandstand, Surrey, from 10am to 5pm. After the success of the last rally in 2002, the organisers have been encouraged to stage another. The Fair has become the number one event for the region.

It is a one day event and will consist of private and trade stalls with added attractions throughout the day, amongst which will be a Bring and Buy sale. Also, on behalf of the RSGB, a National Construction Contest will be held, with a trophy. Morse testing facilities will be available as well. There will also be a display of military vehicles by VMARS (Vintage and Amateur Radio Society), plus a WW2 operations room talking station!

Refreshments are available, and further entertainment will be provided by Ken Mackintosh and his 17-member band.

Booking contact: Brian Cannon G8DIU, 38 Sandringham Road, Worcester Park, Surrey KT4 8UJ. Tel/fax 01737 279108. Email: Brian.Cannon@btinternet.com.

PICO CAT

AS you are no doubt aware, Pico specialises in the field of virtual instruments for data acquisition. They say that they have always been recognised for providing innovative low-cost alternatives to traditional test equipment and data acquisition products.

For many years Pico have generously supported *EPE*'s innovative readers by awarding prizes to the best *Ingenuity Unlimited* designs each year. They also supported our recent *Teach-In 2002* series. Teachers will be interested to know that Pico place a heavy emphasis on scopes and loggers for Education.

We thoroughly recommend that you get a copy of Pico's latest catalogue – over 40 pages of full-colour glossy A4 – detailing their entire range of products and accessories.

For further information contact Pico Technology Ltd., Dept. EPE, The Mill House, Cambridge Street, St Neots, Cambs PE19 1QB. Tel: 01480 396395. Fax: 01480 396296. Email: sales@picotech.com. Web: www.picotech.com.

WCN BARGAINS

"100's of bargains inside" proclaims WCN Supplies' latest catalogue, issue 17. In its 44 A4-sized pages there is a vast array of products on offer, ranging from batteries, connectors and fans, through buggies and paintball (yes indeed!), passive and active electronic components, to meters and tools.

To get your copy of this catalogue, contact WCN Supplies, Dept EPE, The Old Grain Store, Rear of 62 Rumbridge Street, Totton, Southampton SO40 9DS.

Tel/Fax: 023 8066 0700.
Email: info@wcnsupplies.fsnet.co.uk.
Web: www.wcnsupplies.com.

Controlling Magic

Barry Fox

MODERN TV, recorder and satellite set top boxes are routinely updated with new operating software sent over the air or by phone line in the small hours without the owner knowing it. New features appear in the morning as if by magic. But the remote control often cannot control them.

Thomson (owner of RCA) has the answer. Thomson will now provide remotes that have an infra-red sensor eye as well as the usual IR transmitter; and the set-top box will have an infra-red transmitter as well as the usual sensor. After the set top box has been updated, instructions appear on screen telling the owner to point the remote at the box and wait a few seconds while it loads new control codes into its memory. The remote then matches the set-top box again.

EPE Benefits EOCS

DON Bray, Hon Editor of the Electronics Organ Constructors Society has written to thank us for Editorial mention. We are indeed pleased to help publicise the EOCS, and have been doing so from time to time for many years.

He says that the EOCS has acquired several new members recently and at least one joined as result of our last mention. He also says that the EOCS magazine shows that there is a considerable interest in PIC programming, which of course we know full well!

For more information about the EOCS, contact Trevor Hawkins, Hon Secretary, EOCS, 23 Blenheim Road, St Albans, Herts AL1 4NS. Tel: 01727 857344.

DATA LOGGING METER

WAVETEK Meterman Test Tools latest DMM 38XR range offers optional real-time data logging by PC. The 38XR is a true r.m.s. meter which measures volts, amps and ohms, as well as temperature, capacitance, frequency and 4-20mA loop current percentage.

The clear 10,000 count display with 0·25% accuracy includes an analogue bargraph. Features include buttons for Min/Max/Avg, Data Hold, Peak Hold and Relative functions, as well as for a neon backlight for use in dim environments.

The meter can be used for data acquisition using any standard PC running Windows. The software stores data for retrieval and further analysis, including interfacing with Excel.

The Meterman 38XR is offered at a suggested retail price of £99.

For more information browse **www.metermantesttools.com** or email **info@metermantesttools.com**.

Constructional Project

PRACTICAL RADIO CIRCUITS

RAYMOND HAIGH

Part 1: Introduction, Simple Receivers and a Headphone Amp.

Dispelling the mysteries of radio. This new series features a variety of practical 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. And because it is so commonplace and affordable, it is accepted without a second thought. The millions who enjoy it, use it, even those whose lives depend upon it, often have little more than a vague notion of how it works.

This series of articles 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. And, with economy in mind, basic components and assemblies are repeated in different receivers.

MAKING WAVES

Radio uses electromagnetic waves to transport speech, music and data over vast distances at the speed of light.

The electromagnetic waves are generated by making an electric current oscillate at frequencies ranging from 10kHz (ten thousand Hertz) to more than 100GHz (one-hundred thousand million Hertz).

The lowest frequencies are used for submarine communications because of their ability to penetrate water to a considerable depth: the highest mainly for satellite communications. Most radio listeners are served by the portion of the spectrum extending from 150kHz to 110MHz.

Frequency of oscillation is measured in Hertz in honour of Heinrich Rudolf Hertz, the physicist who first demonstrated the existence of electromagnetic waves in 1886.

Before the valve era, radio frequency oscillations were generated by using an electrical discharge to shock-excite a tuned circuit (H. Hertz and G. Marconi), by the negative resistance of an electric arc (V. Poulsen), and by mechanical alternators (E. Alexanderson). Semiconductors now play an increasing role, but valves are still used in high-power transmitters.

As their name suggests, the waves comprise an electric and a magnetic field which are aligned at right angles to one another. The electric field is formed by the rapid voltage fluctuations (oscillations) in the aerial. Current fluctuations create the magnetic field.

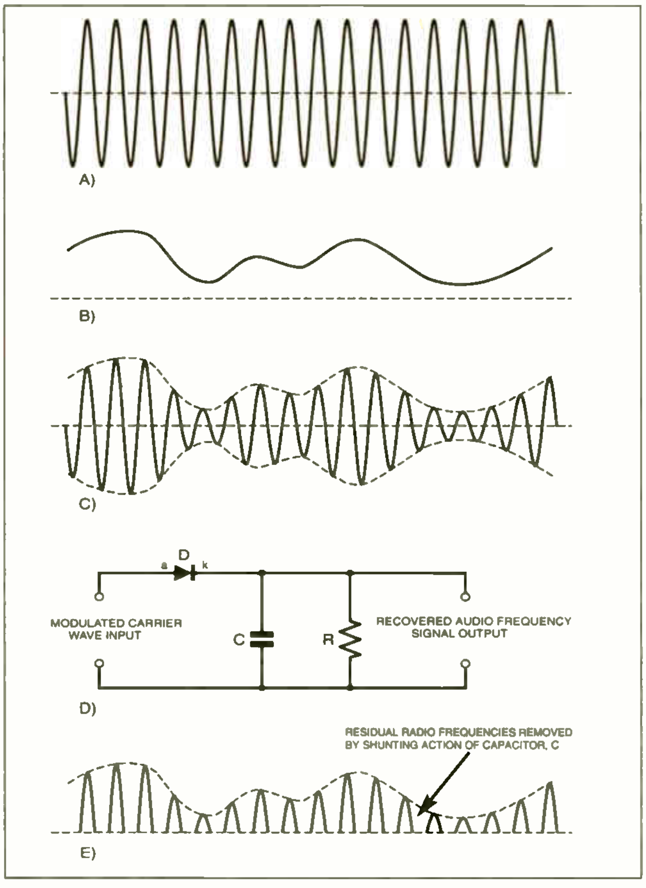


Fig.1.1. Modulation and detection: (A) Radio frequency carrier wave. (B) Audio frequency signal. (C) Carrier wave modulated by audio signal. Average value of imposed audio signal voltage is zero. (D) Diode detector, D, working into load resistor, R, rectifies the modulated carrier wave. Reservoir capacitor, C, removes residual radio frequencies and enables the audio frequency output voltage to approach its peak value. (E) Recovered audio frequency signal.

HITCHING A RIDE

Electromagnetic waves cannot, by themselves, convey any information. They are essentially ***radio frequency carriers***, and arrangements have to be made for the audio frequency speech and music signals to hitch a ride. This is done by modulating the radio frequency carrier with the audio frequency signals.

If the amplitude of the carrier is varied in sympathy with the signal, the process is known as *amplitude modulation* (a.m.), and typical waveforms are depicted in Fig.1.1. Varying the carrier frequency is, of course, known as *frequency modulation* (f.m.).

Marconi's Morse signals were transmitted by simply switching the carrier on and off. It was R. A. Fessenden who, in 1906, used a carbon microphone (said to be water cooled) to directly modulate the radio frequency (50kHz) output of an alternator and be the first to transmit speech and music.

PROPAGATION

The oscillations produced by the transmitter are fed to an aerial system in order to radiate the electromagnetic energy. The lower the frequency the longer the wavelength and the bigger the aerial.

Aerial designs vary, but the dipole adopted by Hertz in 1886 is still deployed at high, very high and ultra high frequencies. The elevated wire and earth arrangement used by Marconi in the 1890's is still used for the radiation of low and medium frequencies.

Transmitter powers range from the miserly one or two watts, radiated by amateurs who specialize in low power communication, to the two-million watts output from some medium wave broadcast transmitters.

Radiation from the transmitter reaches the receiver by either the ground wave (line of sight or diffraction around the earth's curvature), or the sky wave (reflected between the ionosphere and the surface of the earth. Propagation path is frequency dependant: by ground wave up to 500kHz, then gradually shifting to sky wave until, above 30MHz, the waves are no longer reflected back by the ionosphere and escape out into space.

Solar radiation has a profound effect on the charged particles which make up the ionosphere, and propagation conditions vary between night and day, seasonally, and according to the eleven-year sunspot cycle.

RECEPTION

Reception involves three essential functions: picking up the energy radiated by transmitters, selecting one station from all the rest, and extracting the modulation from the carrier wave in order to make the transmitted speech or music audible to the listener.

Signal Pick Up

Receiving aerials respond to either the electric or the magnetic field radiated by the transmitter. Sets that use telescopic rod or wire aerials pick up the electric field. Receivers that have loop aerials, i.e., a coil wound on a frame or a ferrite rod, respond to the magnetic field.

Portable receivers usually incorporate both: long and medium waves (150kHz to 1·6MHz) are covered by a loop with a ferrite rod core, and the v.h.f. f.m. band (88MHz to 108MHz) and shortwave bands by a telescopic aerial.

Station Selection

In order to select one station from the thousands that are spread across the radio frequency spectrum, the receiver has to be tuned to the carrier frequency of the transmitter.

Sir Oliver Lodge was stressing the importance of tuning, a condition he called "syntony", as early as 1889, and he patented his system in 1897. This is one of the most fundamental patents in radio, and his method is still universally adopted.

Lodge's invention exploits the way an inductor (coil) and capacitor combination resonate at a particular frequency. If the capacitor is connected in parallel with the inductor (see Fig.1.2a) the circuit presents a high impedance at its resonant frequency and a lower impedance at all others.

Connecting the capacitor in series with the inductor (Fig.1.2b) results in a low impedance at resonance and a higher impedance at other frequencies. If the inductor or the capacitor (usually the capacitor) is made variable, it is possible to tune the circuit across a range of frequencies.

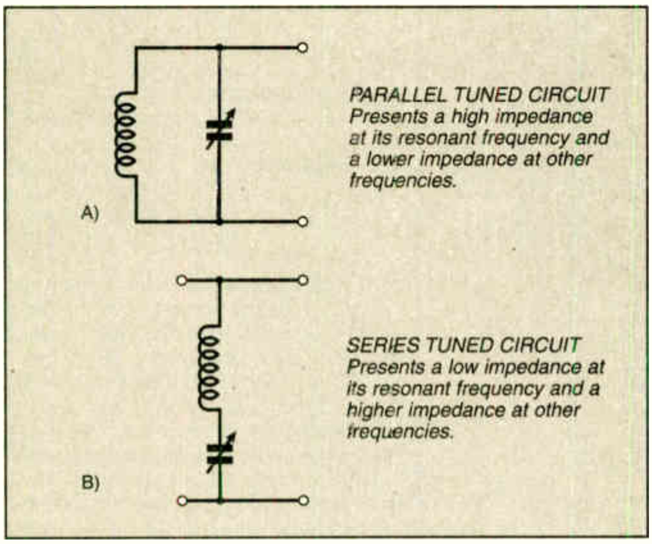


Fig.1.2. Basic tuned circuits. Combining an inductor (coil) and a capacitor produces a circuit which resonates at one particular frequency. The resonant frequency can be varied by changing the amount of inductance or capacitance (usually the latter). The tuning of all radio receivers and transmitters depends upon this phenomenon.

IMPORTANT EVENTS

1831
In published papers and a letter deposited with the Royal Society (opened in 1937), Michael Faraday tentatively proposes electromagnetic wave theory.

1864
James Clerk Maxwell's mathematical analysis of Faraday's work published in his paper: *A Dynamical Theory of the Electro-magnetic Field.*

1888
Heinrich Rudolf Hertz uses a crude spark transmitter and receiver to demonstrate the existence of electromagnetic waves.

1889
Sir Oliver Lodge lectures on the need to tune the transmitter to receiver, a condition he called "syntony".

1893
Sir Oliver Lodge uses an invention of Edouard Branley's as a sensitive detector of electromagnetic waves. (The coherer).

1901
Guglielmo Marconi transmits radio signals across the Atlantic.

1904
Sir John Ambrose Fleming patents the diode valve.

1906
Dr Reginald Fessenden modulates a carrier wave and broadcasts speech and music. Dr Lee de Forest makes a patent application for his triode valve, the first electronic amplifying device.

1913
Major Edwin Howard Armstrong invents the regenerative receiver.

1918
Armstrong invents the superheterodyne receiver.

1921
Armstrong invents the super regenerative receiver and W. G. Cady uses quartz crystals to stabilize oscillators.

1933
Armstrong demonstrates his system of frequency modulated radio transmission.

1947
John Bardeen, Walter Brattain and Dr William Shockley develop the transistor at the Bell Telephone Laboratories.

Sharpness of tuning depends mainly on resistive and other losses in the inductor or coil: the lower these losses the sharper the tuning. Resistive and dielectric losses in the capacitor also affect performance, but, with modern tuning components, these are usually so small they can be ignored.

The ability of the coil to resonate sharply, i.e., be more selective, is known as its "Q" factor: the sharper the resonance the higher the Q.

Resonant tuned circuits magnify signal voltages, a phenomenon that is crucial to radio reception. If a signal of the same frequency as the resonant frequency of the tuned circuit is applied to the coil/capacitor combination, its voltage will be increased in proportion to the Q of the coil. With a Q of 100, a 1mV signal will be magnified to 100mV or 0·1V. We will be returning to this later.

Demodulation

With amplitude modulated signals (a.m.) the process of recovering the modulation is essentially one of rectification. In Fig.1.1d, diode, *D*, rectifies the incoming radio frequency carrier wave and capacitor, *C*, shunts residual radio frequencies to ground (earth) leaving only the audio frequency modulation. Capacitor, *C*, also exhibits a reservoir action enabling the audio frequency voltage to approach its peak value.

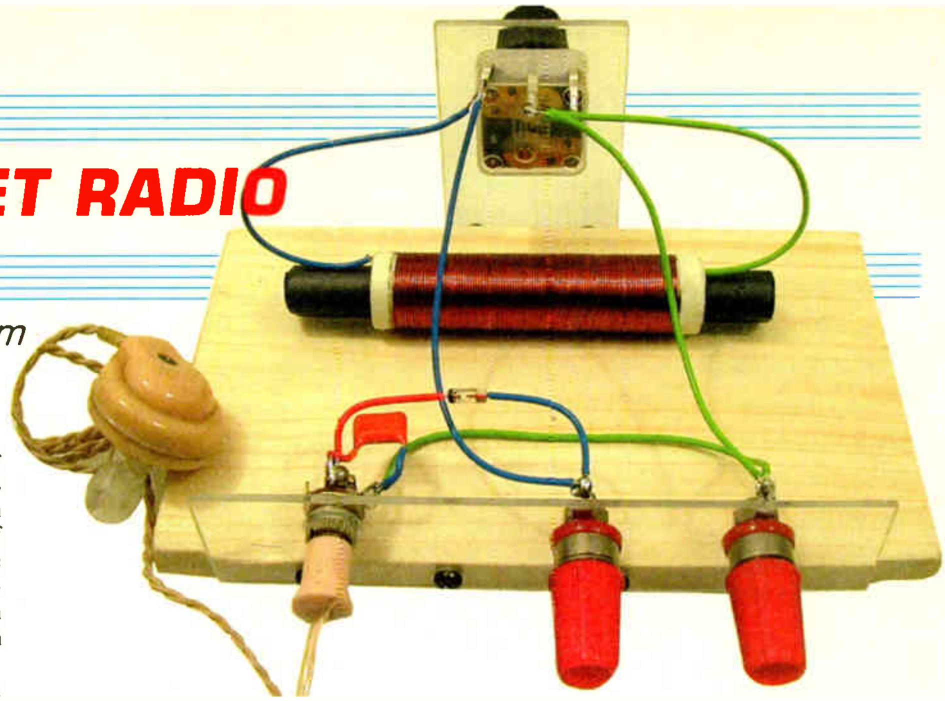
The diode and, indeed, any other a.m. demodulator, is called a *detector*, a hang-over from the earliest days of radio when glass tubes filled with metal filings were used to simply detect the presence of electromagnetic waves.

In 1889, whilst working on the protection of telegraph equipment from lightning, Sir Oliver Lodge noticed that metal surfaces, separated by a minute air gap, would fuse when an electrical discharge occurred close by. He used the phenomenon to detect electromagnetic waves, and called devices of this kind *coherers*.

About this time, Edouard Branley discovered that a spark in the vicinity of a mass of metal particles lowered their resistance. Lodge found this arrangement to be more sensitive and, in 1893, adapted it for use as a detector.

Subsequently, J. A. Flemming's diode valve, patented in 1904, and crude semiconductor devices, were used as rectifiers in order to demodulate signals.

CRYSTAL SET RADIO



The author's Crystal Set "knock-up" on a wooden baseboard. This uses two screw terminals for the Aerial and Earth wire connections instead of croc. clips.

A modern-day "museum piece" receiver

THE CAT'S WHISKER

The most popular of the semiconductor detectors was the "crystal" or "cat's whisker" which consisted of a short length of springy brass wire touching a crystal of galena (lead sulphide). Adjustment of the point of contact was critical, but these crystal detectors could be more sensitive than Flemming's diode valve. They were much less expensive.

The modern equivalent of the crystal detector is the point contact germanium diode. Here, a gold-plated wire contacts a wafer of germanium, the assembly being enclosed within a glass tube. These diodes are still used to demodulate the signals in most domestic a.m. radios.

CRYSTAL SET

The simplest receiver, known as a *Crystal Set*, consists of nothing more than a coil, tuning capacitor, diode detector, and a pair of earphones.

A typical circuit diagram for a Crystal Set Radio is given in Fig.1.3, where inductor or coil L1 is tuned by variable capacitor VC1 to the transmitter frequency. Diode D1 demodulates the signal, which is fed straight to the earphones. There is no amplification.

A long (at least 20 metres), high (7 metres or more) aerial and a good earth (a buried biscuit tin or a metre of copper pipe driven into damp ground) are required in order to ensure audible headphone reception. The earphones originally used with these receivers had an impedance of around 4000 ohms and were very sensitive (and heavy and uncomfortable). They are no longer available, but a crystal earpiece, which relies on the piezoelectric effect, will give acceptable results. Low impedance "Walkman" type earphones are *NOT* suitable.

DRAWBACKS

Quite apart from the absence of amplification, two factors seriously limit the performance of crystal receivers.

Germanium diodes become increasingly reluctant to conduct as the applied voltage falls below 0·2V, and this makes the receiver insensitive to weak signals. Silicon diodes have a threshold of around 0·6V, and are, therefore, unsuitable for circuits of this kind.

The earphone loading imposes heavy damping on the tuned circuit, reducing its *Q* and, hence, its selectivity, i.e. its ability to separate signals. With such low selectivity insensitivity can be a blessing, and crystal sets are normally only capable of receiving a single, strong transmission on the long and medium wavebands. (They will sometimes receive more than one if a shortwave coil is fitted).

The aerial and diode can be connected to tappings on the tuning coil in order to reduce damping, but the improvement in selectivity is usually at the expense of audio output.

When valves cost a week's wages and had to be powered by large dry batteries and lead/acid accumulators, the construction of simple receivers of this kind could be justified. With high performance transistors now costing only a few pence or cents, crystal sets are now regarded as "nostalgic pieces".

Some readers may, however, wish to build one out of curiosity, or for the novelty of having a receiver that does not require a power supply. Moreover, the components required are all used in more complex receivers to be described later.

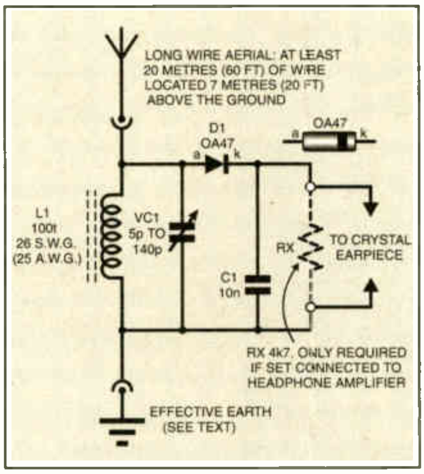


Fig.1.3. This simplest of radio receivers uses a germanium diode as the "cat's whisker" crystal detector.

CIRCUIT DETAILS

Ferrite loop aerial L1 and polythene dielectric variable capacitor VC1 form the tuned circuit. Point contact germanium diode D1 demodulates the signal; capacitor C1 bypasses residual r.f. (radio frequencies) to earth and also exhibits a reservoir action, enabling the a.f. (audio frequency) output to approach its peak value. The recovered audio signal is fed directly to a crystal earpiece.

Signal voltages induced in the ferrite loop aerial by the radiated magnetic field are much too weak to produce an output from the detector, and the component is used here simply as a tuning coil. The ferrite core does, however, reduce the number of turns required for the coil winding, thereby reducing its resistance and increasing its *Q* factor.

COMPONENTS

CRYSTAL SET

Resistor

RX	4k7 0·25W 5% (only required if set is connected to amplifier)

Capacitors

C1	10n disc ceramic.
VC1	5p to 140p (minimum) polythene dielectric variable capacitor (see text)

Semiconductors

D1	0A47 germanium diode

Miscellaneous

L1	ferrite rod, 100mm (4in.) x 9mm/10mm (3/8in.) dia., with coil (see text)

Crystal earpiece and jack socket to suit.; plastic control knob; plastic insulated flexible cable for aerial wire, downlead and earth connection, 30 metres (100 ft) minimum; buried biscuit tin or 1 metre (3ft) of copper pipe for earth system; 50gm (2oz) reel of 26s.w.g. (25a.w.g.) enamelled copper wire, for tuning coil; card and glue for coil former; multistrand connecting wire; crocodile clips or terminals (2 off), for aerial and earth lead connection; solder etc.

Approx. Cost Guidance Only **£4** *excl. earpiece & wire*

CONSTRUCTION

The circuit is simple enough to be assembled on the work bench, and a printed circuit board layout is not given. The components and the various interwiring connections are illustrated in Fig.1.4.

COIL DETAILS

Full construction and winding details for the ferrite tuning/aerial coil L1 are shown in Fig.1.5. The coil is made from 26s.w.g. (25a.w.g.) enamelled copper wire, close wound on a cardboard former. This same ferrite tuning coil forms the loop aerial in the following TRF Receiver.

The r.f. bypass capacitor C1 can, in practice, be omitted with no noticeable reduction

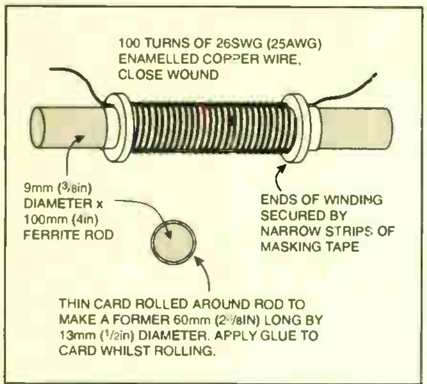


Fig.1.5. Construction and winding details for the ferrite rod tuning/aerial coil L1. This loop aerial is also used in the TRF Receiver.

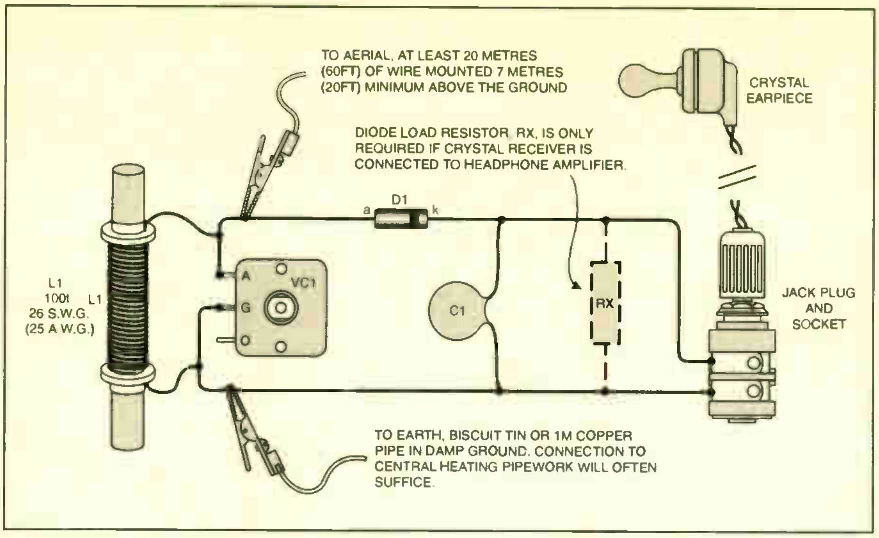


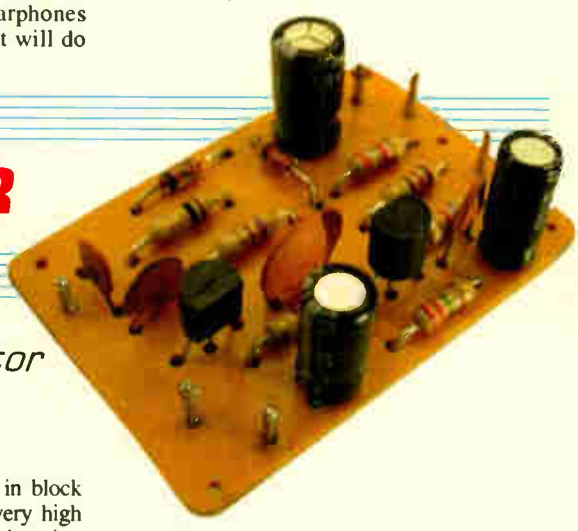
Fig.1.4. The components and various interwiring connections for the simple crystal set. This circuit is easily "lashed-up" on the workbench and no circuit board layout is given. The author's demonstration set is shown in the heading photograph.

in performance. However, if the set is to be connected to either the headphone amplifier (Fig.1.10) or speaker amplifier described next month, this component, together with diode load resistor, RX, must be included.

AMPLIFICATION

Audio frequency amplification ***after*** the diode detector will permit the use of low impedance Walkman type earphones or even loudspeaker operation. It will do nothing, however, to overcome the diode's insensitivity to weak signals. For this we must have radio frequency amplification of the signals picked up by the aerial ***before*** they reach the detector. (The standard circuit for a transistor portable receiver has three stages of radio frequency amplification ahead of the diode).

MK484 TRF RECEIVER



Uses a single i.c. radio chip and a transistor

TRF RECEIVER

Receivers with tuned circuits and amplification, at signal frequency, ahead of the detector stage were known, during the valve era, as tuned radio frequency, or t.r.f., receivers.

This arrangement was adopted by Ferranti when they designed their popular ZN414 radio i.c. Introduced in 1972, the chip relied upon a then new manufacturing technique developed by Bell Laboratories and known as collector diffusion isolation.

No bigger than a single transistor, and requiring a power supply of only 1·5V, the device enabled truly miniature receivers to be built, one of which was featured on the BBC TV science programme, *Tomorrow's World*. The chip is still produced, but in a plastic package instead of the original metal case and with the type number ***MK484***.

MK484 Specification . . .

Supply Voltage (via external load resistor)	1·1V to 1·8V
Current Drain (affected by signal level)	0·3mA to 0·5mA
Frequency range (peaks at 1MHz)	150kHz to 3MHz
Input Impedance	1·5 megohms
Output Impedance	500 ohms
Sensitivity	better than 100μV
Power Gain	70dB
Internal Component Count:	10 Transistors 15 Resistors 4 Capacitors

INTERNAL ARRANGEMENT

The chip's internal architecture, in block form, is depicted in Fig.1.6. The very high impedance input stage minimizes damping on the tuned circuit, enabling it to maintain a high Q factor and, consequently, reasonable selectivity. This is followed by three stages of radio frequency amplification ahead of a two transistor detector or demodulator.

Chip characteristics and pinout details are also listed with the block diagram Fig.1.6. Internal capacitors impose the low frequency operating limit, and the performance of the transistors determines the tail-off at high frequencies.

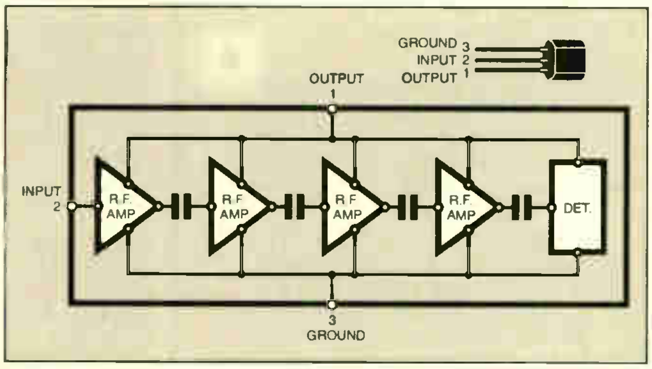


Fig.1.6. Block diagram showing the internal arrangement of the MK484 radio i.c.

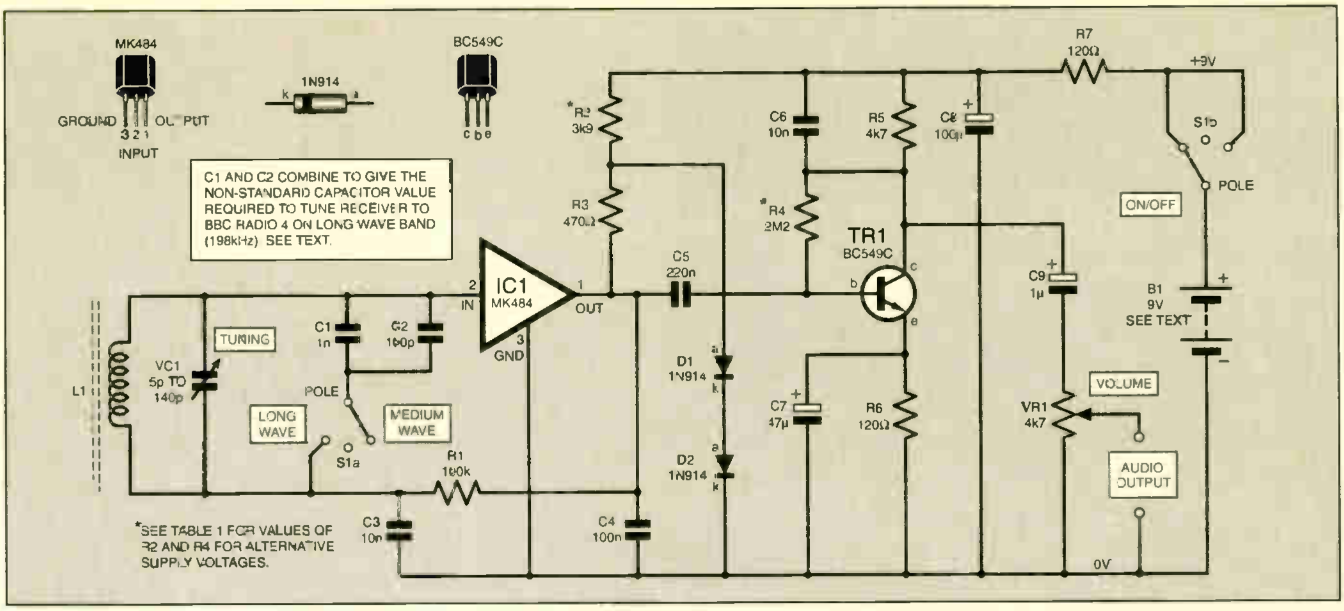


Fig.1.7. Complete circuit diagram for the MK484 TRF Receiver.

TRF CIRCUIT

The circuit diagram for a simple TRF Receiver using the MK484 i.c. is given in Fig.1.7. Inductor or coil L1 is "tuned" by variable capacitor VC1, from roughly 550kHz to 1·7MHz, i.e., over the medium wave band.

Provision is made for toggle switch S1a to connect an additional capacitor across L1 to tune it to a lower frequency long wave station. For *BBC Radio 4* on 198kHz, a non-standard component is required, and this is made up from capacitors C1 and C2.

Tuning coil L1 is wound on a ferrite rod in order to form a loop aerial which, as we have seen, responds to the magnetic fields radiated by transmitters. The high permeability ferrite material concentrates the lines of magnetic force, and the signal developed across the coil is equal to that picked up by an air-cored loop of around 200mm (8in.) diameter. The threshold sensitivity of IC1 is better than 100µV, and this is sufficient for the reception of strong signals via the loop.

SELECTIVITY

Current drawn by IC1 increases as signal strength increases, and the gain of the MK484 is supply voltage dependant. Connecting all of the stages to the supply via the audio load resistor R3 produces a measure of automatic gain control (a.g.c). (Increased current demand at high signal levels increases the voltage drop across the load resistor thereby reducing the gain of the chip.) IC1 input pin 2 is biased via resistor R1, and r.f. bypass capacitors C3 and C4 ensure stability.

The value of the audio load resistor (sometimes called the a.g.c. resistor) R3 can range from 470 ohms to 1000 ohms. Selectivity is better when the value is kept low: gain is greater when the value is high. Most readers will need all the selectivity they can get and a 470 ohm resistor is used in this circuit.

Optimum supply voltage with a 470 ohm load is around 1·2V: more than this can cause instability problems, less will reduce gain. The voltage delivered by a fresh dry cell can be as high as 1·7V and the chain of silicon diodes, D1 and D2, each of which begins to conduct at a 0·6V threshold, holds the supply at the correct potential.

Some readers will no doubt wish to use the circuit with different supply voltages, and the value of dropping resistor R2 should be altered to avoid excessive current drain. Table 1.1 gives suitable values for this resistor for various battery voltages.

AUDIO OUTPUT

The output from IC1 pin1 is low, so the audio amplifier stage, TR1, is included to increase it to a useable level. The signal from IC1 pin 1 is applied to TR1 base (b) via d.c. blocking capacitor C5, and the output is developed across collector (c) load resistor R5.

Emitter (e) bias is provided by resistor R6 which is bypassed by capacitor C7. Base bias is derived via resistor R4. Connecting this resistor to the collector rather than the supply rail provides a measure of negative feedback, stabilizing the stage against temperature and transistor gain variations. The value of this resistor has to be optimized for different supply voltages, and appropriate values are given in Table 1.1.

Table 1.1: MK484 TRF Receiver
(Values of resistors R2 and R4 for different supply voltages)

Voltage	*R2*	*R4*
1·5V	100Ω	180k
3V	1k	1M
4·5V	1k8	2M2
6V	2k2	2M2
9V	3k9	2M2

COMPONENTS

Approx. Cost Guidance Only **£10**
excl. case, earpiece, wire & batt.

TRF RECEIVER

Resistors

R1	100k
R2	3k9 see Table 1.1
R3	470Ω
R4	2M2 see Table 1.1
R5	4k7
R6, R7	120Ω (2 off)

All 0·25W 5% carbon film

Potentiometers

VR1	4k7 rotary carbon, log.

Capacitors

C1	1n polystyrene (see text)
C2	100p polystyrene or "low k" ceramic (see text)
C3, C6,	10n disc ceramic (2 off)
C4	100n disc ceramic
C5	220n disc ceramic
C7	47µ radial elect. 16V
C8	100µ radial elect. 16V
C9	1u radial elect. 16V
VC1	5p to 140p (minimum) polythene dielectric variable capacitor

Semiconductors

D1, D2	1N914 silicon signal diodes (2 off)
TR1	BC549C *npn* small signal transistor
IC1	MK484 radio i.c.

Miscellaneous

S1	d.p.d.t. centre-off toggle switch
L1	ferrite loop aerial: 100mm (4in.) x 9mm/10mm (3/8in.) dia. ferrite rod with coil (see text)

Printed circuit board available from the *EPE PCB Service*, code 392; plastic case, size and type to choice; plastic control knob (2 off); 50gm (2oz) reel of 26s.w.g. (25a.w.g.) enamelled copper wire, for tuning coil; card and glue for coil former; crystal earpiece and jack socket to suit; multistrand connecting wire; 9V battery, clips and holder; p.c.b. stand-off pillars; mounting nuts and bolts; solder pins; solder etc.

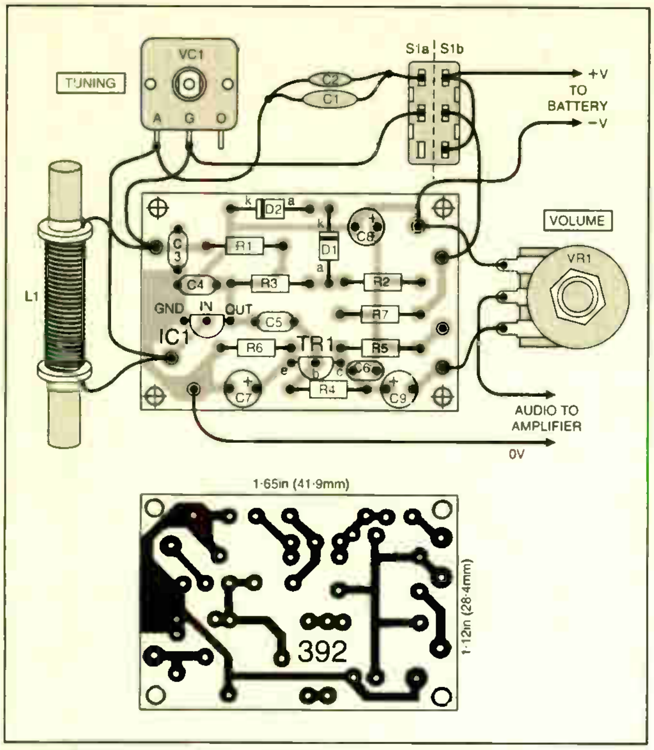


Fig.1.8. Printed circuit board component layout, interwiring to off-board components and full-size underside board copper track master.

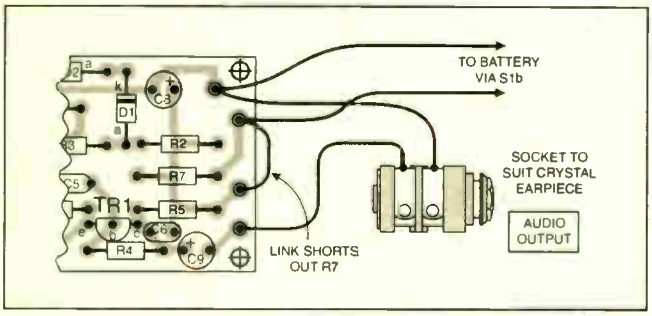
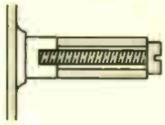


Fig.1.9. Connecting a crystal earpiece, via socket, directly to the p.c.b. in place of the Volume control. Note the "shorting" link wire.

VARIABLE CAPACITORS

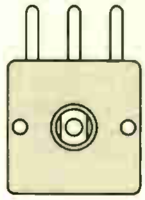
(Polythene dielectric type)

Some retailers supply extenders for the stubby spindle. If an extender has to be fabricated, use a 6mm diameter tubular stand-off bolted to the central hole in the spindle (bolt is usually 2mm). Grip the capacitor spindle when tightening bolt. **Do not tighten against internal end stop.**



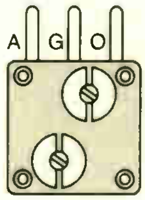
Secure capacitors to bracket or front panel with two bolts driven into threaded holes in its front plate. **Bolts** (usually 2mm) **must not extend through the thickness of the front plate.**

Twin-gang capacitor lead-outs are usually thin metal strips. Moving vanes (the strip often marked 'G') should be connected to ground or the 0V rail. Strips for the fixed vanes, normally used to tune the aerial and oscillator circuits in a superhet receiver, are often marked "A" and "O". One or both should be connected to the "hot" end of the simple receiver's tuning coil.



Internal trimmers should be set to minimum capacitance when a variable is used with simple receivers. Twin-gang polyvaricons have two trimmers. Four-gang units have four trimmers.

For complete coverage of the medium wave band with this ferrite loop aerial, the variable capacitor should have a 5pF minimum capacitance and a maximum capacitance of at least 140pF. The aerial tuning section of most polythene dielectric variables, as used in transistor portables, should be suitable.



If necessary, both sections (aerial and oscillator) can be connected in parallel to ensure the necessary maximum capacitance. This will, however, double the minimum capacitance and slightly curtail coverage at the high frequency end of the band.

Headphone and loudspeaker amplifiers will, in most cases, be connected across the same battery power supply, and resistor R7 and capacitor C8 decouple the tuner circuit in order to prevent instability. Bypass capacitor C6 connected across collector load R5 is also included to avoid instability. Audio output is taken from the collector of transistor TR1 and connected to the Volume control VR1, via d.c. blocking capacitor C9.

A crystal earpiece can be connected in place of the volume control but the output, especially when weaker signals are being received, will be barely adequate. With this arrangement there is no need for resistor R7, and provision is made, on the printed circuit board, for it to be shorted out (see Fig.1.9).

CONSTRUCTION

If you have not already made up the "tuning coil" for the Crystal Set, construction of the TRF Receiver should commence with the winding of the ferrite loop aerial as detailed earlier in Fig.5 and as follows. Wind thin card (a postcard is ideal) around a 100mm (4in.) length of 9mm (3/8in.) diameter ferrite rod until an overall diameter of 13mm (1/2in.) is achieved. Apply adhesive as the card is wound on.

Coil L1 consists of 100 turns of 26s.w.g. (25a.w.g.) enamelled copper wire close wound, i.e. with turns touching. Secure the start and finish of the winding with thin strips of masking tape wound tightly around the former. The task of producing a neat coil can be eased by slightly spacing the turns as they are wound on and repeatedly pushing them together with the thumb as the winding proceeds.

The inductance of this loop winding is higher than normal in order to ensure full Medium Wave coverage with the specified tuning capacitor (medium wave loops usually comprise about sixty turns on a 9mm (3/8in.) dia. rod). Longer rods, which will increase signal pick-up, may be used if a larger receiver can be tolerated.

Use rubber bands, strips of card or wood or plastic blocks to secure ferrite loop aerials. Do not use metal mounts as these can form a shorted turn and dramatically reduce efficiency.

RECEIVER BOARD

Most of the TRF Receiver components are assembled on a small printed circuit board (p.c.b.). The topside component layout, off-board interwiring and a full-size underside copper foil master are shown in Fig.1.8. This board is available from the *EPE PCB Service*, code 392. How to connect an earpiece directly to the Receiver p.c.b. is illustrated in Fig.1.9.

Insert and solder in position the resistors and capacitors first and the semiconductors last. The 3-pin MK484 radio i.c. must be mounted close to the board to prevent instability: leave just sufficient lead length for the application of a miniature crocodile clip as a heat shunt whilst soldering.

Take care to remove all traces of the enamel from the ends of the coil winding in order to ensure a good connection. Solder pins, inserted at the lead-out points, will simplify the task of off-board wiring.

HEADPHONE AMPLIFIER

Add-on amplifier for personal listening

The single transistor Headphone Amplifier circuit illustrated in Fig.1.10, will ensure an acceptable output via Walkman type 'phones. The audio input signal is coupled to the base of transistor TR1 via d.c. blocking capacitor C1. Base bias resistors R1 and R2, fix the standing collector current at around 4mA. Emitter bias is provided by R3, which is bypassed by C3.

Walkman type 'phones form transistor TR1's collector load, both earpieces being wired in series to produce an impedance of 64 ohms. Bypass capacitor C2 acts as a high frequency shunt across the 'phone leads. This measure avoids instability problems and is particularly necessary when the amplifier is used with some of the more sensitive receivers to be described later in the series.

Bypass capacitor C4 ensures stability when tuner and amplifier stages are powered by the same battery, particularly when battery impedance rises as it becomes exhausted. On/off control, S1b, is one half of a two-pole, centre-off, toggle switch.

CONSTRUCTION.

All parts, except the 'phone socket and battery, are assembled on a small p.c.b. and the component layout, off-board wiring and full-size copper foil master are given in Fig.1.11. This board is available from the *EPE PCB Service*, code 393.

Follow the assembly sequence suggested for the TRF radio board. Again, solder pins at the lead-out points will ease the task of off-board wiring.

Wiring the output to the tip and centre ring on the jack socket will result in the series connection of the earpieces and produce a nominal 64 ohm load for transistor TR1.

SPOT CHECKS

Check the two p.c.b.s for poor soldered joints and bridged tracks. Check the orientation of electrolytic capacitors and semiconductors.

Make sure the off-board wiring has been correctly routed and, if all is in order, connect the battery power supply. Current consumption of the tuner/amp with a 9V supply and resistors R2 and R4 as specified in Table 1.1 should be approximately 2·5mA.

Readers who are keen to minimize battery drain could reduce bias resistor, R2, in Fig.1.10. to 4·7kΩ or less. This will lower the standing current drawn by the Headphone Amplifier at the expense of maximum undistorted output.

The add-on amplifier stage will permit low-impedance Walkman type 'phones to be used with the Crystal Set (Fig.3). A Volume control is unnecessary: simply connect a 4700 ohm resistor (RX) to act as a diode load in place of the 'phones, and link receiver to amplifier via d.c. blocking capacitor, C1.

COMPONENTS

HEADPHONE AMPLIFIER

Resistors

R1	39k	See SHOP TALK page
R2	5k8 (see text)	
R3	150Ω	

Capacitors

C1	1µ radial elect. 16V
C2	100n disc ceramic
C3	47µ radial elect. 16V
C4	100µ radial elect. 16V

Semiconductors

TR1	BC549C *npn* small signal transistor

Miscellaneous

S1	d.p.d.t. centre-off toggle switch (see text)

Printed circuit board available from the *EPE PCB Service*, code 393; jack socket to suit 'phones; multistrand connecting wire; 9V battery, clips and holder; p.c.b. stand-off pillars; solder pins; solder etc.

Approx. Cost Guidance Only **£6** *excl. 'phones*

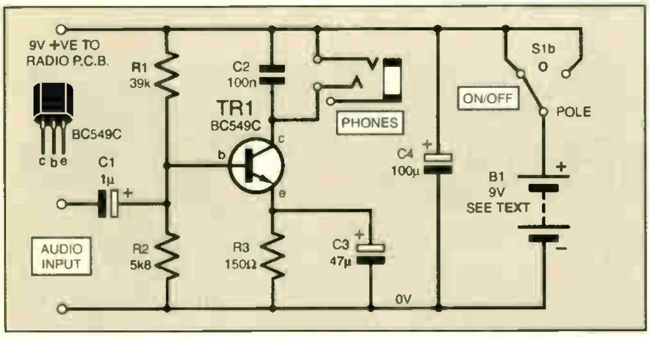


Fig.1.10. Circuit diagram for a single transistor Headphone Amplifier.

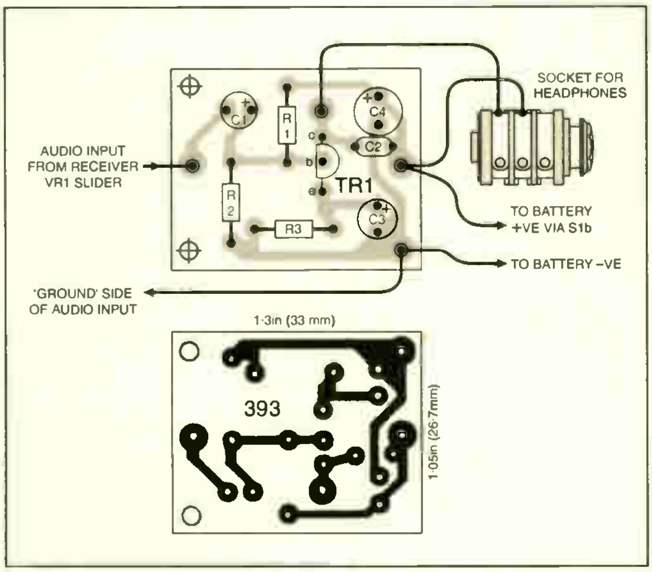


Fig.1.11. Headphone Amplifier printed circuit board component layout, wiring details and full-size copper foil master.

PERFORMANCE

Performance of the MK484 TRF Receiver and Headphone Amplifier combination is far superior to the simple Crystal Set. The MK484 is, moreover, sufficiently sensitive to operate from a ferrite-cored loop and an external wire aerial and earth are not required.

Selectivity is barely adequate, and very powerful signals tend to spread across the dial. Rotating the ferrite loop aerial to null out the offending station will, however, usually effect a cure. (Loop aerials are directional and signal pick-up falls to a minimum when the axis of the coil is pointing towards the transmitter).

Although the circuit will permit the clear reception of a number of stations, sensitivity is not sufficient for the reception of weak signals. A simple add-on circuit, which will transform the performance of the receiver and make it as selective and sensitive as a commercial superhet, will be described next month.

Next month's article will also include an amplifier for readers who want loudspeaker operation, and a design for another simple, but high performance, medium and long wave receiver using individual transistors.

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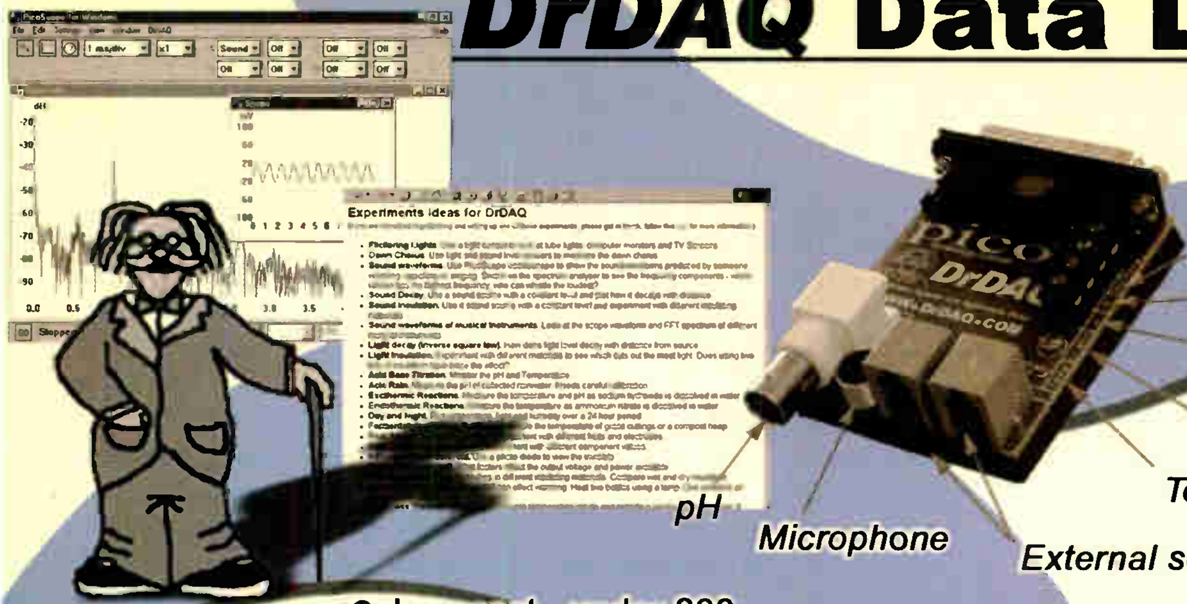

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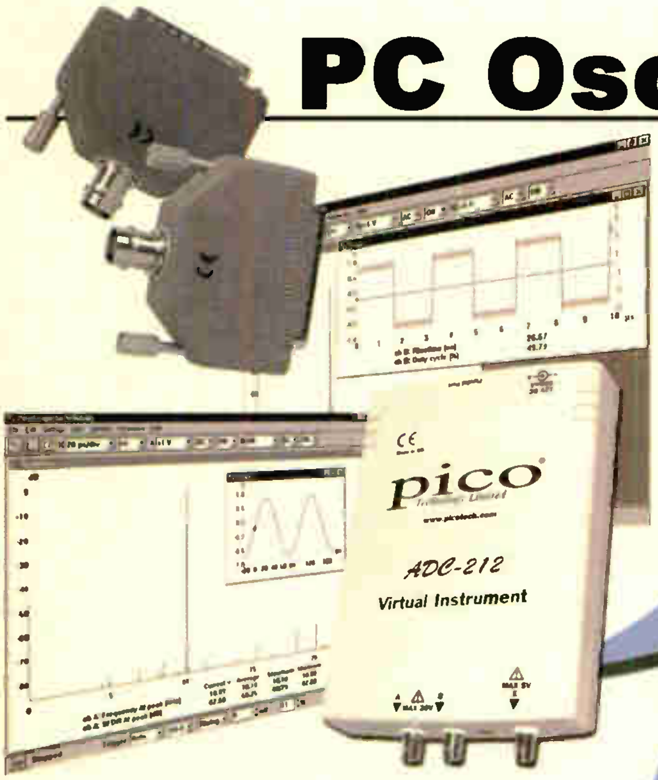

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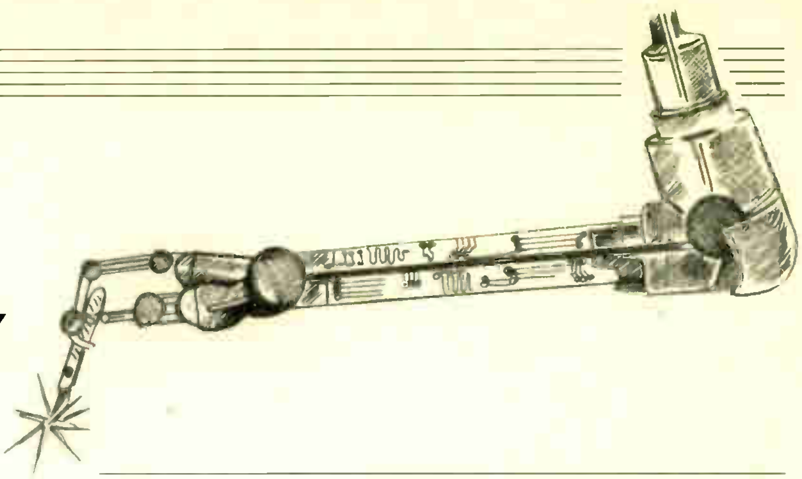


ALAN WINSTANLEY and IAN BELL

We round off our three-part mini series showing beginners how to read circuit diagrams.

IN the April and May issues we outlined the technique that every electronics enthusiast needs in order to be able to read a circuit diagram. We looked at basic schematic symbols for passive and semiconductor devices, and we also showed you how to compare transistor and diode symbols against their physical counterparts.

We round off this mini guide with a look at integrated circuits and last but not least, methods of depicting power rail connections. Earth, bus, ground, chassis – what do all these terms mean? Read on!

A Chip Off The Block

These days, integrated circuits (i.c.s) are fundamental to the majority of *EPE* constructional projects, but even the most sophisticated of microcontroller device, such as the popular PICmicro family that are used in almost all of our micro projects, can be drawn in our circuit schematics very simply as a box!

Almost every i.c. package, with the exception of voltage regulator i.c.s and some specialist devices, contains at least eight pins: a modern microprocessor for a PC contains many hundreds of pins - and millions of miniature transistors inside! Circuit diagrams typically show just a simple box outline together with a pin number.

As an example of how i.c.s are shown in schematic diagrams, the 555 timer is shown in Symbol File-4 of Fig.1. Notice how the pin's functions are also labelled (often using shorthand that is puzzling to the inexperienced constructor), but on more complex circuit diagrams there may not be room to show this information. If we want to know what's actually inside the device, we could refer to a manufacturer's data sheet, but for many purposes it's all right just to treat the device as a building block.

Our very simple "circuit diagram" of Fig.1, April '03 p263, holds true for depicting the use of integrated circuits. Each i.c. pin has a unique number, and we draw solid lines showing how each pin is wired to the rest of the circuitry. Sometimes, if a pin is to be left unconnected, you may see the letters "n.c." for "no connection" used. Otherwise, the pin may not be shown at all.

In the case of, for example, logic gates, it is common to separate out the individual gates and label them individually. A good example was shown in Fig.1, May '03 p334 – it shows two logic i.c.s (IC2, IC4) and a separate NAND logic gate that is part of a 74LS00 i.c.; hence the NAND gate's pins are numbered to correspond with the dual-in-line package numbering scheme. Note, however, that the NAND chip's essential power supply rails were not included (see later).

Pinout data for chips can be obtained by searching manufacturers' web sites including Philips Semiconductors (**www-eu.semiconductors.philips.com**) and Texas Instruments (**www.ti.com**).

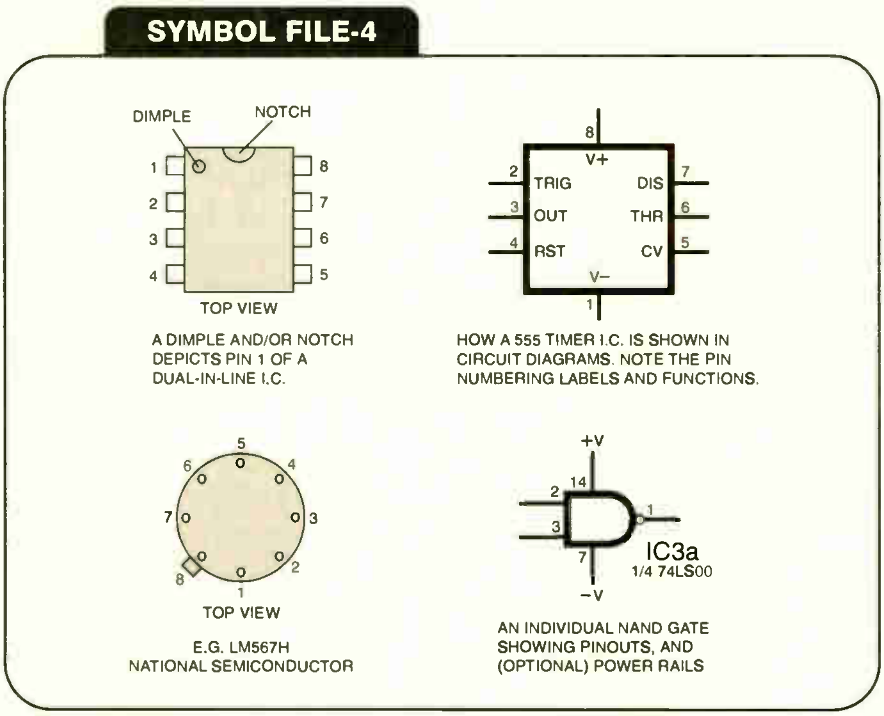


Fig.1. A comparison of integrated circuit (i.c.) styles and pinout information in circuit diagrams.

Identity Parade

As for identifying which way round an i.c. is connected, note that all dual-in-line (d.i.l.) chips follow a standard scheme, but unlike pinouts for transistors or l.e.d.s (which are always viewed from below), we show an **aerial view** of integrated circuits. The location of pin 1 can always be derived from a notch or a circular mark (or both) moulded into the i.c. package, and the rest of the pin numbers follow a standard pattern from there.

In some cases, alternative packages are used including TO5 metal can i.c.s, and it is best to consult manufacturer's datasheets to confirm the pinout details. There are other types of flat-pack i.c. available in industry that use complex multi-pin surface mount techniques, which won't be discussed further here.

Board the Bus

As you may imagine, when there are many i.c.s in a circuit schematic then the interwiring can become highly complicated, to the point that it becomes pointless trying to draw every line. When data has to be shifted or output by i.c.s. the data is transported by a "bus" – if the data is 8 or 16 bits wide or more, then in order to avoid drawing a rat's nest of lines in a circuit diagram, a wider line may be drawn, with pinout information being derived from the schematic as shown in Fig.2, which was part of our 6502 Micro Lab microprocessor trainer published in 1993. The pins of the microprocessor feed into a bus, the other end of which feeds into individual pins of the target component. Like-named pins are connected on each i.c.

Power Play

This brings us to the final aspect of drawing circuit diagrams and the methods depicting the *power rails*. These days, a computer-aided design (CAD) package is often used to simulate circuits on-screen and also to produce schematics and p.c.b.s.

The CAD program already "knows" the pinouts of each device drawn into the circuit diagram. The designer can therefore draft a diagram to depict how the components should be wired together, which creates a *netlist* (computerised p.c.b. data describing which components are connected where).

Using the netlist, p.c.b. software can then route a p.c.b. foil design, because the program also "knows" the *physical shape and pinout* of each device used. Unfortunately for us, the power supply details are often hidden in the background when circuits are drawn with CAD packages. The software knows the power connections needed for each i.c., so it does not show them in the schematic.

However, in the drawings used in *EPE*, supply rails are always shown clearly, and we include the power supply rails for individual logic gates etc. as well; usually, one gate is shown wired across the power supply (e.g. the NAND gate in Symbol-File 4 shows the power rails for the entire 74LS00 chip – all four gates being powered through this connection).

Down to Earth

The automatic assumption of power supply rails can also be seen in more basic circuit diagrams, and it can cause an awful lot of confusion for beginners. The author recalls how, as a young enthusiast, he was fascinated by American text books on hobby electronics, but it was very strange to see how even the most trivial battery circuit appeared to be connected to earth (called "ground" in the USA and elsewhere). Why would a battery circuit need to be earthed?

In order to avoid cluttering circuit diagrams with "unnecessary" lines, one of the power supply rails (almost always 0V) can be omitted, and instead a ground symbol is used. In Fig.3 an example circuit uses the earth symbol to show how those components are actually to be connected to 0V. In automotive circuit diagrams, the chassis of the vehicle is usually wired to the negative battery terminal, and it is very common to therefore use ground or chassis symbols throughout the circuit to depict a chassis connection. Strictly speaking, a chassis symbol is used to show a *physical connection* to the metal frame of an apparatus or a vehicle, whilst a ground symbol is used to denote a common connection (usually a 0V rail). *A.R.W.*

- The component photos used in this mini series are included on the author's CD-ROM *Electronic Components Photos Vol. 1* available from *EPE*. It is ideal to help with presentations, catalogues, tutorials, projects etc. – see the *EPE Electronics CD-ROM* advertisement and order form elsewhere in this issue.

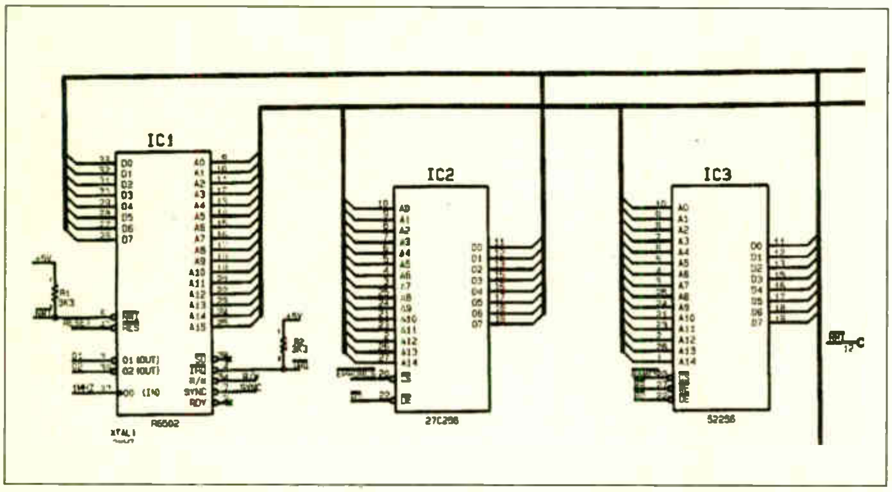


Fig.2. A typical example of how complex data buses might be shown on schematic diagrams.

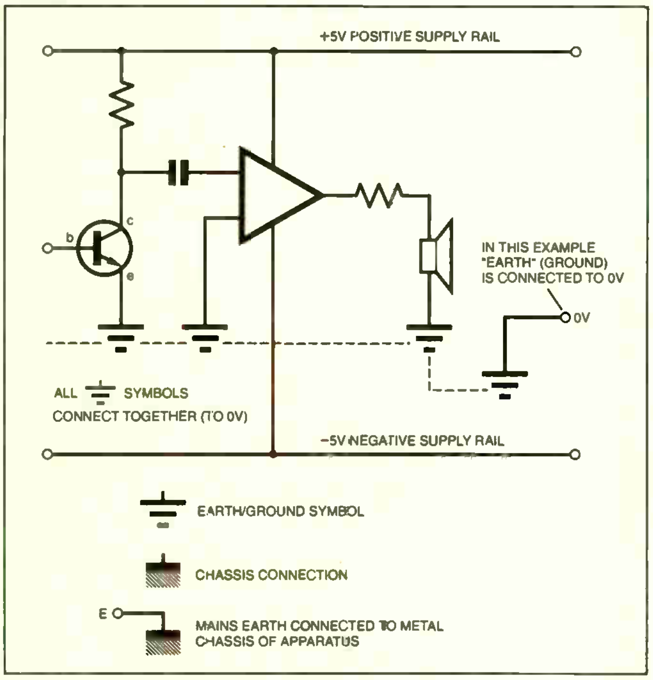
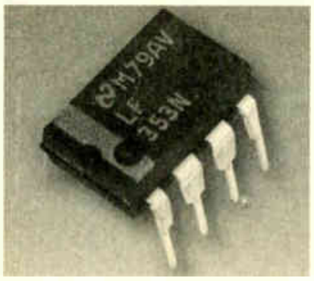
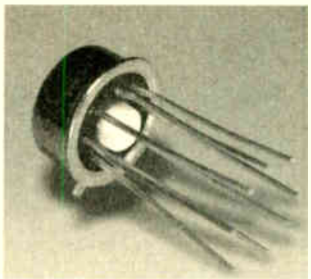


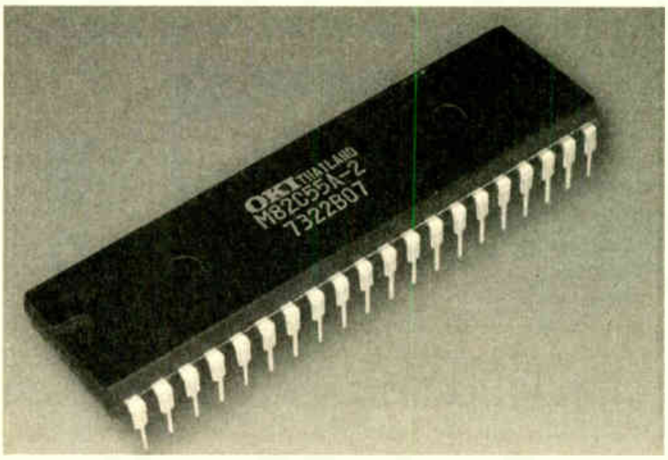
Fig.3. The use of ground and chassis symbols helps to avoid cluttering circuit diagrams with unnecessary lines.



8-pin i.c. (d.i.l.) package.



TO5 metal can package i.c.



40-pin dual-in-line (d.i.l.) plastic package i.c.

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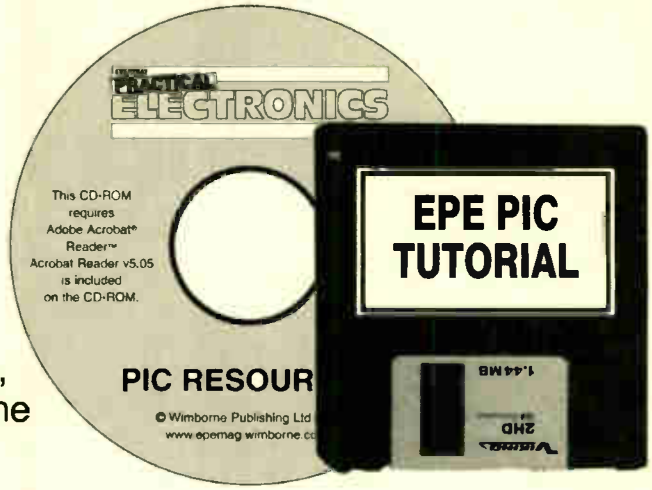
EPE PIC TUTORIAL V2

JOHN BECKER PART THREE

Quite simply the easiest low-cost way to learn about using PIC Microcontrollers!



In this final part we look at some of the more sophisticated aspects of using PICs, and highlight some differences between the '84 and the '87x and '62x families.

REFERRING back to Listing 30 and Program TK3TUT30 of Part 2 last month, we continue examining the program for a 24-hour clock displayed on an alphanumeric l.c.d.

TIME OUT TO L.C.D.

As with 7-segment l.e.d. clock counting routines, with the l.c.d. program the numerical values are held as BCD counts and each digit is, of course, between 0 and 9 decimal. To the l.c.d., though, values 0 to 9 represent the characters which it holds at its character register addresses 0 to 9, which is not the same thing. The l.c.d.'s characters which "look like" our 0 to 9, are held at its addresses 48 to 57, in other words, they are ASCII characters.

With the 7-segment display, we had to use a table to convert from decimal to a code that it would show meaningfully. With the l.c.d., the conversion is much easier, we simply add the difference between the decimal value and its ASCII value, i.e. we increase the value by 48.

Conveniently, 48 decimal has a binary value of 00110000. The BCD values for decimal 0 to 9 lie between binary 00000000 and 00001001. All we need to do, therefore, is to set bits 4 and 5 of the time digit value in order to increase it by 48, i.e. decimal 9 becomes binary 00111001, which equals 57, the ASCII code for numeral 9.

The easiest way to set bits 4 and 5 is to either add 48 to the digit's value, or to OR 48 with it. In other words, to use either ADDLW 48 or IORLW 48 as the command. In this situation they both have the same effect. To use BSF would require two commands instead of just one. In the following conversion example, the additive technique is used (IOR is used in the program), as shown in Listing 30A.

The SWAPF STORE2,W swaps the nibbles of the value held in STORE2 and holds the result in W, putting the tens into the LSN position. Command ANDLW 15 isolates that nibble, zeroing the MSN. Now ADDLW 48 converts the value to the ASCII character, and LCDOUT is called, which sends the data to the l.c.d. (Have you noticed the similarity to the nibble extraction used for 7-segment displays?)

LISTING 30A

```
SWAPF STORE2,W      ; get tens
ANDLW 15
ADDLW 48
CALL LCDOUT
MOVF STORE2,W       ; get units
ANDLW 15
ADDLW 48
CALL LCDOUT
MOVLW ':'           ; insert colon
CALL LCDOUT
```

Next, MOVF STORE2,W brings the entire byte into W, ANDLW 15 isolates the nibble which is in the correct LSN position. Again ADDLW 48 and CALL LCDOUT are performed. Following that, the ASCII value for a colon (58) is sent to the l.c.d., using the single quotes method previously seen in tables.

CLOCKING ON

Hours, minutes and seconds values are dealt with similarly, although minutes are followed by the decimal point (ASCII 46). Seconds are not followed by any character, although they could have a space character (ASCII 32) sent after the units. The sequence of events, from individually incrementing time to outputting the data to the l.c.d. is shown in Listing 30 (Part Two).

Now compare this listing with that for outputting the time data to the 7-segment displays (TK3TUT28). Look especially at the clock count section (from CLKADD to end of ADDCL2). The second version, of which the main part is shown in Listing 30, is considerably more compact.

After initialisation and general set-up, the program enters the MAIN routine. At each 1/25th second time-out, CLKADD is called and the CLKCNT counter decremented, as we saw earlier. Only if the value of CLKCNT is zero is the next routine entered. After resetting CLKCNT, the address of CLKSEC is set in the indirect address register FSR, a loop (LOOP) is set for three operations and STORE1 is cleared for use as an up-counter. In the three steps round the loop, CLKSEC is dealt with first, then CLKMIN and then CLKHRS.

First time round the loop, at ADDCLK the first byte to be incremented is, of course, CLKSEC. This is then checked for a units value greater than nine and action taken accordingly. Next, the value within STORE1 is copied into W and a table (CHKVAL – see full listing) is called, returning with the maximum permitted value for the byte being processed, storing it in STORE2.

The value of the time byte (CLKSEC at this moment) is then copied into W, which is then subtracted from STORE2. If the Carry flag is set, then STORE2 is greater than CLKSEC (there is no borrow) and an exit is made from the loop, no further action being needed, and a jump is made to the display routine (CLKSHW).

If CLKSEC is greater than STORE2 a borrow occurs, thus CLKSEC is cleared, counter STORE1 is incremented for the sake of the table jump address, and the FSR address is incremented (to point now to CLKMIN). The loop counter (LOOP) is decremented and, if it is not zero, the loop is repeated, this time incrementing and checking CLKMIN in the same way as CLKSEC was dealt with. If CLKMIN is reset, the loop is repeated for the third occasion, this time for CLKHRS.

Two sub-routines are used with CLKSHW, to save repetition of too many commands. The routines are LCDLIN and LCDFRM. The former is responsible for setting the starting display cell position on the l.c.d. Since in a larger program this position could change frequently, it is worthwhile having a generalised routine for this purpose. In this case, we want the time to be shown at the start of the second l.c.d. line, so the value B'11000000' (the address of line 2 cell 0) is moved into W and LCDLIN called. All LCDLIN does is set the RSLINE flag for command mode (BCF RSLINE,4), call LCDOUT, and reset the RSLINE flag to character mode (BSF RSLINE,4).

Next, the value of CLKHRS is moved into W and LCDFRM called. This routine does the swapping, ANDing and ORing necessary for numerical conversion to the ASCII value. After this, the colon is sent directly to LCDOUT. Similar commands are then given with regard to CLKMIN and CLKSEC. The program then returns to the MAIN routine to begin again.

It is worth commenting at this point that the starting l.c.d. cell position can be set to any value via the LCDLIN routine. Line 1 needs bits 7 and 6 set to 1 and 0 respectively. Line 2 needs bits 7 and 6 set to 1 and 1 respectively. The cell position on the lines is controlled by the final four binary digits, bit 3, 2, 1, 0. For example, to set for line 1 cell 8 (regarding the first cell as zero) the value of B'10001000' should be sent to LCDLIN, for line 2 cell 15 the value is B'11001111'.

EXERCISE 23

23.1. Extend the program so that the clock also keeps track of months and years.

TUTORIAL 24

CONCEPTS EXAMINED

Adding time-setting switches

CONNECTIONS NEEDED

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

The clock program of TK3TUT30 that is now being run is perfectly usable as a real-time clock, as is the 7-segment version (but see later). They both have a major problem though, the programs have to be started (reset) at exactly midnight for the time shown to be accurate. What we need is the ability to set the current time via switches, as with most other time-keepers. Here we show how switched time-setting can be programmed into the l.c.d. version.

We have already looked quite heavily at the use of switches in earlier sections. It is not hard to implement switched time-setting routines, but it takes quite a few commands (as Listing 31 shows), especially as we are allowing you a luxury: the ability to count upwards or downwards on both minutes and hours. Many clocks do not allow this, and it can be a right pain if you overshoot the time you want! We also allow you the option of a fifth switch to reset the seconds, although you will need to add that switch externally to *TK3*'s p.c.b.

First, though, attention must be paid to the rate at which the digits are changed by the switches. We could easily insert a switch checking routine either on each 1/25th count, or on each second. However, the first is too fast for convenience, and the other too slow. A better rate is on every half-second. This can be arranged by halving the prescaler rate, setting it for a ratio of 1:64 instead of 1:128. Thus, in the initialisation, instead of commands MOVLW B'10000110' and MOVWF OPTION_REG, we use:

```
MOVLW B'10000101'
MOVWF OPTION_REG
```

LISTING 31 – PROGRAM TK3TUT31

```
MAIN      BTFSS INTCON,2
          GOTO MAIN
          BCF INTCON,2
          CALL CLKADD
          GOTO MAIN
CLKADD    DECFSZ CLKCNT,F
          RETURN
          MOVLW 25
          MOVWF CLKCNT
          CALL GETKEY
          INCF HLFSEC,F
          BTFSC HLFSEC,0
          CALL CLKIT
          RETURN

 (Section from CLKIT to end of
LCDLIN omitted)

GETKEY    BTFSS PORTA,3
          GOTO CHKSW2
          BSF EVENT,0
          MOVLW CLKHRS
          GOTO TIMSET
CHKSW2    BTFSS PORTA,2
          RETURN
          CLRF EVENT
          MOVLW CLKMIN
TIMSET    MOVWF FSR
          BTFSC PORTA,0
          GOTO SUBTIM
          BTFSS PORTA,1
          RETURN
ADDTIM    INCF INDF,F
          MOVLW 6
          ADDWF INDF,W
          BTFSC STATUS,DC
          MOVWF INDF
          INCF EVENT,W
          CALL CHKVAL
          MOVWF STORE2
          MOVF INDF,W
          SUBWF STORE2,F
          BTFSS STATUS,C
          CLRF INDF
          GOTO CLKSHW
SUBTIM    MOVLW 1
          SUBWF INDF,F
          BTFSS STATUS,C
          GOTO SUBSET
          BTFSC STATUS,DC
          GOTO ENDSUB
          MOVF INDF,W
          ANDLW B'11110000'
          IORLW 9
          MOVWF INDF
          GOTO ENDSUB
SUBSET    INCF EVENT,W
          CALL CHKVAL
          MOVWF INDF
ENDSUB    GOTO CLKSHW
```

Counter CLKCNT is still set for 25 but we use an additional counter HLFSEC for half seconds, so that although the switches are sampled every half second, the seconds themselves are still incremented correctly.

Referring to Listing 31, you will see the command CALL GETKEY, which is then followed by INCF HLFSEC,F. Only if bit 0 of HLFSEC is 1 will the CLKADD routine be entered. Imagine now that the switches on PORTA are designated as follows:

SW4 = seconds reset
SW3 = hours
SW2 = minutes
SW1 = plus (+)
SW0 = minus (–)
(SW4 is the optional switch referred to a moment ago)

At GETKEY, if switch SW3 is pressed (hours), EVENT bit 0 is set to 1. This file value will be used when accessing the CHKVAL table for the maximum roll-over value for hours or minutes. Now the address of CLKHRS is moved into W and a jump to TIMSET is made.

At this routine, the plus (+) and minus (–) keys are read for their status, and the addition (ADDTIM) or subtraction (SUBTIM) routine is jumped to and processed. In these routines, not only have the units to be checked for values greater than nine, but the overall BCD value has to be checked for greater than 23 (hours) and greater than 59 (minutes).

In the addition routine, the excess value is checked for, and the value is reset to zero if it is exceeded. In the subtraction routine, zero is checked for, in which case the maximum allowed value is moved into the byte as the reset value. In both instances, the value within EVENT is moved into W and table CHKVAL is called for the maximum value.

All the commands involved in these routines should by now be familiar to you without further explanation. Load TK3TUT31.HEX and experiment with setting the time.

TIMING ACCURACY

It is important to be aware that the accuracy of a crystal controlled clock using coding such as this is not perfect. Crystals are subject to manufacturing tolerance in respect of the exact frequency at which they oscillate. Unless the crystal on the p.c.b. is oscillating at exactly 3276800·00Hz, the timing will drift over extended periods.

In other hardware designs it is possible to include a trimmer capacitor in the oscillating circuit to adjust for timing drift. It is also possible to include sophisticated adjustment routines in the program to compensate. Such an example is included with the *PICronos L.E.D. Wall Clock* published in *EPE* June '03. Such techniques, though, are beyond the scope of these Tutorials.

EXERCISE 24

24.1. Change the role of switch SW4 and create a routine that will also show how many hours, minutes and seconds there are until midnight (00:00.00 hours or 24:00.00 if you find it easier) when you press a switch, clearing the answer when the switch is released.

LISTING 32A – PROGRAM TK3TUT32.ASM

```
SETPRM   MOVWF EEADR          ; Copy W into EEADR to set EEPROM address
         BANK1
         BSF EECON1,WREN      ; enable write flag
         BANK0
         MOVF STORE1,W        ; get data value from STORE1 and hold in W
         MOVWF EEDATA         ; copy W into EEPROM data byte register
MANUAL   BANK1                ; these next 12 lines are according to
         MOVLW H'55'          ; Microchip manual dictated factors
         MOVWF EECON2         ; they cause the action required by
         MOVLW H'AA'          ; by the EEPROM to store the data in EEDATA
         MOVWF EECON2         ; at the address held by EEADR.
         BSF EECON1,WR        ; set the "perform write" flag
CHKWRT   BTFSS EECON1,4       ; wait until bit 4 of EECON1 is set
         GOTO CHKWRT
         BCF EECON1,WREN      ; disable write
         BCF EECON1,4         ; clear bit 4 of EECON1
         BANK0
         BCF INTCON,6         ; clear bit 6 of INTCON
         RETURN               ; and RETURN
```

LISTING 32B

```
GETPRM   MOVWF EEADR          ; copy W into EEADR to set EEPROM address
         BANK1
         BSF EECON1,RD        ; enable read flag
         BANK0
         MOVF EEDATA,W        ; read EEPROM data now in EEDATA into W
         RETURN               ; and RETURN
```

24.2. This one is more complicated! By doing exercise 24.1 you have lost the ability to reset the seconds count when you want to – unless you amend the program, seconds will be reset whenever SW4 is pressed. It is possible to amend the program so that switch SW1 and SW0 still serve as plus and minus controls, but SW2 could be used to select whether it is the minutes or the hours that are amended, with a suitable symbol indicating which value is under control. SW3 could then be used to reset the seconds, with SW4 simply controlling the midnight countdown display. Have a go at this challenge!

TUTORIAL 25

CONCEPTS EXAMINED

Writing and reading EEPROM file data
Register EECON1
Register EECON2
Register EEDATA
Register EEADR

We have already shown how convenient it is to be able to repeatedly change the program data within a PIC. The demos and your experiments would simply not have been practical had we been using a microcontroller which required erasing by ultraviolet light each time a new program had to be loaded into it.

Now we come to another great advantage of most PICs, including the PIC16F84, the presence of an EEPROM data memory which can be written to and read from whenever we want, and which will not lose the data when the power is switched off.

We shall now show the commands needed for EEPROM data memory read/write operation and then in Tutorial 26 demonstrate a simple program that makes use of the facility.

The full program for this initial discussion is on your disk as TK3TUT32, its main contents are shown in Listings 32A and 32B. Note that this program cannot be run as it stands and is for use as a subroutine within a main program. Also note that the program is specific to the PIC16F84 and that other PIC families may require slightly different coding. Examples for the PIC16F87x and PIC16F62x families are discussed later.

In some respects, use of the EEPROM read/write facility is similar to that used in indirect addressing, a special register (EEADR) is loaded with the address within the EEPROM at which the data is to be stored or retrieved. This register can be likened to FSR.

The data which has to be written to the EEADR register is loaded into register EEDATA (equivalent to INDF).

On retrieving data from the EEPROM, register EEADR is loaded with the address from which the data is to come, and then the PIC copies the data from that position into EEDATA.

Prior to writing data to the EEPROM, a write-enable flag has to be set in register EECON1. Another flag is set in EECON1 when data is to be read from the EEPROM.

To transfer data from EEDATA to the EEPROM file pointed to by EEADR, an obligatory routine as specified in the PIC's datasheet has to be performed. This routine initialises operations built into the PIC and which last for a predetermined time.

A flag (EECON1,4) is set by the PIC when these operations have occurred and its setting has to be waited for before further program commands can be performed. Failure to wait for the flag setting can disrupt the correct storage of the data.

An example of how the writing routine is used is shown in Listing 32A. Prior to entry into the routine at SETPRM, the data to be written is temporarily placed in file STORE1 (or any name you like). Then the EEPROM address at which the data is to be stored is moved into W and the call to SETPRM is issued.

On entry to SETPRM, the contents of W are copied into EEADR, and then, via BANK1, the command BSF EECON1,WREN is given, setting the EEPROM into write-enable mode, after which follows a reset to BANK0. Data is then copied from STORE1 into W and then into EEDATA.

Now the routine specified in the PIC's datasheet is started at label MANUAL. The 12 lines of this routine, from BANK1 down to BCF INTCON,6 should be followed parrot-fashion in any other EEPROM-writing program. The final return command could be replaced by a GOTO, or by the program immediately following on into another routine.

Reading data from the EEPROM is very simple, as Listing 32B shows. The routine is entered at GETPRM with the EEPROM file address held in W. This is copied into EEADR then, via BANK1, the enable read flag is set (BSF EECON1,RD) and BANK0 reset. The data required is immediately available to be copied into W by the command MOVF EEDATA,W.

EXERCISE 25

There is no exercise for this Tutorial.

TUTORIAL 26

CONCEPTS EXAMINED

Illustrating use of EEPROM data read/write
Converting binary value to hexadecimal

CONNECTIONS NEEDED

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

Program TK3TUT33.ASM illustrates an example of writing to and reading from the PIC's Data EEPROM. It uses the l.c.d. to display three values, and switches SW0 to SW2 to increment them. Switch SW3 causes the new values to be stored into the Data EEPROM at consecutive addresses from 0 to 2.

After the program's initialisation sequence, data currently stored in the EEPROM is recalled as shown in routine GETVALUES in Listing 33. To retrieve a value the address at which it is stored in the EEPROM is first loaded into W (0 in the first instance). The routine at GETPRM (discussed in Tutorial 25) is then called, and a return is made to the calling routine with the retrieved EEPROM value held in W. This is then stored into the register required (in the first instance VALUE0).

The procedure is repeated three times and then a call is made to the display routine SHOWVALS in which the values are shown in hexadecimal.

The MAIN routine is then entered in which the four switches are read at 1/5th of a second intervals (set by routine PAUSIT). If any of switches SW0 to SW2 are found to be pressed, the associated VALUE is incremented in binary and the display routine called again, followed by a return to label MAIN.

If switch SW3 is found to be pressed, the data storage routine is called, at STOREIT. The value to be stored (VALUE0 in the first instance) is called into W and moved into a temporary store, STORE1. The EEPROM address at which the data is to be stored (0 in the first instance) is then called into W and the SETPRM routine called,

LISTING 33 – PROGRAM TK3TUT33.ASM

```
GETVALUES   MOVLW 0            ; get values from EEPROM address 0 to 2
            CALL GETPRM        ; store into VALUE
            MOVWF VALUE0
            MOVLW 1
            CALL GETPRM
            MOVWF VALUE1
            MOVLW 2
            CALL GETPRM
            MOVWF VALUE2
            CALL SHOWVALS      ; show values
MAIN        CALL PAUSIT        ; 1/5th sec pause
            BTFSC PORTA,0      ; is SW0 pressed?
            GOTO INCVAL0       ; yes
            BTFSC PORTA,1      ; no, is SW1 pressed?
            GOTO INCVAL1       ; yes
            BTFSC PORTA,2      ; no, is SW2 pressed?
            GOTO INCVAL2       ; yes
            BTFSC PORTA,3      ; no, is SW3 pressed?
            GOTO STOREIT       ; yes
            GOTO MAIN          ; no
INCVAL0     INCF VALUE0,F      ; inc VALUEs as called and then show
            CALL SHOWVALS
            GOTO MAIN
INCVAL1     INCF VALUE1,F
            CALL SHOWVALS
            GOTO MAIN
INCVAL2     INCF VALUE2,F
            CALL SHOWVALS
            GOTO MAIN
STOREIT     MOVF VALUE0,W      ; store all VALUEs into EEPROM
            MOVWF STORE1
            MOVLW 0
            CALL SETPRM
            MOVF VALUE1,W
            MOVWF STORE1
            MOVLW 1
            CALL SETPRM
            MOVF VALUE2,W
            MOVWF STORE1
            MOVLW 2
            CALL SETPRM
(routine to display STORED)
WAITSW      BTFSC PORTA,3      ; wait until switch SW3 released
            GOTO WAITSW
(routine to clear STORED)
            GOTO MAIN
```

where the data is stored at the required address (as discussed in Tutorial 25).

Following storage of all values, the word STORED is displayed on screen for as long as switch SW3 is held pressed. When the switch is released, the word is cleared and a jump back to label MAIN is made, to await the next switch press.

For convenience in this Tutorial, in the data display routine the binary values are converted to hexadecimal and then displayed. In Tutorial 33 later, conversion of binary numbers to decimal values suitable for l.c.d. display use is illustrated.

In the binary to hex routine, an extract of which is shown in Listing 33A, the byte value is first swapped into W to put the MSN (most significant nibble) into the righthand position, and a call made to a conversion table, HEXTABLE (see full listing). Here the value in W is ANDed with B'00001111' to extract just the lower nibble, and ADDed to PCL. The table jump then returns with the hex value for that nibble, which is then sent to the l.c.d. The procedure is repeated for the LSN of the value byte.

To prove that the data has been stored, note the three values, switch off the power for a few seconds and then switch back on. The data displayed on screen when the program restarts will be the same as that noted. You can also examine all the Data EEPROM values via *TK3*'s EEPROM Message Read facility.

LISTING 33A

```
            SWAPF VALUE2,W
            CALL HEXTABLE
            CALL LCDOUT
            MOVF VALUE2,W
            CALL HEXTABLE
            CALL LCDOUT
```

EEPROM data storage and retrieval has many applications in practical situations. For example, the option is valuable when setting up a program during the testing or tuning stages, allowing the values to be recalled next time the program is run.

The values to be stored need not have originated from switches, they could be provided by other functions within a program. Storage of the values can be in response to a switch press, as illustrated, or could again be triggered by some aspect within the running program, such as in response to clocked timing values.

It is vital to appreciate that a PIC's Data EEPROM has a finite number of times that it can be written to – around one million times according to the PIC16F84's datasheet. This may seem a large number, but it can soon be consumed by incautious programming causing the EEPROM to be repeatedly written to.

During program development when automatic EEPROM writing is included, it is worthwhile putting in a temporary intercept counter and l.e.d. or l.c.d. display routine to monitor the number of times that calls are made to the EEPROM write routine.

EXERCISE 26

The following two exercises are complicated and should only be attempted by those who have successfully followed the Tutorials so far!

33.1 To illustrate EEPROM writing and reading, the author considered modifying the 4-note playing program of TK3TUT19 so that it became eight notes, which were played in the order specified by data in the EEPROM. The data would have been entered via the switches, using the l.c.d. to display which note numbers were being stored at which EEPROM addresses.

A separate switch would have been used to start and stop the note sequence being played. Each note would have had a duration of one second, although it would be possible to set their durations by switches. It would seem preferable to have separate up/down switches, a MODE switch to select the functions of the other switches on a cyclic basis, and a Start/Stop switch. It should be possible to do it with the four switches on *TK3*'s p.c.b. Can you do it?

33.2. You will have discovered that precise musical tuning of the four notes in program TK3TUT19 is not possible using the length of a loop to determine the frequency. It *is* possible though, if within the loop you use a 24-bit counter (three bytes, MSB, NSB, LSB) and add a 16-bit number (two bytes) to it. The toggling of PORTA RA4 would then depend on one of the bit values of the counter's MSB. The additive value depends on the note to be generated and so eight notes need one each.

It is suggested that you try this technique with the program modified in 33.1. The principle was illustrated in the author's *StyloPIC* of July '02 (on the PIC Resources CD-ROM)..

(A similar additive technique can also be used to adjust the precise timing of a crystal controlled clock, as used in the *PICronos* clock referred to earlier).

TUTORIAL 27

CONCEPT EXAMINED

Interrupts
Command RETFIE

CONNECTIONS NEEDED

SW0 to RB0
LD0 to RA0
LD1-LD7 to RB1-RB7
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

LISTING 34 – PROGRAM TK3TUT34

```
        ORG 0
        GOTO 5
        ORG 4
        GOTO INTRPT
        ORG 5

        CLRF PORTA
        CLRF PORTB
        BANK1
        CLRF TRISA
        CLRF TRISB
        MOVLW B'10000111'
        MOVWF OPTION_REG
        BANK0

        MOVLW B'10100000'
        MOVWF INTCON

START   NOP
        GOTO START

TEST    BSF PORTA,0
INTRPT  MOVLW 2
        ADDWF PORTB,F
        BCF INTCON,2
```

From here on, none of the commands examined directly relate to extending or modifying any of the foregoing programs. Connect l.e.d. LD7 to PORTA pin RA0 and switch SW0 to PORTB RB0.

INTERRUPTS

Early on in this series, mention was made of Interrupts, saying they would be examined later. That "later" has arrived!

An Interrupt, as the term implies, literally is an "interrupt" to the program, causing it to stop what it is currently doing, and perform another action or set of actions, returning to where it left off when the interrupt occurred.

Interrupts can be set to occur from several sources, of which two seem the most likely ones to be required: externally from another piece of equipment, such as a switch or from a trigger pulse generated by another electronic circuit; internally, at the end of a time-out period generated by the PIC's own timer.

There are other interrupt possibilities, but which are probably of more benefit to experienced programmers and which will not be detailed here. Readers wanting more information on interrupts are referred to Malcolm Wiles' *Programming PIC Interrupts* of *EPE* Mar/Apr '02 (on the PIC Resources CD-ROM).

There are countless situations where interrupts can be put to good use. Let's examine two of them.

First, the address to which the program must jump when interrupted has to be specified. This is where the ORG 4 statement now comes into its own. Following that statement, and prior to the ORG 5 statement, the jump address is inserted. Let's call the jump address INTRPT. So, at the beginning of the program listing we make the following statements:

```
ORG 0        ; Reset Vector address
GOTO 5       ; go to PIC address
               location 5
ORG 4        ; Interrupt Vector
               address
GOTO INTRPT; go to interrupt routine
ORG 5        ; Start of Program
               Memory
```

Since the program, once triggered by an interrupt, automatically jumps to the program address stated, we can simply set up a holding routine which waits until the interrupt occurs, and then the routine specified at the interrupt address is performed.

We could actually allow the entire program to be performed without using a holding routine, jumping to the specified routine when the interrupt does occur. This is tricky, though, and can be dangerous to the correct operation of the main program. Allowance has to made for a particular operation to be completed before the interrupt routine is performed. It is this type of information and how to handle it that Malcolm discusses in his article.

For our purposes now the use of a holding routine illustrates the essential point about an interrupt action. It can be as simple as:

```
START:  NOP
        GOTO START
```

The program would normally be constantly looping through the two commands NOP and GOTO START, waiting for an interrupt to occur. On its occurrence, the loop would be exited, and a jump made to the routine at INTRPT. Obviously, at the end of the routine caused by the interrupt, a return to the program point from where the interrupt jump was made must be specified. There is a command which is used for this purpose, RETFIE.

TIMER INTERRUPT

A simple program which makes use of an internally timer-generated interrupt to increment a count on PORTB is shown in Listing 34. Here, the timer is set in the same way as we have been doing previously. Then the INTCON register is told that an interrupt is to be generated when the timer rolls over to zero:

```
MOVLW B'10100000'
MOVWF INTCON
```

Setting bit 7 of INTCON enables the program to respond to any interrupts generated. Setting INTCON bit 5 enables the timer as the source of the interrupt. The stage is now set and the START loop entered. Each time a timer interrupt occurs, a jump is made to INTRPT, where PORTB has a value of 2 added to it (to bypass LD0) and a return made to START by the command RETFIE, to await another interrupt.

To prove that the program is not just "dropping out" of the START loop, a command to set PORTA RA0 high has been included immediately following the GOTO START command. As you will see via l.e.d. LD7, this action is never performed.

Load and run TK3TUT34.HEX which illustrates this interrupt.

LISTING 35 – PROGRAM TK3TUT35

```
        ORG 0
        GOTO 5
        ORG 4
        GOTO INTRPT
        ORG 5

        CLRF PORTA
        CLRF PORTB
        BANK1
        CLRF TRISA
        MOVLW B'00000001'
        MOVWF TRISB
        MOVLW B'11000111'
        MOVWF OPTION_REG
        BANK0

        MOVLW B'10010000'
        MOVWF INTCON

START   NOP
        GOTO START

INTRPT  MOVLW 2
        ADDWF PORTB,F
        BCF INTCON,1
        RETFIE
```

EXTERNAL INTERRUPT

If, instead of using the timer to generate interrupts, we want an external source to generate them, one pin that can be used for this purpose is PORTB RB0, designated in the pinout diagram as RB0/INT. (Logic level changes on PORTB RB4 to RB7 are other possible interrupt sources.) To use RB0 as the interrupt source, INTCON bit 4 must be set, as follows:

```
MOVLW B'10010000'
MOVWF INTCON
```

INTCON bit 7 must, as shown, also be set to enable the interrupt.

(Note that if the l.c.d. is connected, the PIC's Light Pull-ups option, discussed later, must be off by setting OPTION_REG bit 7 high, as shown in Listing 35, otherwise the influence of the l.c.d. may prevent the interrupt from being generated.)

Suppose now that we want an external interrupt on RB0 to cause the rest of PORTB to be incremented. Each time this interrupt occurs, the jump from the holding loop is performed as before. However, it is now INTCON bit 1 which is set on the interrupt and has to be cleared before returning to the holding loop, i.e. BCF INTCON,1.

Load TK3TUT35 which illustrates this external interrupt. The interrupt is generated using switch SW0.

Since the switches used on the p.c.b. are probably only low-cost types, it is possible that switch-bounce will cause slightly erratic behaviour of the l.e.d.s. It should become clear, however, that the count is basically incremented when the switch is pressed, not when it is released.

If a signal generator that outputs a square wave is connected to RB0 and monitored on a scope, the triggering edge should be obvious when the generator's rate is set very slow. The signal generator must produce clean 0V to +5V pulses.

INTERRUPT EDGE

It is possible to change the interrupt response to occur on either edge of the external pulse. As illustrated in TK3TUT35, it is in response to the rising edge. To use the falling edge, OPTION_REG bit 6 must be cleared during the BANK1 setup routine, e.g.:

TABLE 6: INTCON REGISTER (Courtesy MICROCHIP)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	EEIE	TOIE	INTE	RBIE	TOIF	INTF	RBIF
bit7							bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: **GIE**: Global Interrupt Enable bit
1 = Enables all un-masked interrupts
0 = Disables all interrupts

Note: For the operation of the interrupt structure, please refer to Section 8.5.

bit 6: **EEIE**: EE Write Complete Interrupt Enable bit
1 = Enables the EE write complete interrupt
0 = Disables the EE write complete interrupt

bit 5: **TOIE**: TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt

bit 4: **INTE**: RB0/INT Interrupt Enable bit
1 = Enables the RB0/INT interrupt
0 = Disables the RB0/INT interrupt

bit 3: **RBIE**: RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt

bit 2: **TOIF**: TMR0 overflow interrupt flag bit
1 = TMR0 has overflowed (must be cleared in software)
0 = TMR0 did not overflow

bit 1: **INTF**: RB0/INT Interrupt Flag bit
1 = The RB0/INT interrupt occurred
0 = The RB0/INT interrupt did not occur

bit 0: **RBIF**: RB Port Change Interrupt Flag bit
1 = When at least one of the RB7:RB4 pins changed state (must be cleared in software)
0 = None of the RB7:RB4 pins have changed state

```
MOVLW B'10000111'
MOVWF OPTION_REG
```

Change TK3TUT35 to respond to the falling edge and observe the result when you now press switch SW0. Note that the settings of OPTION_REG bits 0, 1 and 2 are irrelevant in this interrupt mode.

As you have seen, INTCON bit 7 is used for enabling (1) and disabling (0) the interrupts, in addition to any other bits required for an interrupt to be enabled. It is possible that at the moment of wishing to disable the interrupts, however, that an interrupt could be in the process of occurring. This would result in the disabling command not taking effect. To ensure that all interrupts are fully disabled (except WDT – see later), the following routine can be used:

```
DISABL  BCF INTCON,GIE
        BTFSC INTCON,GIE
        GOTO DISABL
```

The term GIE is that equated for use as INTCON bit 7. It should be equated as such in the initialising commands. Its use is in keeping with the PIC datasheet, which calls this bit by that name, standing for Global Interrupt Enable.

Malcolm discusses disabling GIE in his *Interrupts* article.

EXERCISE 27

27.1. Modify one of the early counting programs so that it is automatically triggered by an interrupt from line RB0 without the need to read the INTCON register flag.

27.2. You know that INTCON bit 1 and INTCON bit 2 are both flags for interrupts. Modify your program from 27.1 so it automatically responds to interrupts from RB0 and from the TMR0 timer.

Hint: once an interrupt has occurred, the INTCON flags can be read to see which source has caused the interrupt. You can also inhibit one interrupt from occurring while you process the first by using other INTCON bits. Use the l.e.d.s to show respective counts from each source.

TUTORIAL 28

CONCEPT EXAMINED

Command SLEEP

CONNECTIONS NEEDED

SW0 to RB0
LD0 to RA0
LD1-LD7 to RB1-RB7
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

SLEEP is a command that is rarely likely to find use by most readers. The function sets the PIC into a very low current power-down mode. This can be useful if the PIC is monitoring or controlling something at a very slow rate. In this situation, there are power saving advantages if the PIC can be put to sleep during periods when it is not required to perform. The PIC can be awoken from SLEEP by a WDT time-out or through an external interrupt.

The program which illustrates the latter is TK3TUT36. First connect l.e.d. LD0 to RA0, and switch SW0 to RB0, then load the program.

The program adds two to the count on PORTB from zero up to the roll-over at 256, at which point PORTA RA0 is set to turn on l.e.d. LD0. At this point, the program is told to SLEEP.

It can only be awoken by pressing switch SW0. Whereupon, RA0 is cleared to turn off LD0, and the PORTB count resumes, until again it rolls over to zero and setting RA0, then falling asleep once more. (This might remind you of your occasional behaviour on a Monday morning after "the weekend before"!) Note the use of two delays (DELAY1 and DELAY2) slowing the program down by 256 × 256 looped actions for the sake of the demo.

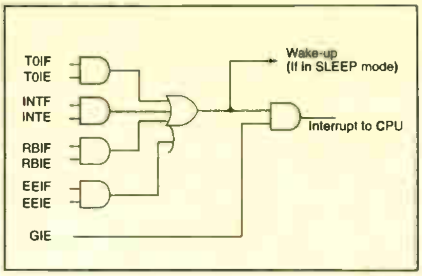


Fig.9. PIC16F84 interrupt logic.

LISTING 36 – PROGRAM TK3TUT36

```
        CLRF PORTA
        CLRF PORTB
        BANK1
        CLRF TRISA
        MOVLW B'00000001'
        MOVWF TRISB
        MOVLW B'11000111'
        MOVWF OPTION_REG
        BANK0
        CLRF DELAY1
        CLRF DELAY2
        MOVLW B'10010000'
        MOVWF INTCON

MAIN    DECFSZ DELAY1,F
        GOTO MAIN
        DECFSZ DELAY2,F
        GOTO MAIN
        MOVLW 2
        ADDWF PORTB,F
        BTFSS STATUS,C
        GOTO BYPASS
        BSF PORTA,0
        SLEEP

BYPASS  BCF INTCON,1
        BCF PORTA,0
        GOTO MAIN
```

EXERCISE 28

28.1. Put the PIC to sleep between each detection of a TMR0 interrupt occurring every 1/25th of a second while allowing it to appropriately increment a seconds counter and show its value on any of the display types covered.

TUTORIAL 29

CONCEPTS EXAMINED

Watchdog timer (WDT)
Command CLRWDT

CONNECTIONS NEEDED

SW0 to RB0
LD0 to RA0
LD1-LD7 to RB1-RB7
CP20 to +5V OUT
CP21 to 0V OUT
Crystal oscillator

The Watchdog Timer (WDT) facility is also probably one for which most readers are unlikely to find much use. The purpose of a WDT is to give the PIC a type of protection against becoming stuck in a perpetual loop. This can happen in several ways, but particularly in the event of unforeseen program errors, or waiting for an external event to happen but which does not (for many and varied reasons, including equipment malfunction).

It is also possible for electrical spikes on power lines to cause the malfunction, although it can be argued that the use of a good power supply should be mandatory in situations where this could be an unacceptable problem.

In effect, the WDT provides a "last-ditch" time-out timer which, if it is allowed to time-out, causes a complete system reset. The idea is that the WDT is set with a timing value, and then at regular intervals in the main loop of the program, this value is repeatedly reloaded into it, i.e. it is reset, using the command CLRWDT. Should a problem occur which prevents the WDT value from being reloaded, the WDT will timeout and cause a full program reset.

The difficulty of using a WDT in many programs is that when the full reset occurs, any variables which are specifically set to known values at the start of the program will once more be reset to them. This means, for example, that event counters within the program will also be reset.

When the existing count value is of importance, rather than use the WDT, the program should be written so that an interrupt (from a switch, for instance) can cause the program to resume running without being reset. However, if it does not matter that the program restarts from the beginning, as in some burglar alarm systems perhaps, then the WDT can be beneficially used.

To use the WDT, the PIC has to be set for this function using the PIC Configuration program. You will recall that when configuring the PIC for RC and crystal modes, WDT was not selected. Now, though, reconfigure the PIC and set the Watchdog on.

Connect RB0 to SW0 instead of LD0, then load TK3TUT37.

WATCH IT!

Observing the l.e.d.s on PORTB, press and release switch SW0, setting on l.e.d.s LD7 to LD1. After a brief pause following the switch being released, the l.e.d.s will all go out as the WDT times out, causing a program reset. Repeatedly pressing SW0 overrides the WDT, resetting its countdown value.

The WDT timing period can be changed in the same way that we set the timing prescaler for the real-time clock, i.e. using bits 0 to 2 of OPTION_REG. Bit 3 of OPTION_REG must always be set so that the prescaler is allocated to the WDT. Try changing the values of OPTION_REG bits 0 to 2; also see what happens when STATUS bit 3 is set to zero. The prescaler is set for its slowest rate in TK3TUT37.

The WDT cannot be disabled from within an operational program. It can only be turned off by reconfiguring the PIC. Consequently, when you have finished experimenting with the WDT, once again reconfigure the PIC with WDT disabled. Unless you do this, none of the other demonstration programs will run correctly.

An independent RC oscillator is used by the WDT and its timing is unaffected by the frequency of the external oscillator that controls the rest of the PIC.

Be aware that during development of the Tutorials, it was found necessary to occasionally run the WDT configuration twice before the PIC would accept this mode. The reason is unknown. If TK3TUT37 does not behave as expected, re-run the configuration for WDT.

LISTING 37 – PROGRAM TK3TUT37

```
        CLRF PORTA
        CLRF PORTB
        BANK1
        CLRF TRISA
        MOVLW B'00000001'
        MOVWF TRISB
        MOVLW B'10001111'
        MOVWF OPTION_REG
        BANK0

TESTON  BTFSS PORTB,0
        GOTO TESTON
        CLRWDT
        MOVLW 255
        MOVWF PORTB
        GOTO TESTON
```

TABLE 7: OPTION REGISTER

(Courtesy MICROCHIP)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{RBPU}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0

bit7 ... bit0

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as '0'
- n = Value at POR reset

bit 7: $\overline{RBPU}$: PORTB Pull-up Enable bit
1 = PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled (by individual port latch values)

bit 6: INTEDG: Interrupt Edge Select bit
1 = Interrupt on rising edge of RB0/INT pin
0 = Interrupt on falling edge of RB0/INT pin

bit 5: T0CS: TMR0 Clock Source Select bit
1 = Transition on RA4/T0CKI pin
0 = Internal instruction cycle clock (CLKOUT)

bit 4: T0SE: TMR0 Source Edge Select bit
1 = Increment on high-to-low transition on RA4/T0CKI pin
0 = Increment on low-to-high transition on RA4/T0CKI pin

bit 3: PSA: Prescaler Assignment bit
1 = Prescaler assigned to the WDT
0 = Prescaler assigned to TMR0

bit 2-0: PS2:PS0: Prescaler Rate Select bits

Bit Value	TMR0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

EXERCISE 29

29.1. Experiment with different timeout periods for WDT, using the OPTION_REG register settings.

TUTORIAL 30

CONCEPT EXAMINED

Misc Special Register bits

We have examined the use of quite a few bits in the Special Functions Registers, but not all of them (see Tables 4, 6 and 7).

OPTION BIT 7

The first bit that we have not demonstrated, although earlier reference has been made to it, is the "light pull-ups" bit of the OPTION register, bit 7. The pull-ups facility allows switches to be used without biassing resistors as it introduces its own pull-up biassing on each of PORTB's pins that are used as inputs (assume as a rule-of-thumb that biassing has an equivalent resistance of about 100kΩ).

Throughout the Tutorials so far, OPTION_REG bit 7 has been held high, initially because the default setting for the register is 11111111, and secondly because when we have been using the register we have been setting bit 7 high in the initialisation block.

We have not needed the pull-ups to be on because the switches have usually been connected to PORTA (which does not have the facility) and they have their own external biassing resistors connected (R17 to R20). In other applications, though, switches can be used on PORTB and external biassing resistors omitted, using the command BCF OPTION_REG,7 to activate the internal pull-ups.

Making use of these pull-ups, however, means that PORTB's input pins are active low (rather than active high as in most of the switch monitoring examples in the Tutorials). This means that the PORTB pins to which the switches are connected are normally held high, a switch press then taking them low. Consequently, it is the low condition which needs to be looked for when a switch is pressed.

A convenient way of detecting if any switch has been pressed is to read PORTB as an inverted value, using the command COMF PORTB,W and read the Z flag of STATUS. If a switch has not been pressed a zero condition will exist following COMF. However, if one or more switches have been pressed, a zero condition will not exist and appropriate action can then be taken, as in the following example:

```
TESTSW COMF PORTB,W   ; invert PORTB into W
       BTFSS STATUS,Z ; is result = 0?
       GOTO ACTION    ; no, a switch has been pressed, so process it
```

```
        RETURN          ; yes, a
                         switch
                         has not
                         been
                         pressed
ACTION
; (routine that results if a switch has been
pressed goes here)
        RETURN
```

Following COMF an AND statement can be made to eliminate those pins which are not associated with the switches.

You could try the light pull-ups option by connecting "flying leads" to the PORTB pins and touch their stripped ends to the +5V and 0V lines. It is suggested that you modify some of the earlier routines that use switches to prove how light pull-ups can be used.

It is worth appreciating that if PIC pins set as inputs are not connected to anything when the light pull-ups are off, erratic behaviour can result as the pins are not sure which condition they should be in, high or low (see the section in Tutorial 4, Part 1, that discussed port pin safety).

OTHER BITS NOT DISCUSSED

There are two bits in the STATUS register (see Table 4, Part 1) whose purpose and use seem obscure:

STATUS bit 3 (PD): POWER-DOWN bit. Set to 1 during power up or by a CLRWDT command. Cleared to 0 by a SLEEP command.

STATUS bit 4 (TO): TIME-OUT bit. Set to 1 during power up and by the CLRWDT and SLEEP commands. Cleared to 0 by a WDT time-out.

There are also other bits which are similar in their setting to those that we have already discussed, and so their examination is not justified here. The bits are principally in the INTCON and OPTION_REG registers (Tables 6 and 7). A summary is as follows:

INTCON bit 0 (RBIF): RB port change interrupt flag. Set when any of RB4 to RB7 inputs change logic state. Has to be reset in software.

INTCON bit 3 (RBIE): RBIF interrupt enable bit; 0 = disable, 1 = enable.

(Malcolm discusses INTCON RBIF and RBIE is his *Interrupts* article.)

OPTION_REG bit 5 (RTS): TMR0 signal edge response to signal on RA4/TOCKI pin;

0 = increment on low-to-high transition
1 = increment on high-to-low transition.

Note that the default value for each bit in OPTION_REG at power-up and reset is 1 (i.e. 11111111).

It is suggested that you write simple routines, along the lines of those that have been used in other demonstrations, to establish for yourself what can be achieved using these bits. It is also well worthwhile reading through the PIC's datasheet in its entirety. There are minor aspects relating to some of the commands that we have discussed that deserve recognition if you wish to delve more deeply into programming these devices.

TUTORIAL 31

CONCEPT EXAMINED

INCLUDE files command
Embedded Configuration data
Embedded Data EEPROM values
Embedded PIC type data
Embedded Radix

CONNECTIONS NEEDED

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

INCLUDE FILES COMMAND

It is possible to input "library" files into the main body of your program. This can be done in one of two ways: either by copying the section from a previous program (as preferred by the author), or to call in a particular file to be "included" at an appropriate point within the program.

LISTING 38 – PROGRAM TK3TUT38

```
#DEFINE BANK0 BCF STATUS,5
#DEFINE BANK1 BSF STATUS,5

          INCLUDE TK3PIC16F84.INC ; call in EQUates data held in INC file

LOOP      EQU H'20'            ; loop counter 1 – general
CLKCNT    EQU H'21'            ; pre-counter for CLOCK
CLKSEC    EQU H'22'            ; CLOCK main counter – secs
CLKMIN    EQU H'23'            ; CLOCK – mins
CLKHRS    EQU H'24'            ; CLOCK – hours
STORE1    EQU H'25'            ; general store 1
STORE2    EQU H'26'            ; general store 2
RSLINE    EQU H'27'            ; RS line flag for LCD
LOOPA     EQU H'28'            ; loop counter for LCD
          ORG 0                ; Reset Vector address
          GOTO 5               ; go to PIC address location 5
          ORG 4                ; Interrupt Vector address
          GOTO 5               ; go to PIC address location 5
          ORG 5                ; Start of Program Memory at location 5
; (main body of program)

          INCLUDE TK3TUT38.INC  ; call in program code held in INC file

          END                  ; final line
```

The latter files can have any extension but it is customary to give them an INC extension, standing for "include" and can be called in by name as in the two examples given in Listing 38, and any number of INC files can be called in.

In this example, the first included file is called by the command:

INCLUDE TK3PIC16F84.INC

This file is a variant of one of Microchip's Include files and contains the full range of EQUated register and bit values as listed in the datasheet for the PIC16F84.

Microchip have INClude files available for other PIC types (see later). It is **essential** that the EQUates INClude file should be for the PIC family for which the main code is written.

The second INClude file is at the program's end. The named file simply contains the program code for the LCDFRM and LCDOUT routines that are used in TK3TUT30. The full listing of the example program in TK3TUT38 shows that the main body of the code is the same as that used in TK3TUT30, but without the EQUates held in TK3PIC16F84.INC, and without the LCDFRM and LCDOUT routines.

There are a number of restrictions that apply when using INClude files, some of which may depend on the assembly program you use. *TK3* operates on the following principle:

- The INCluded filename must not contain directory (folder) or drive path information
- The file must be in the same directory as the main calling code. Thus if the directory address of the main code is C:\PIC\TestFile.ASM then the INClude file must also be within directory C:\PIC\ e.g.:

C:\PIC\TK3PIC16F84.INC

There are two main regions in PIC source codes from which INClude files may be called when using *TK3*. Those containing EQUates and Defines must be placed near the top of the main code in the region where the main code EQUates and Defines are placed. They must occur before the first ORG statement is made in the main code. INClude files called in this region must *not* contain true program commands.

The second region is at any suitable point within the body of the main code, and may be the first command of that code (i.e. at address location 5 – ORG 5), at the end as shown here, or anywhere else that you prefer.

Include files in the main body of the code may contain their own Equates and Defines, but not Includes. Beware of using ORG statements within Include files since they may disrupt the correct assembly of the rest of the code.

In this example the Defines are stated first, then the basic EQUates data is called in, then the EQUates specifically required as register names of your choice are then stated. These must include the register names needed by any INCluded program code routines, in this case those needed by

TK3TUT38.INC (but also see CBLOCK in Tutorial 48).

Whilst some assemblers (including *TK3*) permit INClude files to contain EQUates and program code, users need to be aware of the danger of the same EQUates names being used for different purposes in different INC files when more than one is called.

When using *TK3* as the assembler, INClude files must *not* contain Macros, which *TK3* does not recognise.

(A Macro is a set of programmer-defined instructions and directives which are given a name. When the name is encountered by the assembler, it is automatically expanded into the defined set of instructions. Thus a Macro is a useful shorthand notation for sequences of code that recur frequently within the program. The subject of Macros is covered in Malcolm Wiles' *PIC Macros and Computed GOTOs*, *EPE* Jan '03, on the PIC Resources CD-ROM.)

EMBEDDED CONFIGURATION DATA

At various points in these Tutorials you have had to set the PIC's configuration data via the PIC Configuration facility. It is possible to embed the data into the program itself rather than set it separately. This ensures that when the program is loaded the PIC is automatically configured correctly for the purpose required.

If you look to the right of the Config screen you will see a hexadecimal value that changes when the various Config option buttons are used. It is this hex value which is used at the head of a program in the form:

```
__CONFIG H'3FF1'
```

The value is preceded by __CONFIG (two underscore characters plus the word CONFIG). When the program is assembled the CONFIG value is noted and then automatically programmed into the designated PIC location (at H'2007'). The statement is placed in the second column of the assembly code, as shown in the full program of TK3TUT38.ASM.

To establish what value to use for a particular program, simply set the Config option buttons to the functions required and use the resulting hex value shown.

The value in this example is for Code Protection (CP) off, Power on Reset (POR) off, Watchdog Timer (WDT) off, crystal XT (crystal frequencies up to 4MHz).

Near the head of TK3TUT38 you will also see a statement commencing LIST P, which will be discussed shortly.

EMBEDDED DATA EEPROM VALUES

In program TK3TUT33 the values for the Data EEPROM are entered via switches on the p.c.b. It is possible to set such values into the program itself and which are then automatically placed into the Data EEPROM at the correct locations when the program is loaded.

The PIC's Data EEPROM region commences at H'2100' and to program it the ASM file requires an ORG statement at the end pointing to this location, e.g.

```
ORG H'2100'
```

The values to be sent are prefixed "DE" and then entered in any of the numerical forms, such as follow:

```
DE 10, 9, 8 ,7 ,6 ,5, 4, 3, 2, 1, 0
DE 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
DE H'A', H'B', H'C', H'FF'
DE 'A', 'B', 'c'
DE B'00000001', B'00000011'
```

When the data is sent it is placed at consecutive addresses commencing from the ORG value stated.

It is permissible to start the data at later locations, for example H'2109', which would place the first value at EEPROM location 9, rather than 0 as stated by H'2100 '.

EMBEDDED PIC TYPE DATA

TK3 and Microchip's MPASM assembler allows the PIC type to be embedded into the program. Whilst *TK3* does not need this to be embedded, the statement is useful if the program is to be assembled by MPASM (as might be the case with programs distributed to *EPE* readers who use MPASM but not *TK3*).

TK3 only makes use of it to set the basic PIC type, as can also be done through the Select PIC Type screen option.

The PIC type statement is made in the form:

```
LIST P = PIC16F84
```

and placed at the head of the program, as shown in TK3TUT38.ASM.

EMBEDDED RADIX

As stated several times in these Tutorials, numerical values can be expressed in various ways, depending on the prefix used (e.g. H' or B'). *TK3* automatically assumes that values without a prefix are in decimal.

However, *TK3* also follows MPASM's option and allows users to express hex or binary values without the use of a prefix and enclosing quotes, defining this requirement in an initialisation line which is prefixed with the statement "LIST". The term *radix* is used in this context, and the radix is then equated to be in decimal, hex or binary, according to the user's preference. For example, the following sets the radix to be in hexadecimal:

```
LIST R=HEX
```

Having specified the radix, any unprefixed value encountered during assembly will be taken to be in that notation. Thus if the radix is decimal (R=DEC), 10 will be taken as decimal ten. If the chosen radix is hex (R=HEX), then 10 will be taken as H'10' (decimal 16). For a binary radix (R=BIN), 10 will be interpreted as B'00000010' (decimal 2).

Obviously, when using a radix of hexadecimal or binary, any decimal values must use the D' prefix and final quote, e.g. D'10'.

A single LIST statement can be used to apply to the PIC type and the radix, separating the two definitions by a comma, i.e.

```
LIST P = PIC16F84, R=DEC
```

It is worth noting perhaps that the author has never wished to use a radix other than decimal.

EXERCISE 31

31.1 Modify TK3TUT38 so that it calls in the PAUSIT routine as a separate INC file, named as you wish, and used in place of that routine in the main code.

31.2 Examine printouts of the LST files created for TK3TUT30, TK3TUT38 and your own program as modified in 31.1. Confirm for yourself that the three listings contain the same equates and program code. (Additional information about the include files will be seen in the last two listings.)

31.3 Set the CONFIG value of TK3TUT38 so that program runs in RC mode (set the RC/XTAL switch appropriately otherwise the program will not run).

31.4 Modify program TK3TUT33 in conjunction with TK3TUT19 so that a tune is held as Data EEPROM statements which are played when a switch is pressed. There are 64 Data EEPROM locations available (from H'2100' to H'213F').

Note that *TK3* also allows Data EEPROM values to be sent via a MSG (message) file but ignore the facility for this exercise (the facility is not available with all assembly programs).

TUTORIAL 32

CONCEPT EXAMINED

PIC16F8x, PIC16F87x, PIC16F6x family coding differences
PIC16F87x PORTA
PIC16F87x Data EEPROM use
PIC16F62x PORTA
PIC16F62x Data EEPROM use

We said earlier that most aspects of using a PIC16F84 are common to other PIC families, but that there are some differences. Whilst these tutorials are not intended to cover all aspects of PIC programming, it is worth highlighting some routines that have been discussed in relation to the PIC16F84 and for which slightly different techniques are required for the PIC16F87x and PIC16F62x families. This section looks at those differences.

EXTRA BANKS

The first thing to note is that the PIC16F87x and PIC16F62x devices both have four Banks, whereas the PIC16F84 only has two. The extra two Banks are numbered 2 and 3. STATUS bits RP0 and RP1 (bits 5 and 6) control Bank selection. It is preferable to ensure that only BANK0 is active when the program starts by issuing the follow commands immediately prior to the initialisation block:

```
BCF STATUS,RP0
BCF STATUS,RP1
```

RP0 and RP1 should be equated in the general EQUates section as:

```
RP0    EQU 5   ; STATUS reg
RP1    EQU 6   ; STATUS reg
```

Unlike the PIC16F8x family, PIC16F87x and PIC16F62x devices

LISTING 39A

```
EEDATA   EQU H'0C'  ; Bank 2
EECON1   EQU H'0C'  ; Bank 3
PIR2     EQU H'0D'  ; Bank 0
EEADR    EQU H'0D'  ; Bank 2
EECON2   EQU H'0D'  ; Bank 3
STATUS   EQU 3      ; STATUS register
W        EQU 0      ; Working register flag
RP0      EQU 5      ; STATUS bank reg
RP1      EQU 6      ; STATUS bank reg
RD       EQU 0      ; EECON1 reg
EEPGD    EQU 7      ; EECON1 reg
EEIF     EQU 4      ; PIR2 reg
WR       EQU 1      ; EECON1 reg
WREN     EQU 2      ; EECON1 reg
STORE1   EQU H'20'  ; or any convenient address
```

have additional memory that can be accessed in their Banks 1, 2 and 3. Accessing this memory is accomplished via PCLATH. See the author's *PIC16F87x Extended Memory*, June '01, and John Waller's *PCLATH* text referred to earlier. Both texts are on the PIC Resources CD-ROM.

PIC16F87x PORTA

PIC16F87x devices allow their PORTA pins to be variously used for analogue input purposes as well as digital. The default condition prior to a program being run is for the analogue aspect to be active. This means that the PIC has to be told when PORTA is to be used for normal digital input/output, normally making this statement as part of the initialisation process.

To set PORTA for digital use, the ADCON1 Special Register value has to be set via BANK1 to 0000011x (where x means that the value of that bit does not matter), e.g.:

```
BANK1
MOVLW B'00000111
MOVWF ADCON1
BANK0
```

These MOVLW and MOVWF commands would normally be included in the BANK0 to BANK1 section of the program's initialisation routine where TRISA etc. are being set.

ADCON1 should be equated in the general EQUates section as:

```
ADCON1 EQU H'1F'      ; (Bank 1)
```

PIC16F87x DATA EEPROM USE

The PIC16F87x family need the EQUates shown in Listing 39A when the Data EEPROM read/write routines are used. The full Write and Read listings are held in TK3TUT39.ASM.

PIC16F87x WRITING TO DATA EEPROM

Writing to the PIC16F87x family is carried out by the routine in Listing 39B, which is entered with W holding the EEPROM byte address at which data is to be stored. The data to be stored is held in STORE1.

LISTING 39B

```
SETPRM   BSF STATUS,RP1      ; set for Bank 2
         BCF STATUS,RP0
         MOVWF EEADR         ; copy W into EEADR to set EEPROM address
         BCF STATUS,RP1      ; set for Bank 0
         MOVF STORE1,W       ; get data value from STORE1 and hold in W
         BSF STATUS,RP1      ; set for Bank 2
         MOVWF EEDATA        ; copy W into EEPROM data byte register
         BSF STATUS,RP0      ; set for Bank 3
         BCF EECON1,EEPGD    ; point to Data memory
         BSF EECON1,WREN     ; enable write flag
MANUAL   MOVLW H'55'         ; these lines cause the action required
         MOVWF EECON2        ; by the EEPROM to store the data in EEDATA
         MOVLW H'AA'         ; at the address held by EEADR.
         MOVWF EECON2
         BSF EECON1,WR       ; set the "perform write" flag
         BCF STATUS,RP1      ; set for Bank 0
         BCF STATUS,RP0
CHKWRT   BTFSS PIR2,EEIF     ; wait until bit 4 of PIR2 is set
         GOTO CHKWRT
         BCF PIR2,EEIF       ; clear bit 4 of PIR2
         RETURN
```

LISTING 39C

```
PRMGET   BSF STATUS,RP1      ; set for Bank 2
         BCF STATUS,RP0
         MOVWF EEADR         ; copy W into EEADR to set EEPROM address
         BSF STATUS,RP0      ; set for Bank 3
         BCF EECON1,EEPGD    ; point to data memory
         BSF EECON1,RD       ; enable read flag
         BCF STATUS,RP0      ; set for Bank 2
         MOVF EEDATA,W       ; read EEPROM data now in EEDATA into W
         BCF STATUS,RP1      ; set for Bank 0
         RETURN
```

LISTING 40B

```
SETPRM   BANK1
         MOVWF EEADR         ; copy W into EEADR to set EEPROM address
         MOVF PROMVAL,W      ; get data value from PROMVAL and hold in W
         MOVWF EEDATA        ; copy W into EEPROM data byte register
         BSF EECON1,WREN     ; enable write flag
MANUAL   MOVLW H'55'         ; these lines cause the action required by
         MOVWF EECON2        ; by the EEPROM to store the data in EEDATA
         MOVLW 'AA'          ; at the address held by EEADR.
         MOVWF EECON2
         BSF EECON1,WR       ; set the "perform write" flag
         BANK0
CHKWRT   BTFSS PIR1,EEIF     ; wait until bit 4 of PIR2 is set
         GOTO CHKWRT
         BCF PIR1,EEIF       ; clear bit 4 of PIR2
         RETURN
```

PIC16F87x READING FROM DATA EEPROM

Reading from the PIC16F87x family is carried out by the routine in Listing 39C, which is entered with W holding the EEPROM byte address to be read. The readback value is then held in W on exit.

PIC16F62x PORTA

PIC16F62x devices allow their PORTA pins to be variously used for analogue input purposes as well as digital. The default condition prior to a program being run is for the analogue aspect to be active. This means that the PIC has to be told when PORTA is to be used for normal digital input/output, normally making this statement as part of the initialisation process. To do so register CMCON has to be set with the value of 7, e.g.:

```
MOVLW 7
MOVWF CMCON
```

LISTING 40A

```
PIR1     EQU H'0C'  ; Bank 0
EEDATA   EQU H'1A'  ; Bank 1
EEADR    EQU H'1B'  ; Bank 1
EECON1   EQU H'1C'  ; Bank 1
EECON2   EQU H'1D'  ; Bank 1
WREN     EQU 2      ; EECON1 reg EEPROM write enable flag
EEIF     EQU 7      ; PIR2 reg
RD       EQU 0      ; EECON1 reg EEPROM read enable flag
WR       EQU 1      ; EECON1 reg EEPROM write initiate flag
PROMVAL  EQU H'70'  ; accessed via Bank 0 and Bank 1
```

This action takes place in BANK0 and can be done immediately prior to the BANK1 initialisation block.

CMCON should be equated in the general EQUates section as:

```
CMCON     EQU H'1F'     ; Bank 0
```

PIC16F62x DATA EEPROM USE

The PIC16F62x family need the EQUates shown in Listing 40A when the Data EEPROM read/write routines are used:

Note that one value, PROMVAL, is required to be accessed via both BANK0 and BANK1. It needs to be EQUated to occur at a location between H'70' and H'7F'. These locations are automatically accessible via any of the four Banks, unlike the "normal" locations between H'20' and H'6F' (see Figure 4.3 in the PIC16F62x datasheet).

The full Write and Read listings are held in TK3TUT40.ASM.

PIC16F62x WRITING TO DATA EEPROM

Writing to the PIC16F62x family is carried out by the routine shown in Listing 40B, which is entered with W holding the EEPROM byte address at which data is to be stored. The data to be stored is held in PROMVAL, which is located in both Banks at or above H'70'

PIC16F62x READING FROM DATA EEPROM

Reading EEPROM data from the PIC16F62x family is carried out by the routine in Listing 40C, which is entered with W holding the EEPROM byte address to be read. The read-back value is then held in W on exit.

LISTING 40C

```
GETPRM BANK1
       MOVWF EEADR    ; copy W into EEADR to set EEPROM address
       BSF EECON1,RD  ; enable read flag
       MOVF EEDATA,W  ; read EEPROM data now in EEDATA into W
       BANK0
       RETURN
```

TUTORIAL 33

CONCEPT EXAMINED

Converting binary values to decimal

CONNECTIONS NEEDED

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

You will recall that the clock counting examples were carried out using binary coded decimal (BCD) routines, which then made outputting the data to the 7-segment and l.c.d. displays comparatively easy. There are many occasions when it is considerably more convenient to process data in binary than in BCD and then to convert it to BCD prior to display.

An excellent routine for doing this conversion was provided to *EPE* by reader Peter Hemsley. It allows a 3-byte value to be converted to eight separate BCD digits. An example of using his code in a practical situation is held in TK3TUT41.ASM – run it and then examine its code.

Peter's code can be copied in to your program and used as a "library" routine, accessed via preparatory commands such as shown in Listing 41.

The values BIN0, BIN1 and BIN2 in the listing hold the processed values (in order of LSB, NSB, MSB), which are then copied into COUNT0, COUNT1 and COUNT2 prior to conversion.

A call to Peter's BIN2DEC routine is then made, after which the values are ORed with 48 to suit them to the l.c.d. and leading zeros are blanked. The decimal results are then output to the l.c.d. on line 1 starting at cell 0. If BIN1 and/or BIN2 are not used, they should be cleared prior to calling the BIN2DEC routine (e.g. CLRF COUNT2 if BIN2 is not used).

Note that command SKPNC in the BIN2DEC routine is an MPASM shortform for "Skip if no Carry". A list of such commands recognised by *TK3* and Microchip's MPASM assembly programs is shown later in Table 8.

LISTING 41 – PROGRAM TK3TUT41

```
; Binary to BCD conversion example
        MOVF BIN0,W          ; copy binary into COUNT
        MOVWF COUNT0
        MOVF BIN1,W
        MOVWF COUNT1
        MOVF BIN2,W
        MOVWF COUNT2
        CALL BIN2DEC         ; call conversion
        MOVLW B'10000000'    ; set LCD line
        CALL LCDLIN
        MOVF DIGIT8,W        ; output to LCD
        CALL LCDOUT
(repeat for DIGIT7 to DIGIT1)
        RETURN
```

EXERCISE 33

33.1 Experiment with using different values held in BIN.

33.2 Write a clock program in which the hours, minutes and seconds are each incremented as binary values and output to the l.c.d. in decimal.

TUTORIAL 34

CONCEPT EXAMINED

Multiplication routine

CONNECTIONS NEEDED

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

PIC16F84, PIC16F62x and PIC16F87x families do not have multiplication commands. *EPE* reader Peter Hemsley's code for multiplying a 2-byte value by another 2-byte value is shown TK3TUT42.ASM. Run it and then examine its code.

An example of its use is shown in Listing 42. The binary value to be multiplied is held in BIN0 (LSB) and BIN1 (MSB) and copied into MULCLSB and MULCMSB. The value by which BIN is to be multiplied is placed into MULPLSB and MULPMSB and may be a numeral as shown (H'0575') or from another pair of bytes whose value has been set elsewhere in the program. The answer is held, in descending order of bytes, in PRODMSB, PRODLSB, MULPMSB and MULPLSB,

LISTING 42 – PROGRAM TK3TUT42

```
        MOVF BIN0,W          ; place value to be multiplied into MULC
        MOVWF MULCLSB
        MOVF BIN1,W
        MOVWF MULCMSB
        MOVLW H'75'          ; place value of multiplier into MULP
        MOVWF MULPLSB
        MOVLW H'05'          ; (multiply by H'0575')
        MOVWF MULPMSB
        CALL MULTIPLY        ; call multiply routine
        MOVF MULPLSB,W       ; copy answer into ANSWER
        MOVWF ANSWER0
        MOVF MULPMSB,W
        MOVWF ANSWER1
        MOVF PRODLSB,W
        MOVWF ANSWER2
        MOVF PRODMSB,W
        MOVWF ANSWER3
        RETURN
```

which are then copied into the four bytes of ANSWER for use elsewhere as required.

If the MSBs of MULC or MULP are not used, they should be cleared before calling MULTIPLY.

Peter's code can be copied into your program and used as a "library" routine, accessed via preparatory commands such as shown in Listing 42.

EXERCISE 34

34.1 Experiment with different BIN and multiplying values.

34.2 Using the Multiply routine, extend the clock program in TK3TUT30.ASM so that a total seconds count since midnight is shown in addition to the basic hours, minutes and seconds. Hint, first convert the BCD values to binary. Several more EQUated registers will be needed to hold the interim calculations.

TUTORIAL 35

CONCEPT EXAMINED

Division routine

CONNECTIONS NEEDED

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

PIC16F8x, PIC16F62x and PIC16F87x families do not have division commands. Peter Hemsley's code for dividing a 2-byte value by another 2-byte value is shown TK3TUT43.ASM.

An example of its use is shown in Listing 43. The binary value to be divided is held in BIN0 (LSB) and BIN1 (MSB) and copied into DIVIDLSB and DIVIDMSB. The value by which BIN is to be divided is placed into DIVISLSB and DIVISMSB and may be a numeral as shown (H'0103') or from another pair of bytes whose value has been set elsewhere in the program. The answer is held, in descending order of bytes, in DIVIDMSB, DIVIDLSB, REMDRMSB, REMDRLSB (REMDR being the undivided remainder). DIVIDMSB and DIVIDLSB are then copied into ANSWER1 and ANSWER0 for use elsewhere as required.

If either DIVIDMSB or DIVISMSB are not used, the respective one should be cleared before calling DIVISION.

Peter's code can be copied into your program and used as a "library" routine, accessed via preparatory commands such as shown in Listing 43.

LISTING 43 – PROGRAM TK3TUT43

```
            MOVF BIN0,W
            MOVWF DIVIDLSB
            MOVF BIN1,W
            MOVWF DIVIDMSB
            MOVLW 3
            MOVWF DIVISLSB
            MOVLW 1
            MOVWF DIVISMSB
            CALL DIVISION
            ; divide by H'0103'
            MOVF DIVIDLSB,W
            MOVWF ANSWER0
            MOVF DIVIDMSB,W
            MOVWF ANSWER1
            RETURN
```

LISTING 44 – PROGRAM TK3TUT44

```
MAIN        BTFSS INTCON,2
            GOTO MAIN
            BCF INTCON,2
            MOVLW B'10000001'
            IORWF CHAN0,W
            MOVWF ADCON0
            CALL DELAYB
            BSF ADCON0,GO
            CALL GETADC
            MOVLW B'10000000'
            CALL LCDLIN
            CALL SHOWVAL
            MOVLW B'10000001'
            IORWF CHAN1,W
            MOVWF ADCON0
            CALL DELAYB
            BSF ADCON0,GO
            CALL GETADC
            MOVLW B'11000000'
            CALL LCDLIN
            CALL SHOWVAL
            GOTO MAIN

GETADC      BTFSC ADCON0,GO
            GOTO GETADC
            MOVF ADRESH,W
            MOVWF ADCMSB
            BANK1
            MOVF ADRESL,W
            BANK0
            MOVWF ADCLSB
            RETURN
```

EXERCISE 35

35.1 Write a clock program in which only seconds are counted. Using the Division facility, convert the seconds to hours, minutes and seconds and output the values to the l.c.d. in decimal.

TUTORIAL 36

CONCEPT EXAMINED

ADC conversion routine for PIC16F87x family

This example is not capable of being run using the PIC16F84 which does not have analogue-to-digital (ADC) capabilities.

Analogue to digital conversion (ADC) is a facility provided with the PIC16F87x family. A full discussion of ADC conversion is too lengthy for this tutorial and readers are referred to Microchip's data sheets for this family.

However, in a nutshell, devices in the PIC16F87x family each have several pins which can be set for use as ADC inputs, the allocation depending on the PIC type. The PIC16F877 has eight pins, RA0 to RA5, plus RE0 to RE2.

There is a choice of which pins are used in ADC mode and the selection is made via register ADCON1 (data sheet section 11-2). ADC channels are accessed via register ADCON0, which also allows the conversion clock rate to be adjusted.

PIC16F87x devices have a 10-bit ADC, held in two bytes, ADRESH (MSB) and ADRESL (LSB). Bit 7 (ADFM) of ADCON1 controls whether the value is justified to the left or right of those registers.

An example program is given in TK3TUT44.ASM, part of which is shown in Listing 44. In the full listing, and from within BANK1, ADCON1 is set for RA0, RA1 and RA3 as ADC inputs, with ADFM set for righthand justification (ADC bits 0 to 7 in LSB, and bits 8 and 9 as bits 0 and 1 of the MSB). It will be seen that TRISA is then set for RA0, RA1 and RA3 as inputs, for ADC use, but also RA4 as an input for normal digital use, and RA2, RA5 as digital output.

The channel selection codes have been set into named registers, CHAN0 to CHAN7, and during the program the desired ADC channel is set via ADCON0 using these register values.

In Listing 44, sampling is done each time the timer rolls over, first for CHAN0 (RA0). Command MOVLW B'10000001' configures bits 7 and 6 for a sampling oscillator rate of Fosc/32, and sets bit 0 to turn on the ADC facility. The value is then ORed with the channel code (IORWF CHAN0,W), and the combined value MOVed into ADCON0.

Following a brief delay, conversion is initiated (BSF ADCON0,GO) and the ADC retrieval routine called (GETADC). Once ADCON0,GO bit is found to be low, the converted value is retrieved and output in decimal to the l.c.d. (via SHOWVAL, see full listing).

Channel 1 is then activated and processed in a similar way, after which the process is repeated from label MAIN.

EXERCISE 36

36.1 Experiment with the ADC routine, accessing other available PIC16F877 pins. A variable voltage can be applied to any ADC pin via TK3's preset VR3. Only apply a voltage within the range 0V to 5V d.c. if you are using an external source.

36.2 Study Microchip's data sheet (DS30292C) for more detail about using the PIC16F877's ADC facility.

TUTORIAL 37

CONCEPTS EXAMINED

CBLOCK equates defining function
I^2C interfacing to serial EEPROM chips (e.g. 24LC256) from PIC16F87x family

CBLOCK COMMAND STRUCTURE

Up to now you have been equating values and addresses using the FILE1 EQU H'20' type of command. This has allowed you to give names to Special File Register address values, and to the normal data registers. There is another method through which data register names can be given addresses, and that is through Microchip's CBLOCK option, as can be used when writing ASM files in their MPASM dialect.

TK3 also recognises the CBLOCK function (since version V1.4) and it represents a very easy way to name addresses which are not critical in terms of their actual locations. This function applies to any of the data registers that lie typically between H'20' and the maximum address available for a specific PIC type. It is not suitable for use with Special Function Registers, whose locations are fixed, or bit values, whose values are also fixed.

CBLOCK is relevant to the discussion now as programs TK3TUT45 and TK3TUT46 will be combined in program

TK3TUT47, along with some other files to create a larger overall function, that of a data logger with facilities for outputting to a PC. Such combining of several program sources is much aided by the CBLOCK function.

Listing 45 shows an example of using CBLOCK to allocate some of the registers used in TK3TUT45.

LISTING 45 – PROGRAM TK3TUT45

```
        CBLOCK
; automatically allocates equated addresses to the following registers:

MEMHI
MEMLO
WADDRL
WADDRH
RADDRH
RADDRL
        ENDC    ; end of allocation block
```

When the assembler comes across the CBLOCK statement it allocates ascending address numbers to each of the names in the list that follows. The program initially sets the starting value in relation to any equated data registers already declared.

For example, the program might have declared the starting value to be H'20'. In Listing 45, MEMHI would then be equated by the assembler to be register H'20', and MEMLO then equated as H'21', and so on. The function is terminated when the assembler finds the ENDC command at the end of the list. The CBLOCK list in TK3TUT45 is much longer than shown in Listing 45.

It is also possible to state the CBLOCK starting address through the CBLOCK command itself. This can take the form of:

CBLOCK H'35'

in which case H'35' will become the starting address.

Or the form could be:

STARTVAL EQU H'22'
CBLOCK STARTVAL

This would allocate H'22' as the start address holding it in STARTVAL. Any name can be used instead of STARTVAL, and any value given to it, in any of the previous discussed forms.

The great advantage of CBLOCK is that Include files can have a series of named registers included within their own CBLOCK function, and for those to be automatically equated appropriately within the main program. Examples of this will be seen in the full listing of TK3TUT47 and the programs it calls as Include files.

In TK3TUT45, because CBLOCK has not been given a starting value, the value is automatically allocated as *TK3*'s default of H'20', and all of its named registers are numbered accordingly. The last value used is then stored by *TK3*, for further use if another file having a CBLOCK list is Included.

Each time a called Include file is pulled in by *TK3*'s assembler, any CBLOCK names within that file are numbered consecutively from the last value. Care has to be taken, of course, that multiple CBLOCK names do not cause the maximum register limit of the PIC to be exceeded, and that identical names are not found in two or more Included files.

The latter situation will be reported as an error condition by *TK3*. The former, though, can only be assessed by inspection of the .LST file generated during assembly.

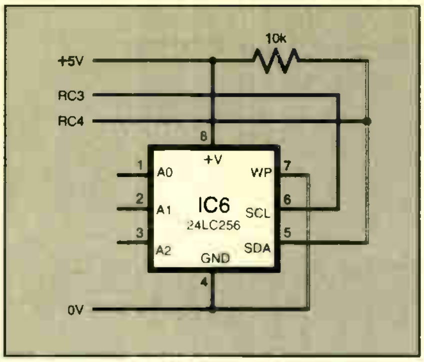


Fig. 10 Basic connections between a 24LC256 and a PIC16F877x.

WRITING TO SERIAL EEPROM

Microchip manufacture a variety of non-volatile serial EEPROM devices which can be readily interfaced to the PIC16F87x family, and possibly other PIC families too, although the author has not done so. Serial EEPROM devices allow large blocks of data to be stored indefinitely and retrieved at a later date, even after power has been switched off and back on again. The facility is of enormous value in applications such as data logging, for example.

The serial devices used by the author in a number of designs are from the 24LCxxx family, in particular the 24LC256 which can store 256K bits of data, i.e. 32768 (32K) bytes of data. The "xxx" in the code number indicates the thousands of bits that the device can store. Microsoft datasheet DS21203F covers the 24LC256.

The basic interfacing to a PIC16F87x is shown in Fig.10.

The interface protocol used by these chips is known as I^2C, pronounced I-squared-C (although you may also hear I-TWO-C used as well). The meaning is Inter-Integrated Circuit, i.e. one i.c. talking to another. This protocol requires just two signal wires to be connected between the PIC and the EEPROM chip, one for data, transmitted in serial format, and the other for a clock signal.

The devices are manufactured so that up to eight can be used in a block without additional circuitry. The choice of which device is accessed is determined by a 3-bit binary address code that is transmitted to the device as part of the data transfer process.

Allocating a device to a particular address is done by connections to the three address pins, A0 to A2. The address is set by the binary code on those pins (from decimal 0 to 7, binary 000 to 111). Internally, the pins are biased to 0V and so to set a pin for 0V you simply leave it unconnected. To set it high the pin is wired to the +5V power line.

The program used by the author since his *8-Channel Data Logger* of Aug/Sept '99 is a slightly modified variant of that supplied by Microchip on their Technical Library CD-ROM disk 2, **download\appnote\category\eeproms\00567.ZIP**. The routine for writing to the serial EEPROM chip is in file **2WDPOLL.ASM**, and reading back from it is in file **2WSEQR.ASM**. The author has slightly modified the programs, particularly to allow the Write facility to be used with a variety of PIC clock rates.

The code shown in Listing 45A is that which calls the Write to EEPROM routine in Microchip's program, allowing the MSB and LSB of a 16-bit data value (two bytes) to be stored at consecutive addresses in the selected EEPROM chip. The full listing is in program TK3TUT45.ASM.

Before calling the entry to the routine at SAVESAMPLE your own program must:

- place the MSB of the data to be stored into MEMHI
- place the LSB of the data to be stored into MEMLO
- set WADDRH with the MSB of the EEPROM chip address required
- set WADDRL with the LSB of the EEPROM chip address required
- load W with the value corresponding to the EEPROM chip to be accessed (between 0 and 7)
- then use the command CALL SAVESAMPLE

On entry to SAVESAMPLE, the value in W (the required EEPROM chip number) is placed into ECHAN. Then at label WRMSB the value in MEMHI is pulled into W, and Microchip's WRBYTE routine is called. The EEPROM address is then incremented and the value in MEMLO is pulled into W and again WRBYTE is called. The EEPROM address is then decremented back to the previous value and an exit made from the routine.

It is important that your program should avoid entry address values which would cause LSB rollover when command INCF WADDRL,F is made.

There is an additional requirement to be met before this routine can be used and it is set at the head of your program. The requirement is to set a delay value for use by Microchip's program to suit the PIC's clock rate.

LISTING 45A

```
SAVESAMPLE
; Entry point for storing double byte data to serial EEPROM
           MOVWF ECHAN
      ; set EEPROM chip number held in W into ECHAN
WRMSB      MOVF MEMHI,W        ; get data MSB
           CALL WRBYTE         ; store it to EEPROM
           INCF WADDRL,F       ; inc EEPROM address
WRLSB      MOVF MEMLO,W        ; get data LSB
           call WRBYTE         ; store it to EEPROM
           DECF WADDRL,F       ; set EEPROM address
                                 back to entry value
           RETURN
```

Microchip's original program used several series of NOP commands to provide several delays in the Write routine, varying between three and five NOPs, depending on the sub-section of the routine. Five NOPs is taken as the delay unit for Microchip's program, which was written for use at 4MHz, and each NOP provides a delay of 1μs at 4MHz.

To simplify the program's use with different clock rates, the author has replaced the several series of NOPs with commands that call a given number of NOPs through a definition at the head of the program:

#DEFINE SERIALDELAY CALL CYCLESx

where "x" in CYCLESx is replaced by a number between 4 and 25. A value of 4 gives the minimum delay possible. A value of 5 is taken as suitable to clock rates of 4MHz and below. A value of 25 would suit the program to a clock rate of 20MHz.

A series of consecutive labels is included in the author's program that accesses Microchip's routines, e.g.:

```
CYCLES25    NOP
CYCLES24    NOP
CYCLES23    NOP
etc., through to:
CYCLES5     NOP
CYCLES4     RETURN
```

Thus if the definition is

#DEFINE SERIALDELAY CALL CYCLES25

the program is assembled such that command SERIALDELAY is replaced by CALL CYCLES25. When run, the program thus calls label CYCLES25 from the various points at which the command SERIALDELAY is given. At the called label, each NOP in the list down to CYCLES5 is then actioned, followed by an exit at CYCLES4.

The number of NOPs introduced in the sequence is related to the rate at which the PIC performs each command with respect to the clock rate. Recall that PICs effectively divide the clock rate by four. Thus a clock rate of 4MHz results in an effective cycle rate of 1MHz.

PIC commands take either one or two cycles to complete (as shown in Table 1, part 1). A CALL takes two cycles to perform, NOP takes one, and RETURN takes two.

If CALL CYCLES4 is performed, the delay is four cycles, CALL = 2, RETURN = 2. CALL CYCLES5 takes five cycles, four for CALL/RETURN plus one for the NOP, and so on.

The object is to introduce a delay of a minimum of 1μs between various actions within Microchip's program, although it does not matter if the delay is longer. To calculate the CALL CYCLESx value use the following method:

- Required clock rate = 20MHz
- Assume Microchip's 4MHz rate requires 5 cycles
- Your rate therefore = 5 × (20 / 4) = 5 × 5 = 25
- Thus you would need to use CALL CYCLES25

READING FROM SERIAL EEPROM

The technique for reading double-byte data back from a serial EEPROM chip is very straightforward. It just involves the following:

- set RADDRH with the MSB of the EEPROM chip address required
- set RADDRL with the LSB of the EEPROM chip address required
- then use the command CALL READ

Microchip's read data routine is then entered and the data recalled from the given EEPROM address is put as the MSB into MEMHI, and as LSB into MEMLO. You can then use these values as you wish.

TUTORIAL 38

CONCEPTS EXAMINED

Outputting serial data from PIC16F87x to PC at selected Baud rate

The PIC16F87x family allow data to be output serially from PORTC RC5 and RC6 as a serial stream conforming to the RS-232 protocol and at a chosen Baud rate. The Baud rate required is normally set via a routine called during a program's initialisation procedure. That Baud rate then remains set for the rest of the program.

The Baud rate can be set for one of many options offered through Microchip's datasheet DS30292A for the PIC16F87x family. The selection can be made as discussed in the datasheet's section 10, with particular reference to Tables 10.3, 10.4 and 10.5.

The datasheet also discusses many aspects of serial output and input and you are referred to it for detailed information. In this Tutorial we simply show a practical example of outputting data, in relation to the mode the author has frequently used.

SETTING BAUD RATE

The routine for setting the Baud rate is shown in Listing 46. On entry at label SETBAUD, a value (20 in this case) is loaded into W (within BANK1) and placed into the PIC's SPBRG register. The value is in respect of a 9600 Baud rate when using a clock rate of 3·2768MHz.

Regrettably, Microchip do not give the SPBRG value for a 3·2768MHz crystal, but they do give two formulae for calculating the value in relation to PIC clock and asynchronous Baud rates. The first formula is used when register TXSTA bit BRGH = 1 (high speed). The second is when BRGH = 0 (slow speed).

Baud = Fosc / (16 × (X + 1) for BRGH = 1
Baud = Fosc / (64 × (X + 1) for BRGH = 0

where *Fosc* is the PIC's clock rate and *X* is the SPBRG value.

Microchip state that it may be advantageous to use BRGH = 1 even for slower Baud clocks, because its equation can reduce Baud rate error in some cases.

Transposing the formula when BRGH = 1, we get:

X = (Fosc / (Baud × 16)) – 1

Thus for Fosc = 3.2768MHz and Baud = 9600 we get:

X = (3276800 / (9600 × 64)) – 1
= (3276800 / 153600) – 1
= 20.333

Only integer (whole number) values can be used and so the calculated SPBRG value is 20. Putting the value of 20 into *X* of the formula, we get an actual Baud rate of:

3276800 / (16 × (20 + 1))
= 3276800 / 336 = 9752·38

This represents an error of (9752.38 – 9600) / 9600 = 0.015873%

An SPBRG value of 21 produces an error of 0·030303%, and 19 would give 1·06667%. An SPBRG value of 20 is thus a reasonable one to use (a certain amount of latitude is normal and the PC's serial input routines should tolerate minor slippage).

Asynchronous mode is needed for the example in Listing 46. The datasheet shows in its Fig.10-1 that the TXSTA register needs bit 4 (SYNC) cleared for this mode. Bit 2 is BRGH and, as indicated above, is set to 1.

Bit 7 (CSRC) is "Don't Care" for asynchronous mode.

Bit 6 (TX9) selects between 9-bit and

LISTING 46 – PROGRAM TK3TUT46

```
; set serial output Baud rate
; as shown is set for 9600 Baud with a 3.2768MHz clock rate

SETBAUD
        BANK1
        MOVLW 20             ; BRG for 9600 Baud from
                               3·2768MHz, brgh=1
        MOVWF SPBRG
        MOVLW B'00000100'    ; set sync=0, brgh=1 + ninth bit
                               not set
        MOVWF TXSTA
        BCF PIE1,TXIE        ; clear interrupt bit
        BANK0
        MOVLW B'10000000'    ; set SPEN bit (7) of RCSTA reg
        MOVWF RCSTA
        BANK1
        BSF TXSTA,TXEN       ; enable transmission (bit TXEN)
        BANK0
        RETURN
```

LISTING 46A

```
; routine that causes the actual output of a serial data byte
SERIALSEND
        BTFSS PIR1,TXIF      ; wait for TXIF bit 4 to go high
        GOTO SERIALSEND      ; (showing TXREG empty)
        MOVWF TXREG          ; put val (held in W) in TXREG
                               ready for sending
        RETURN
```

8-bit transmission (1 and 0 respectively). 8-bit is required in the example.

Bit 5 (TXEN) enables/disables transmission (1 and 0 respectively).

Bit 3 is unimplemented in the PIC16F87x and so ignored.

Bit 1 (TRMT) indicates whether the transmit shift register is empty (1) or full (0).

Bit 0 is the 9th bit of transmit data (and can also be used as a parity bit). It is not needed in the example, and so is set to 0.

Consequently, following the setting of SPBRG, TXSTA is loaded with B'00000100'. Next the Transmit Interrupt Enable bit (TXIE) of register PIE1 is cleared to disable the interrupt, and BANK0 is then selected again.

Next the SPEN bit (7) of register RCSTA is set to enable pins RC6 and RC7 for serial port mode. After which register TXSTA bit TXEN is set within BANK1 to enable transmission. Setting back to BANK0 follows, and the Baud rate setting routine is exited.

In other applications, the only values that concern you are those for Baud rate (SPBRG) and the initial setting of TXSTA. The other statements can be repeated parrot-fashion.

The Microchip INClude file PIC16F877.INC holds the values for the named registers and bits, and allocates them when imported to the program.

SERIAL OUTPUT

Listing 46A shows the routine that causes the actual output of a serial data byte. The SERIALSEND routine is entered with W holding the value to be transmitted. A wait is then made until bit TXIF of the PIR1 register goes high, indicating that register TXREG is ready to be loaded with the byte to be sent.

As soon as TXREG is loaded with the value in W, the transmission is then automatic, and out of your hands! Consequently, the routine is then exited and your program can get on with what else it wants to do, typically at this time to get the next value to be transmitted until all values have been sent.

PIR1 TXIF automatically goes low when TXREG is loaded, staying low until transmission of that byte has been completed.

So that's all there is to transmitting data from a PIC as a stream of serial data at a known Baud rate. The destination is likely to be a PC, but it could be sent to any device capable of reading serial data.

Describing how a PC (or other device) receives the data is beyond the scope this series, but *EPE* has published several examples of PC programs that do so. The *BioPIC Heart Monitor* of June '02, shows an example written in QBasic. The *Earth Resistivity Logger* of Apr/May '03 shows an example written in Visual Basic (VB6) using Robert Penfold's INPOUT32.DLL as the active software interface.

We shall also be publishing shortly Joe Farr's serial input/output OCX facility for use with Visual Basic. Joe has written it specially for *EPE* and it will be a boon to users of VB. Details will be announced in due course.

It should be noted that whilst the author has found QBasic can input serial data directly from a PIC, VB6 behaves more reliably when a dedicated RS-232 chip is used between the PIC and the PC. An example of using a MAX232 device in this role is shown in the *Earth Resistivity Logger* Part 1, April '03.

TUTORIAL 39

CONCEPT EXAMINED

Practical example of recording analogue data to serial EEPROM and subsequent outputting as RS-232 serial data.

This Supplement does not have enough space to include Tutorial 39 and it has been placed on the PIC Resources CD-ROM as EPE PIC Tutorial V2 Extra.

Nor has there been space to include the table of Reset Conditions for the PIC16F84. This may be found on Microchip's datasheet 30430C. Datasheets 30292C and 40300 are for the PIC16F87x and PIC16F62x families respectively. Browse **www.microchip.com**.

TUTORIAL 40

CONCEPTS EXAMINED

Programming
PICs vs. Hardware
Summing-up

PROGRAMMING

To the uninitiated, it may seem that a software programmer simply sits down and writes all the commands in a single operation. If only it were that simple! Before a single line of code is written, there is a great deal of thought involved about the overall objective and how each step on the way to achieving it might be performed. Part of this consideration relates not only to the logic of the software routines, but also to the control requirements of external interfaces.

There are two schools of thought about the planning. The first considers that the use of flow charts is an essential requirement. The other doesn't! The advantage of using a flow chart is that it shows the questions and answers of each stage of the program in a diagrammatic form. Theory says that this chart then enables the code to be written to meet each of the requirements illustrated.

The use of a flow chart certainly helps in concentrating immediate thought processes, and in recapturing concepts in the future, but it cannot display the command by command reasoning of each line of code. Only the code itself shows that, unless you translate each line of code into lengthy textual comments, in which case there is the danger of getting bogged down with words.

Additionally, there is always the possibility that some logical consideration has been omitted from the flow chart and which only comes to light once you try to run the program, requiring the chart to be redrawn as well as the software having to be rewritten. The author finds that the detailed thinking about the program structure already builds up as a mental flow chart which does not require to be set down on paper.

It is acknowledged that in a commercial situation it would be mandatory for the program structure to be well documented with flow charts – the program might eventually need to be changed by someone other than the original program writer. In that case, the flow chart would give a more immediate insight into the original programmer's thought processes.

Although the author does not use flow charts when programming, let us not deter you from drawing them if you prefer to do so. You may well find that they help you to grasp what you are doing more readily than just relying on your mental "visualisation" processes.

To discuss flow charts more fully is beyond the scope of these Tutorials, but you will find examples of them on Microchip's Technical Library CD-ROM. It has to be said, though, that even in that publication, which is full of PIC datasheets and program listings, flow charts are not widely used.

STAGE-BY-STAGE

Whether or not you use flow charts, you should never attempt to write the entire program from beginning to end in one operation. That way can lead to extensive problems when you try to debug the program having found that it does not do what you expected. Take each routine stage-by-stage. Get one small section of code working before you move onto the next. Then get that next small section working before you try to join it to the previous part. "Be methodical" is the key command when programming.

In many ways, the manner in which these Tutorials have been presented has been along those lines. We have tried to show you individual structures which first stand on their own, and then are extended or joined to others to achieve a larger operational system. Taking TK3TUT2 as the effective starting point, that program used only 16 command lines. Gradually we developed other programs as stand-alone routines. Then things began to take a broader structure as concepts were integrated into a more sophisticated whole. With TK3TUT33, 232 commands were sent to the PIC.

As you get further into PIC programming, you may decide that you would like to write code in conjunction with a simulation program. These help you to debug code on your PC before downloading it to the PIC. They will not replace the thought processes needed when writing code, but they will let you find many (but not all) of the errors more quickly.

However, the author finds it very easy to check program operation when the code is in the PIC and the PIC is connected to its various interfaces. Had the PIC16F84 not been an EEPROM device, then this would not be an acceptable technique, but it *is* rapidly reprogrammable and so is usable as a live test-bed.

One further point, when writing a program the author finds it useful to supplement its software file name with a suffix number, increasing the number at each save of a major addition or change to the previous code written. This allows an earlier version to be recalled should the need arise. Thus you would number as, for example, PICIT01.ASM, PICIT02.ASM, PICIT03.ASM, etc.

PICS vs. HARDWARE

As enormously beneficial as the use of a microcontroller can be, there is the likelihood that it may be regarded by the inexperienced as the ultimate answer to all electronic circuit design. This is most definitely not the case. All that a microcontroller will do is assist in using software commands to replace a fair number of operations for which many electronic components would otherwise be needed. It cannot substitute for all electronic requirements.

There are also situations in which a microcontroller *can* be used but it is not necessarily desirable that it should. What you will discover as you get further into programming, is that the act of programming a PIC to replace a given number of logic chips takes far longer than if you were to design a circuit that performed the same function but only used such chips.

Unless you actually *want* to get a PIC to do something because it *can* and you see it as a challenge, always ask yourself if the additional development time is worth it in order to save a chip or two.

SUMMING-UP

When writing software, you will find much frustration through the inability to immediately see the bug in a program routine. Eventually, though, you will spot it and the relief and exhilaration of at last getting that part to work is enormous. In that frame of mind, you will move onto writing the next sub-routine with the utmost confidence and anticipation of not making a mistake on *this* one.

Would that it were so! You can, and you will, make mistakes. But the ultimate satisfaction of a complete working design makes it all worthwhile.

If you can't take occasional bouts of desperation, isolation from friends and family, followed by periods of ecstasy and feelings of well-being towards all humanity, leave programming alone. The author, though, has become a "programming-addict" and thrives on the challenges, come what may!

Finally, remember that Murphy's Law has its most powerful influence when programming is involved. If the microcontroller or other computer *can* misunderstand what you *mean* by your commands, it *will*. It is up to you to see the way in which each and every one of your commands will *actually* be interpreted. You are the intelligent one, the computer simply obeys your commands!

TABLE 8 MPASM SHORTHAND COMMANDS The following MPASM shorthand commands are recognised by *TK3*.

Command	*Equiv. coding*	*Meaning*
ADDCF f,d	BTFSC STATUS,C INCF f,d	Add Carry to File
ADDDCF f,d	BTFSC STATUS,DC INCF f,d	Add Digit Carry to File
B k	GOTO k	Branch to
BC k	BTFSC STATUS,C GOTO k	Branch on Carry to k
BDC k	BTFSC STATUS,DC GOTO k	Branch on Digit Carry
BNC k	BTFSS STATUS,C GOTO k	Branch on No Carry
BNZ k	BTFSS STATUS,Z GOTO k	Branch on Not Zero
BNDC k	BTFSS STATUS,DC GOTO k	Branch on No Digit Carry
BZ k	BTFSC STATUS,Z GOTO k	Branch on Zero
CLRC	BCF STATUS,C	Clear Carry
CLRDC	BCF STATUS,DC	Clear Digit Carry
CLRZ	BCF STATUS,Z	Clear Zero
MOVFW,f	MOVF f,W	Move File to W
NEGF f,d	COMF f,F INCF f,d	Negate file
SETC	BSF STATUS,C	Set Carry
SETDC	BSF STATUS,DC	Set Digit Carry
SET Z	BSF STATUS,Z	Set Zero
SKPC	BTFSS STATUS,C	Skip on Carry
SKPDC	BTFSS STATUS,DC	Skip on Digit Carry
SKPZ	BTFSS STATUS,Z	Skip on Zero
SKPNC	BTFSC STATUS,C	Skip on No Carry
SKPNDC	BTFSC STATUS,DC	Skip on No Digit Carry
SKPNZ	BTFSC STATUS,Z	Skip on Not Zero
SUBCF f,d	BTFSC STATUS,C DECF f,d	Subtract Carry from File
SUBDCF f,d	BTFSC STATUS,DC DECF f,d	Subtract Digit Carry from File
TSTF f	MOVF f,F	Test File

Where: d = destination (0 or 1 – W or F) f = file k = literal value

APPENDIX A: BUGGED TEASER

Now to give your understanding of PIC programming (and your logical thinking) a bit of a test!

Load TK3TUT48.ASM into your text editor. Add an appropriate initialisation routine at the beginning, and add a suitable set of l.c.d. operating routines as illustrated earlier. Save the code as two slightly different file names, then work on the second file.

TK3TUT48 has a number of bugs deliberately included – your task is to debug the program and get it working as a frequency counter! Some of the deliberate errors will be reported by the Assembler following assembly. These are "literal" errors which anyone might make while creating a PIC program – simple slips in thinking. The others, though, are "logical" errors – much more significant errors in a programmer's analysis of a situation and its interpretation, but still errors anyone could make.

First of all, get the l.c.d. to display the opening message correctly (and without the program "crashing"). Then, with the aid of a signal generator (0V/5V output logic level) set to about 10kHz (you must decide which PIC input pin to use), solve the remaining logical problems. You'll probably curse the author a few times before you solve it all, but keep at it!

Having solved it (and felt the satisfaction of success!), think about how switches and other routines could extend the counter's range.

APPENDIX B: USEFUL PIC INFORMATION

Microchip web site:
http://www.microchip.com

EPE web site:
http://www.epemag.wimborne.co.uk

EPE PIC-project source code files:
ftp://ftp.epemag.wimborne.co.uk/pub/PICS

FURTHER READING

The following texts are on the PIC Resources CD-ROM:

Asynchronous Serial Communications (RS-232), John Waller, unpublished

EPE StyloPIC (precision tuning of musical notes), John Becker, July '02

How to Use Graphics L.C.D.s with PICs (detailed control information for PIC16F877), John Becker, Feb '01 (Supplement)

How to Use Intelligent L.C.D.s, Julyan Ilett, Feb/Mar '97

PIC Macros and Computed GOTOs, Malcolm Wiles, Jan '03.

PIC Magick Musick (illustrates use of 40kHz ultrasonic transducers), John Becker, Jan '02

PIC to Printer Interfacing (Epson dot matrix printers), John Becker July '01

PIC Toolkit Mk3, John Becker (PIC programmer p.c.b./circuit for TK3), Oct '01

PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

PIC16F87x Additional Memory (how to use it), John Becker, June '01

PIC16F87x Microcontrollers (review), John Becker, April '99

PIC16F87x Mini Tutorial, John Becker, Oct '99

Programming PIC Interrupts, Malcolm Wiles, Mar/Apr '02

Using I^2C Facilities in the PIC16F877, John Waller, unpublished

Using PICs with Keypads (16-key "data" keypads), John Becker, Jan '01

Using Square Roots with PICs, Peter Hemsley, Aug '02

Using TK3 with Windows XP and 2000, Mark Jones, Oct '02

Using the PIC's PCLATH Command, John Waller, July '02

☐

Constructional Project

BACK TO BASICS

BART TREPAK — Part Five

Illustrating how useful circuits can be designed simply using transistors.

MINI THEREMIN

DESPITE their obvious uses in amplifying the sound of conventional acoustic musical instruments, transistors have had a great impact in terms of the actual generation of musical notes and rhythms.

This is especially true since integrated circuits (which are comprised of many transistors) were first introduced, enabling instruments such as electronic organs and synthesisers to be produced. These can produce sounds which mimic conventional instruments and are played selecting the required notes by pressing switches normally arranged as a piano keyboard.

In such instruments, each note may be generated by its own oscillator, or by a master oscillator and many divider stages to obtain the lower notes. Notes are then processed by filters and envelope shapers which tailor the waveform to produce the required sound, and fed to an amplifier and loudspeaker.

THEREMIN

One instrument that differs radically from keyboard instruments is the Theremin, named after its inventor Leon Theremin. A Theremin produces the notes in a completely different way and does not even require the musician to touch the instrument to play it!

All the notes are produced using the interaction of just two oscillators and the instrument can only play one note at a time. As well as the standard musical tones, all other frequencies in between can also be produced, gliding between them in response to hand movements.

This provides some interesting sounds but also makes the instrument quite difficult to play. This is even more true of the simplified version described here – professional Theremins also have a control enabling the signal to be muted by the performer so that the notes do not have to glide from one pitch to the next.

BEAT FREQUENCY

The operation of a Theremin is based on two high frequency tuned circuit oscillators running at almost identical frequencies. This type of oscillator was discussed in the *Metal Detector* project in Part Two of this series (March '03).

Referring to the circuit diagram shown in Fig.30, the oscillators are based around transistors TR1 and TR2. Note that in this case, however, the two oscillators use an inductive tap to generate the feedback, which is applied to the transistor bases via capacitors C1 and C3.

The first oscillator frequency is variable and the second is fixed. The frequency of oscillation depends on the values of the inductors and their tuning capacitors C2 and C4. In the case of the variable oscillator around TR1, it is also governed by the additional capacitance of the player's hand close to a metal plate or aerial. The inductance values are adjustable so that the frequencies of both oscillators can be tuned as required.

As the hand is moved closer to the plate, this capacitance increases causing a corresponding decrease in the frequency of the oscillator. The changes in capacitance are minute, however, resulting in only very small changes in frequency.

MIXED SOUNDS

The outputs of two oscillators are mixed, resulting in both sum and difference frequencies. If the two basic frequencies are close enough, the resultant beat frequencies will be in the audio range. The interesting thing is that although the original frequencies are high and well above the audio range, a small change in one of them produces a large change in the audio beat frequency producing a very sensitive instrument with a wide pitch range.

The outputs from the oscillators are coupled by resistors R3 and R4 to capacitor C5 and into the mixer stage around TR3.

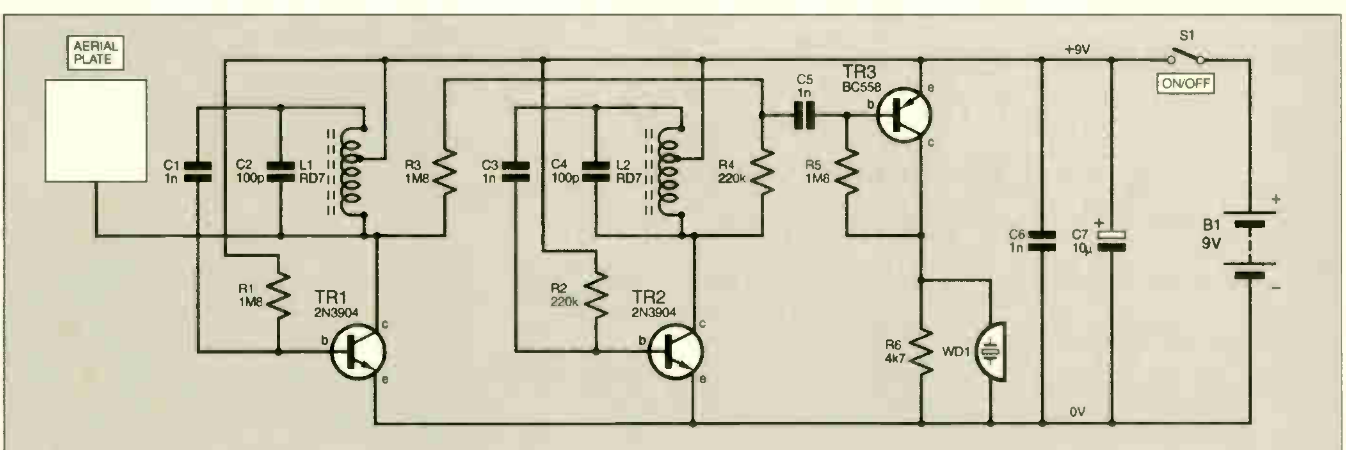


Fig.30. Complete circuit diagram for the Mini Theremin.

COMPONENTS

Resistors
R1, R3, R5 1M8 (3 off)
R2, R4 220k (2 off)
R6 4k7
All 0·25W 5% carbon film

See SHOP TALK page

Capacitors
C1, C3, C5, C6 1n disc ceramic, 2·5mm pitch (4 off)
C2, C4 100p disc ceramic, 2·5mm pitch (2 off)
C7 10µ radial elect. 16V

Semiconductors
TR1, TR2 2N3904 *npn* transistor (2 off)
TR3 BC558 *pnp* transistor

Miscellaneous
L1, L2 Toko RD7 inductor (2 off)
S1 s.p.s.t. min. toggle switch
WD1 piezo sounder

Stripboard, 19 holes x 8 strips; PP3 battery and clip; plastic case to suit; copper-clad p.c.b. laminate or aluminium place, approx. 40mm x 50mm (see text); connecting wire; solder, etc.

Approx. Cost Guidance Only **£6** *excl. case & batt.*

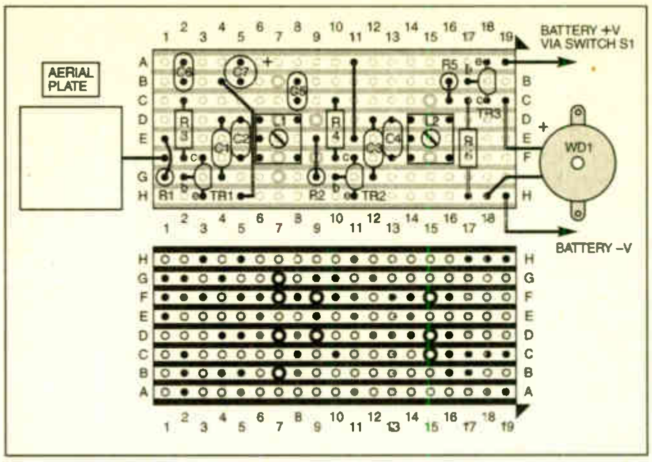
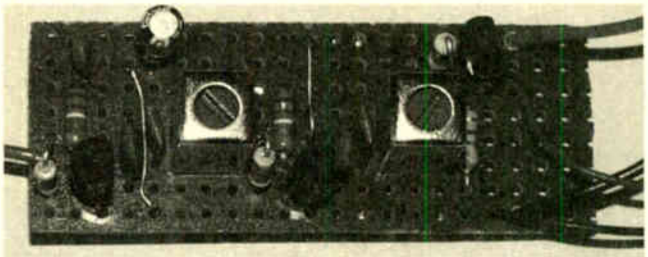


Fig.31. Stripboard component layout, interwiring and details of breaks required in the underside copper tracks.



Component layout on the completed circuit board.

The resistors have relatively high values to prevent the oscillators from interacting undesirably and locking together. The mixer also amplifies the resultant frequencies and drives the piezo transducer WD1.

Frequencies above the audio range are largely attenuated by the capacitance of the transducer, leaving only the audio tone beat frequency. However, if the output is to be connected to an external amplifier in place of WD1, a 2200pF capacitor should be connected in parallel with resistor R6 as the signal could otherwise cause interference in radio equipment.

The circuit is powered by a 9V battery, supplied via switch S1. Capacitors C6 and C7 are included to ensure a low impedance supply at both low and high frequencies. The current consumption is about 1mA.

CONSTRUCTION

The complete circuit is built on a small piece of stripboard having 19 holes × 8 strips, as shown in Fig.31. Before starting construction, the tracks should be cut in the places indicated using a 2·5mm drill, or the special tool available for this.

Two wire links are also required and these can be made from discarded component leads. As with all projects in this series, the layout applies to the specified transistors and if substitutes are used, care should be taken as pinouts may differ.

Inductors L1 and L2 are small i.f. (intermediate frequency) transformers normally used in radio receivers and the types specified do not have integral capacitors. The cans have solder lugs enabling these to be soldered to fix them, although in this application the lugs do not fit into the pitch of the stripboard so they are simply bent up underneath the component before it is mounted.

WD1 is a piezo sounder (not to be confused with a piezo buzzer which contains an integral drive circuit) and this may be connected either way around.

The "tuning" plate should consist of a small piece of aluminium or copper-clad p.c.b. laminate, measuring about 40mm × 50mm, connected to the circuit by a short wire. Alternatively, this can take the form of a short aerial 10cm to 15cm long connected to the same point on the circuit.

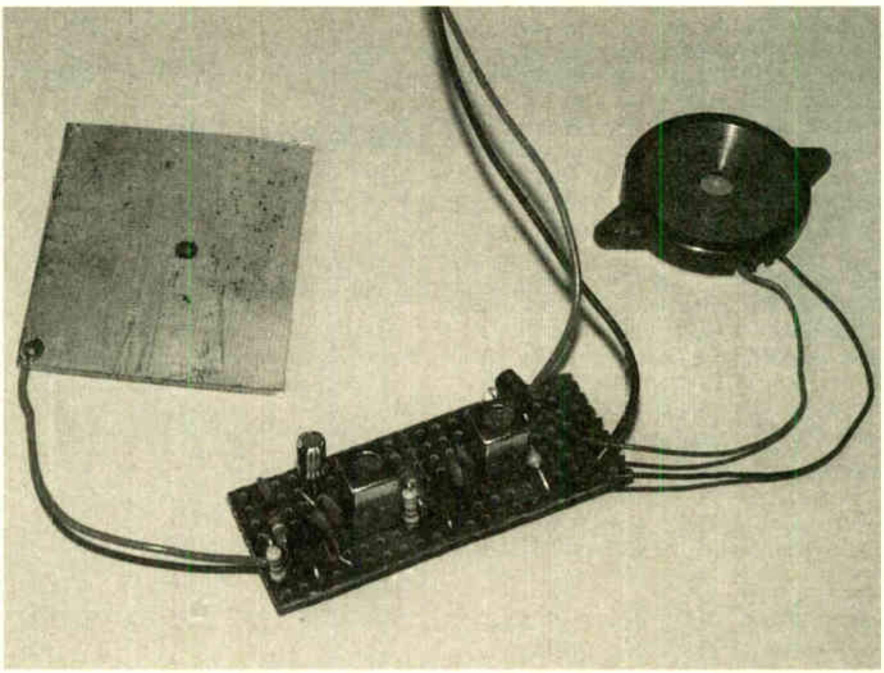
If the unit is to be mounted in a box, a plastic case with a battery compartment would be most suitable.

TUNING

When finished, the circuit must be tuned for correct operation by adjusting the inductor cores so that both oscillators are working at around the same frequency. Only use a plastic blade for adjusting the cores – a metal tool could damage them.

It is best to set one core to about its mid-position and adjust the other until a whistle is heard from the sounder. Bringing your hand near the sensor plate will then result in a lower pitch sound. Alternatively the circuit may be adjusted beyond this point so that the frequency rises as your hand approaches the sensor.

Apart from its undoubted(?) musical applications, the unit could find uses as a rudimentary proximity alarm to detect the presence of people or animals, although the stability of this simple circuit is not ideal for such applications.



Finished Mini Theremin showing wiring to the "tuning" plate and piezoelectric sounder. The tuning plate is an off-cut from a piece of copper-clad board.

TWILIGHT SWITCH

Note that the mains voltage existing at the output of both these circuits is dangerous and these two options should only be built under competent supervision. Suitable insulation, earthing and fuse arrangements must be provided.

The opto-triac type MOC3020 can handle output currents up to 100mA, i.e. a maximum of 23W of 230V a.c. mains power. The typical maximum size of mains driven lamp that can be used with it is thus approximately 15W.

With relay control, the maximum lamp power is limited only by the rating of the relay contacts.

A problem that could be encountered if a mains lamp is fitted is that of the circuit oscillating. When the light level falls, the light will switch on and the ambient brightness will increase causing the lamp to switch off again. The large hysteresis should help to prevent this but it is important that the sensor is positioned so that it cannot "see" the light from the lamp.

THIS circuit is designed to switch on a low-power lamp when it gets dark and switch it off again at sunrise. It could, for example, be used as a burglar deterrent to give the impression that a house is occupied, or to light a path or porch during the hours of darkness.

With a slight modification, it could also be used as a medicine cupboard alarm to give a warning when it has been opened or, by changing the sensor, as a temperature controller (thermostat).

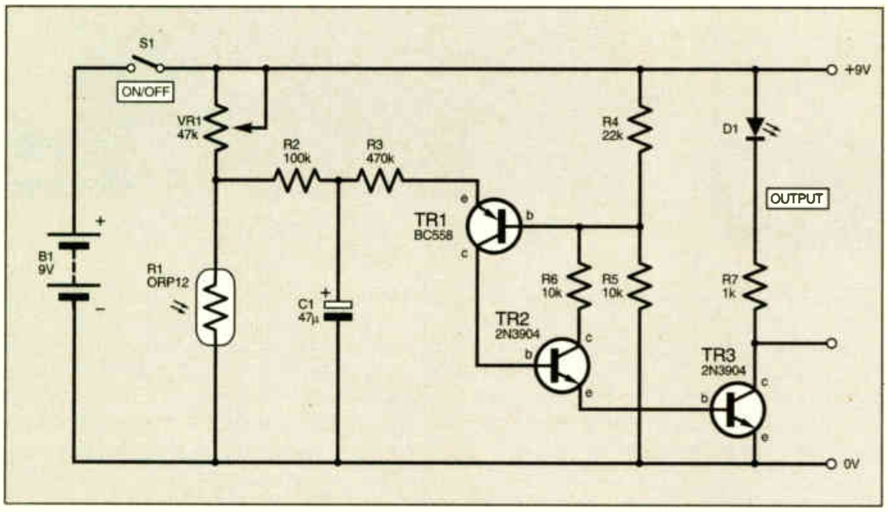


Fig.32. Circuit diagram for the light sensitive Twilight Switch.

CIRCUIT DETAILS

Referring to the circuit diagram in Fig.32, light dependent resistor (l.d.r.) R1 is used as the light sensor. In bright conditions, its resistance is around 2kΩ rising to over 20kΩ in low light and over 1MΩ in darkness.

Transistors TR1 and TR2 form a complementary Schmitt trigger circuit that has two switching thresholds. Assuming both TR1 and TR2 are on, resistors R4 and R5 are connected across the power supply as a potential divider. They set the voltage applied to the base of TR1 at just under 3V, assuming a 9V supply.

With the l.d.r. in darkness, the voltage at its junction with preset VR1 will be above that on TR1's base. The sensor voltage is applied to TR1's emitter via resistors R2 and R3. Capacitor C1 smooths out fluctuations in light intensity during daylight conditions, such as caused by shadows moving across the l.d.r., or illumination by car headlights at night.

LIGHT LEVELS

During darkness, the voltage from the l.d.r. will be sufficient to cause transistor TR3 to be turned on via TR1 and TR2. As a result, l.e.d. D1 is switched on, via ballast resistor R7.

As the light level increases, the resistance of the l.d.r. falls so that the input voltage to the circuit also falls. Once it falls below 2V, TR1 begins to switch off. This causes TR2 to switch off raising the voltage on TR1's base, causing both transistors to switch off rapidly. With TR2 off, TR3 also switches off, as does l.e.d. D1.

With falling light levels, the l.d.r. resistance increases and the voltage at TR1's emitter rises. However, since TR2 is off, the threshold voltage will now be determined only by R4 and R5 (about 3V with the component values given). The input level will therefore have to rise above this value before TR1 can switch on and the circuit revert to its former state with all three transistors on.

It will be seen that there is a difference between the brightness levels at which the circuit switches on and off. This property is called hysteresis and is useful as it gives the circuit a "snap" action, switching on and off rapidly even if the input is changing slowly. It also prevents the lamp switching on and off as the thresholds are approached. Note that altering the value of R6 will vary the hysteresis.

MAINS OPTION

Transistor TR3's collector load, comprising l.e.d. D1 and R7, could be replaced by, or used in conjunction with, an opto-isolated triac or a relay to switch on a mains lamp, as shown in Fig.33b and Fig.33c.

COMPONENTS

Resistors
- R1 — ORP12 light dependent resistor
- R2 — 100k
- R3 — 470k
- R4 — 22k
- R5, R6 — 10k (2 off)
- R7 — 1k

All 0·25W 5% carbon film

See SHOP TALK page

Capacitor
- C1 — 47µ radial elect. 16V

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

Miscellaneous
- S1 — s.p.s.t. min. toggle switch
- VR1 — 47k skeleton preset potentiometer
- WD1 — piezo buzzer

Stripboard, 14 holes x 7 strips; PP3 battery and clip; case to suit (see text); relay (optional), 12V coil with mains contacts, opto-triac (optional) MOC3020 or MOC3040, 12V Buzzer (optional); connecting wire; solder, etc.

Approx. Cost Guidance Only **£6**
excl. case, relay, opto-triac & batt.

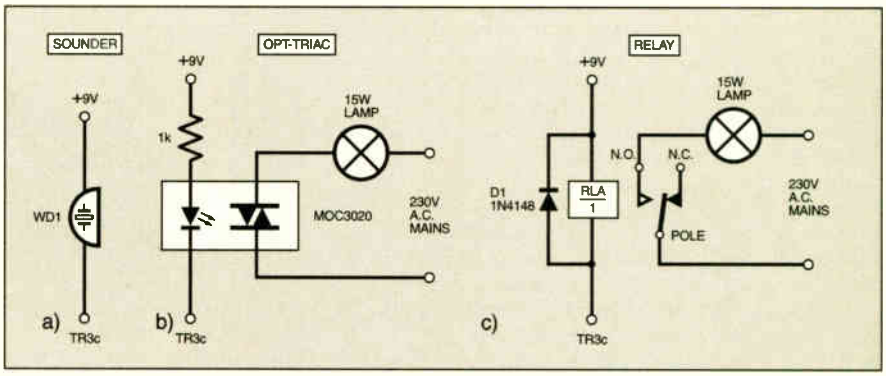


Fig.33. Circuit details for alternative output options.

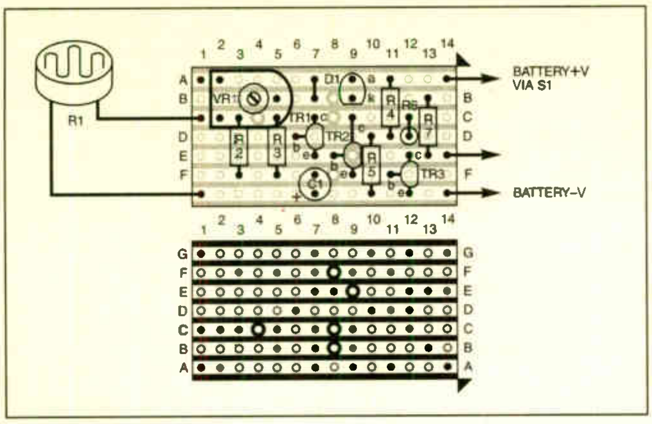
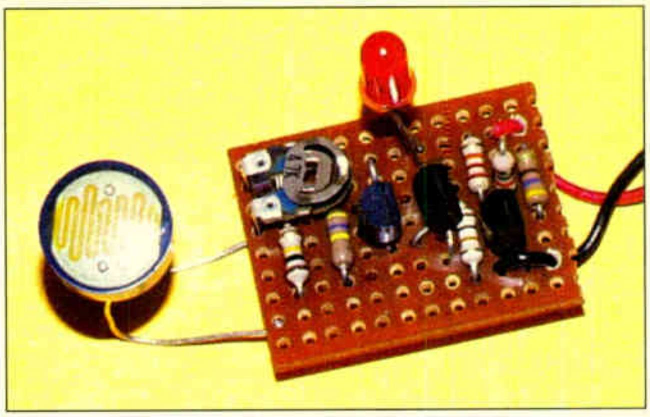


Fig.34. Component layout, wiring and copper break details.



Completed prototype Twilight Switch.

OTHER OPTIONS

A simple thermostat could be built by replacing the l.d.r. with an n.t.c. thermistor (negative temperature coefficient – resistance falls with increases in temperature). Depending on the resistance of the type used, the value of VR1 may need to be altered.

By connecting a buzzer across l.e.d. D1 and R7, and transposing the l.d.r. and preset VR1, a simple medicine cupboard alarm can be made. In this case TR3 will switch on when the ambient light level increases (i.e. when the cupboard door is opened) and switch off when it is dark.

The response delay can be removed if required by omitting capacitor C1.

CONSTRUCTION

The circuit may be built on a piece of stripboard measuring 14 holes by 7 strips as shown in Fig.34. Before assembling and soldering the components on the board, the tracks should be cut in the places indicated by means of a 2·5mm drill or the tool available for this purpose.

Take care to ensure that the transistors, l.e.d. and electrolytic capacitor C1 are inserted the correct way around. There is also one link required which can be made from a piece of discarded resistor lead.

It is also important to connect the buzzer (if used) correctly. These components often have the polarity indicated by the lead with red being positive. Note that a unit with an internal oscillator is required.

The l.d.r. (or thermistor) is not polarity sensitive and may be connected either way around.

The mains switching options **must NOT** be built on the stripboard but as a separate unit and connected to the control circuit by suitable leads. To ensure safety with the mains switching option, the complete circuit must be mounted in an earthed metal case with a suitable mains input plug and outlet socket for the lamp. A fuse and fuseholder should be included, rated to suit the lamp used.

Do not adjust the circuit with the mains connected or operate the unit with the box open. If the circuit is used to control a mains lamp, the l.e.d. will be superfluous but may be retained.

Setting up consists of adjusting preset VR1 so that the circuit switches at the required light level. This may be simulated by shielding the l.d.r. and adjusting VR1 accordingly and is best done before C1 is soldered into the circuit so that the unit responds immediately to changes in light levels. □

New Technology Update

Adding silicon to Li-Ion battery electrodes improves charge level performance. Ian Poole reports.

BATTERY technology is an increasingly important part of today's electronics scene. It was not many years ago when Nickel Cadmium cells were the only rechargeable types on the market. By today's standards they were inefficient in terms of energy storage density. Additionally the cadmium they contained made them difficult to dispose of in an environmentally friendly manner.

Since then technology has moved on significantly. Nickel Metal Hydride cells arrived. These cells provided an improvement in performance, but probably more important they were more environmentally friendly. However, a significant leap in performance has been made by the introduction of Lithium Ion or Li-Ion cells. This technology offers a significant improvement in performance, enabling much higher levels of charge to be stored in a given volume or battery weight.

Even these new cells, though, are undergoing further development to improve their performance. Developments at the Sandia Labs in California promise to give improvements of up to 400% according to Jim Wang, Manager of the Analytical Materials Science Department at Sandia.

Li-Ion Cells

Like many other types of cell, Lithium Ion cells consist of a positive electrode, a negative electrode and a separator. The cathode or positive electrode consists of lithium metal oxide. The other metal in this oxide may be a variety of metals. One that is often used is cobalt. The anode or negative electrode is made from activated carbon. Between these two electrodes there is a physical separator to ensure that the two electrodes do not touch, and it also acts as an electrolyte to provide a conduction path between the electrodes.

In the charge-discharge cycle a complicated chemical reaction occurs where the lithium in the positive electrode is ionised during the charge process, ions moving to the other electrode. During the discharge part of the cycle, ions move to the positive electrode and return it to its original structure.

Lithium-Ion cells offer many advantages over previous types of cell. They have a long cycle life, and they offer approximately two and a half times the energy density of Nickel Cadmium. When compared to Nickel Metal Hydride, they offer approximately twice the energy density. Their voltage is higher than the other two technologies. At 3·6 volts it is three times that of the other commonly used forms of cell. This is a major advantage in many applications where the 1·2 volts provided by both Nickel Cadmium and Nickel Metal Hydride is normally too low. Additionally the self discharge characteristic of these cells is very low. However, one of the major advantages is that they offer a competitive cost when compared to the other technologies.

Their major disadvantage is that they must not be electrically stressed. Overcharging them destroys them very quickly. To overcome this, battery management systems are always employed with these cells.

Improvements

The developments that have been undertaken at Sandia not only promise more powerful batteries, but also ones that last longer. It is found that when Li-Ion batteries are cycled through a charge-discharge cycle they loose a small amount of capacity each time.

To overcome this problem, Sandia have added silicon to the anode structure. The silicon on its own offers more than 10 times the capacity potential of graphite, but is hampered by a rapid capacity loss during the battery cycling phase. When small particles of silicon are combined within a graphite matrix, however, the large capacities are retained.

The silicon on its own is not suitable for constructing anodes and therefore a mix of the two materials is used. The marriage of silicon and graphite may improve the specific capabilities of commercial graphite anode materials up to 400%, said Jim Wang.

The silicon graphite composites can be produced using a simple milling process. This is a standard production methodology that is common within industry. This means that it is relatively easy to implement and no new processes or handling techniques are required.

In a conventional cell, one lithium ion is absorbed between each six carbon atoms. In the new cell technology each silicon atom holds four lithium ions. This is a 24-fold increase in capacity per atom.

There are a number of problems to be overcome. The silicon anode needs a very large surface area. In addition to this it must be physically able to cope with the doubling in size that the silicon undergoes when it absorbs that vast amount of lithium.

Both these problems have been overcome by using small silicon particles in a matrix of graphite. This allows the silicon to present a sufficiently high surface area whilst also still being able to expand without distorting the overall anode assembly.

Development Process

In reaching its conclusions about the new material's performance, Wang and other researchers at Sandia took a methodical approach that spanned three years. First they produced composite powders with varying silicon-to-carbon ratios and microstructures. Then they produced electrodes from the resultant powders and evaluated their performance by electrochemical measurements. They then examined structural changes in the electrodes during cycling to understand the lithium transfer mechanism and materials phase changes to further improve the new material.

According to Greg Roberts, a Post Doctoral team member at Sandia, the research and development focused on the replacement of graphite electrodes in rechargeable lithium batteries and this has taken many forms over the years. He explained that possible replacement candidates included non-graphitic carbons, intermetallics, oxides, nitrides, and composites.

While each material has unique advantages and disadvantages that need to be considered when designing a battery for a specific application, Roberts said the silicon/graphite electrode materials are promising for applications that require high capacities delivered at low-to-moderate rates.

Sandia researchers acknowledge that there are some potential problems with the new material. The complete elimination of fading of long-term cycling capacity in the silicon-based electrodes may not be possible, though it is possible that it can be minimised by the design of the carbon-silicon composite microstructure.

The research team are confident that the silicon/graphite electrode materials have opened the door for future breakthroughs. "We believe that only other silicon-containing electrode materials can compete with the large capacities that our silicon/graphite composites have demonstrated," Wang said.

Impact

It is anticipated that the discovery will have wide-ranging impact on a variety of consumer and defence applications as the use of Li-Ion batteries is now widespread and there is always a great demand for increased battery life. Mobile phone and laptop computer users will welcome any improvements in battery life.

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Robert Penfold

MSCOMM VOLTAGE LEVELS, AND BATCH COUNTING

CONTROL of and reading from the serial port handshake lines has been covered in recent *Interface* articles. The software side of things is reasonably straightforward using the MSCOMM ActiveX control, and interfacing circuits to the handshake lines is also reasonably simple.

The only slight complication in the hardware is the use of nominal signal voltages of ±12V for all RS232C lines including the handshake types. In most cases it is possible to drive RS232C inputs from ordinary 5V logic levels provided short cables of no more than two metres or so are used.

There is no guarantee that it will work reliably with all RS232C ports, but it always seems to. There is no risk of anything being damaged, so there is no harm in trying. If it fails to work, the port must be driven at the proper signal voltages via line drivers.

Stepping Down

Driving ordinary logic inputs from an RS232C output is a different matter. The signal voltages are nominally plus and minus 12V, but can be somewhat higher in practice. The output potentials do fall significantly under heavy loading, and the output current is limited to about 20mA. Even so, drive voltages well outside the limits for most logic chips are produced.

Stating that normal logic inputs should not be driven from serial port outputs will sometimes bring a response or two from readers who say they have tried it and it works. A few logic devices are designed to have compatibility with serial outputs as well as standard 5V logic types, and it is obviously all right to use these with RS232C ports.

Some logic chips might actually work when driven direct from a serial port, with their input protection circuits clipping the inputs at safe levels. However, relying on protection circuits to prevent a project from being zapped is not really an approach that can be recommended. The long-term reliability of such an arrangement is far from certain.

Although it might actually work with some chips, it will destroy others or cause them to malfunction. Trying to directly drive expensive chips would be foolhardy and probably costly as well. It is much better to use line receivers that provide the necessary voltage reductions.

There are special line receiver chips available, but a simple common emitter switching circuit such as the one shown in Fig.1 will usually suffice. It has to be borne in mind that there is an inversion through this circuit, and through any normal line driver and receiver circuits. This should not cause any major problems, and where necessary it is just a matter of writing the software to take the inversion into account.

The MAX202 chip is a good choice if line drivers are required. This chip operates from a single 5V supply from which it generates supplies of ±10V using a simple switching power supply.

As can be seen from the circuit of Fig.2, no inductors are required. The supplies are generated using four capacitors and electronic switches in essentially the same arrangements used with the popular ICL7660 supply chip. Capacitors C2 to C5 must be high quality components such as tantalum types. Two line drivers are provided, together with two line receivers.

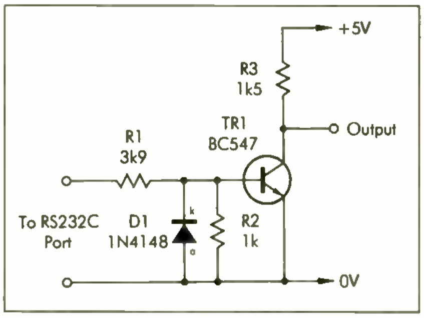

Fig.1. A simple but effective line receiver circuit.

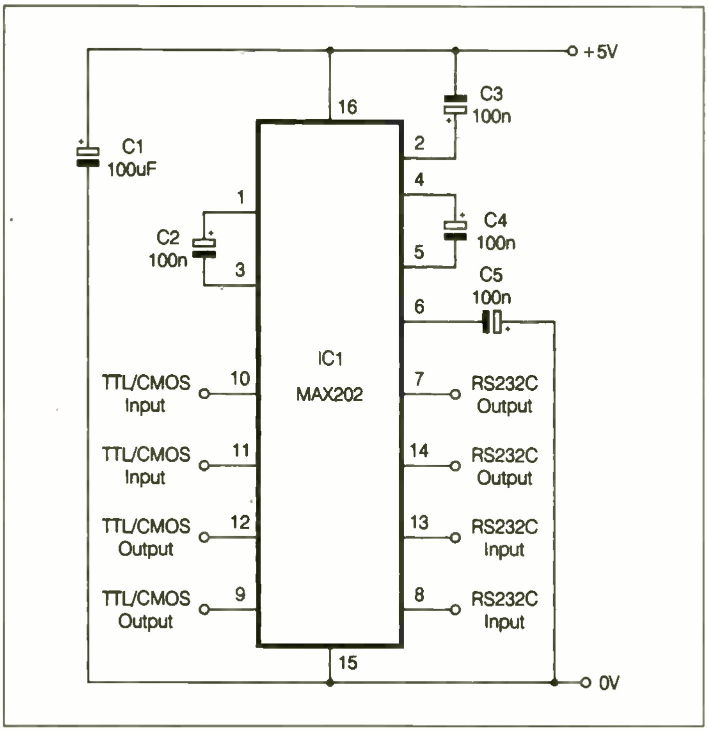

Fig.2. The Maxim MAX202 RS232 transceiver chip provides two proper line drivers and receivers.

Count On It

One of the most common requests from readers used to be circuits for what is generally termed batch counting. In other words, a counter of the type that is used for counting products as they roll off the end of a production line. This type of thing has many other uses, such as lap counting for model racing cars and counting the number of pages produced by a printer. MSCOMM makes it easy to count transitions on the serial port handshake inputs, as it can generate an event on each one.

The difficult part of batch counting is finding a means of reliably detecting objects as they pass. Generating a basic signal is often quite straightforward, but spurious pulses tend to be a problem. These are more or less guaranteed to appear with simple mechanical sensing via a microswitch due to contact bounce. For one reason or another, spurious pulses often occur with other types of sensing such as optical and magnetic types. A grossly excessive count is produced unless these pulses are filtered out.

A monostable circuit is one of the most simple but effective methods of removing switching glitches. A simple "switch-debouncing" circuit, based on a 555 timer, is shown in Fig.3. A low-power version of the 555 is specified, but the circuit will work just as well with the standard device, albeit with a higher current consumption.

The circuit uses the timer chip (IC1) in the standard monostable mode, and it is triggered when switch S1 closes. In practice S1 is a microswitch that is activated by each object as it passes by.

The timing components are resistor R1 and capacitor C2. These set the pulse duration at just under 250 milliseconds, but other pulse times can be obtained by altering the value of capacitor C2. The pulse duration is proportional to the value of this component.

Spurious pulses might trigger the circuit and produce extra output pulses if the pulse duration is too short.

Objects might slip though uncounted if the pulse duration is too long. It often requires some experimentation in order to find a suitable pulse length.

Optical Count

Mechanical sensors are cheap and reliable but are not well suited to all applications. The usual alternative is some sort of optical sensor and Fig.4 shows a typical circuit diagram for a simple light sensor circuit; this is essentially the same circuit as Fig.3. As before, a monostable based on a 555 timer is used to remove any glitches and produce a "clean" output pulse.

The circuit is triggered by a potential divider circuit that has resistor R2 and preset potentiometer VR1 as the upper arm and the collector-to-emitter resistance of phototransistor TR1 as the lower arm. Under standby conditions the sensor is in relatively dark conditions and it therefore exhibits a high resistance.

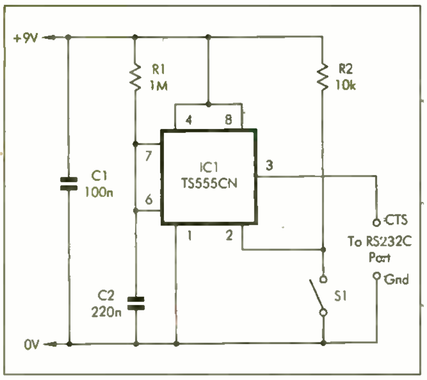

Fig.3. A monostable is a simple but effective means of switch debouncing.

Consequently, the voltage fed to pin 2 of IC1 is well above the trigger threshold, which is one third of the supply voltage. A suitably large increase in the light level received by TR1 results in a large fall in its collector-to-emitter resistance, and the voltage fed to pin 2 of IC1 then falls below the trigger level, instigating the output pulse at IC1 pin 3.

Preset VR1 enables the sensitivity of the circuit to be varied, with lower values giving higher light threshold levels. TR1 can be practically any phototransistor, and inexpensive types should be perfectly suitable. Note that Fig.4 correctly shows no connection to the base (b) terminal of TR1. The circuit will also work quite well using most light-dependent resistors (l.d.r.s), including the ORP12 and near equivalents.

On Reflection

One way of using this type of sensor is to have a light source positioned next to TR1 so that light is reflected from the counted objects and back onto TR1. This will only work properly if the objects being counted are suitably reflective. The alternative is to have the light source directed at TR1, with the objects blocking the light as they pass. With this second method the two arms of the potential divider circuit should be swapped, so that the voltage falls below the trigger level when TR1 is in dark conditions.

In some cases it will be possible to use the ambient light as the light source. In a lap counter for a model racetrack for example, TR1 could be mounted in the track and aimed upwards. The model car would then cast a shadow over TR1 each time it passed over it, and with preset VR1 at a suitable setting this should produce reliable triggering. A bit of trial and error will be needed in order to find a suitable setting for VR1, but there will

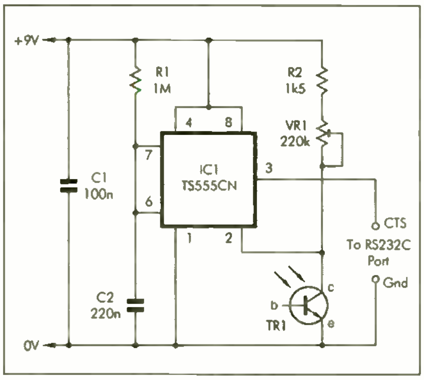

Fig.4. Circuit diagram for a light-activated sensor that includes a monostable to remove spurious pulses.

usually be a fairly wide range of acceptable settings.

Software

An extremely simple program is all that is needed for lap/batch counting. The form is equipped with a label having a large font size, and this is used to display the count.

A command button labelled "RESET" is also, needed, and operating this will reset the count to zero. The MSCOMM ActiveX control must also be added to the form. The following simple routine is all that is needed to provide the counting action:

```
Dim counter As Variant

Private Sub Command1_Click()
Label1.Caption = 0
End Sub
```

Fig.5. Screen shot of the batch counter program in operation.

```
Private Sub Form_Load()
MSComm1.PortOpen = True
End Sub

Private Sub MSComm1_OnComm()
If (MSComm1.CommEvent =
  comEvCTS) Then
counter = counter + 1
Label1.Caption = counter \ 2
End If
End Sub
```

The first line of the program simply defines "counter" as a global variable. The routine for the form opens the serial port, and the routine for the MSCOMM control then waits for transitions on the CTS handshake input.

When a transition is detected, the value stored in "counter" is incremented by one. There is one pulse but two transitions per object, so the value in counter is divided by two before being transferred to the caption of the label.

Note that the division is provided by the backslash (\) character so that any decimals are stripped from the value. This means that the first transition is effectively ignored, and the displayed count is incremented by one on every second transition. This avoids having the counter briefly read "0·5", "1·5", "2·5", etc. The routine for the command button simply sets the caption at "0" when the button is left-clicked.

A high frequency on the CTS line seems to overload the program, causing erratic operation. It works well in batch counting and similar applications where the input frequency is very low, and will usually be just a fraction of one Hertz. Fig.5 shows an example of the program in operation.

Using a suitable interface it should be possible to use the handshake inputs in other low frequency counting applications, such as a heart rate monitor, which is something that will be covered next time.

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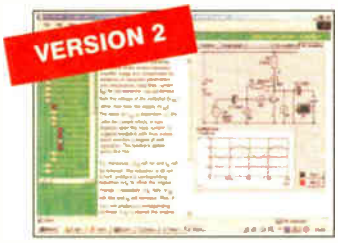
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

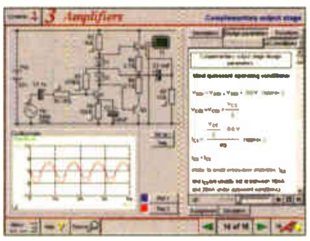
ELECTRONIC CIRCUITS & COMPONENTS V2.0



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.

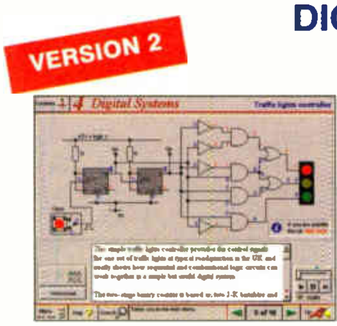
ANALOGUE ELECTRONICS



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.

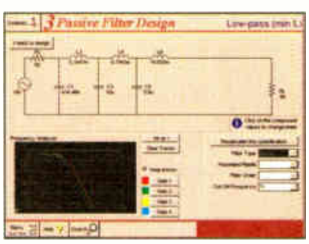
DIGITAL ELECTRONICS V2.0



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.

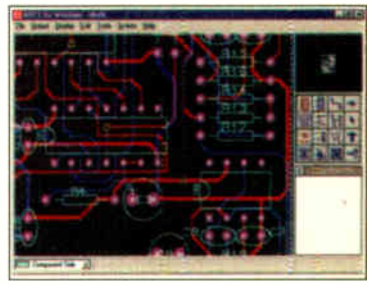
FILTERS



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

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Institutional (Schools/HE/FE/Industry) .... **£99 *plus* VAT**
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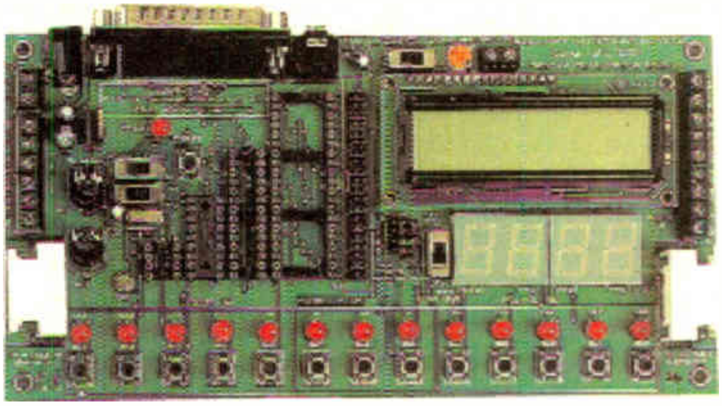

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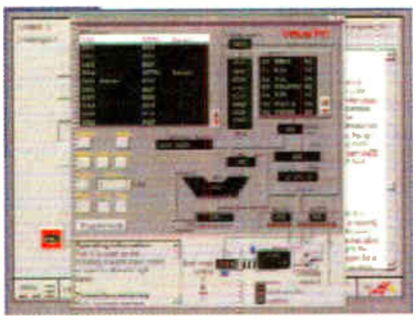
● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture 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.



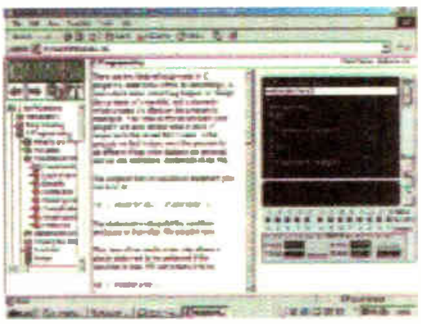
Virtual PICmicro

'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

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

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

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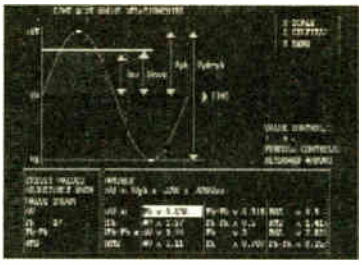

Sine wave relationship values

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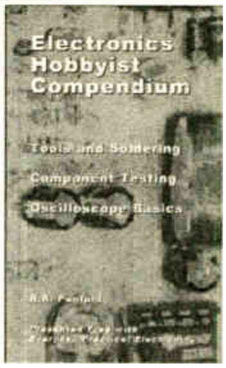

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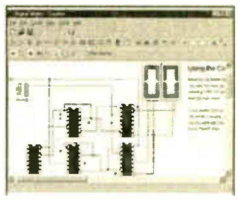

Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability • Software for simulating digital logic circuits • Create your own macros – highly scalable • Create your own circuits, components, and i.c.s • Easy-to-use digital interface • Animation brings circuits to life • Vast library of logic macros and 74 series i.c.s with data sheets • Powerful tool for designing and learning.
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Car Alarm Battery Saver – Un-nobbled!

MY new car alarm locks to the steering wheel, preventing the car from being steered, as well as providing a vibration-triggered alarm in a plastic housing (this deafens the thief inside the car, not the neighbours outside!). It is armed and disarmed by entering a code on a keypad. The user "teaches" the code to the alarm, which is remembered as long as the internal batteries remain live – which is not that long, due to the high current drain!

On delivery, disappointment followed the opening of the box. Unlike the catalogue description, there was no lead to take power at 12V from the cigarette-lighter (accessory) socket. "We forgot to tell you, we changed the design", said Customer Services. No, I didn't ask for a refund, I'm an *EPE* reader! Consequently, the circuit in Fig.1 was developed, to economise on batteries.

Switching between the power from a lead plugged into the accessory socket and that from the internal batteries is seamless, preventing loss of code memory. This even works at the most critical time if a would-be thief triggers the alarm and then pulls out the plug in the hope of cutting the power. The internal batteries (well rested and not depleted) see that the alarm continues to sound and scares off the thief. In normal operation, the internal batteries are only required to keep the memory alive whilst the car is underway with the alarm removed and safely stowed behind the seat.

Circuit Details

Plenty of decoupling surrounds the three-terminal 6V regulator IC1, this is a harsh environment. Electrolytic capacitors are not good at handling pulses, so paralleled disc ceramics are used to get rid of short spikes.

The use of a Zener diode, D1, following the regulator may seem strange. However, if the regulator fails closed-circuit, 12V appears where only 6V is expected but Zener diode D1 conducts, clamps the voltage and blows the ultra-fast closely-rated fuse FS1. Of course this is catastrophic, the regulator must be replaced and even a 5W Zener might sacrifice itself. With a low-current fuse and lack of space, though, the use of a full-blown (pun?!) thyristor crowbar is not justified.

While the regulated 6V is present, the *p*-channel MOSFET TR1 is held off via diode D3 and the alarm is powered via diode D2. On loss of the 12V input, D3 isolates the gate (g) of TR1 from all influences other than that of resistor R1. This resistor pulls the gate of TR1 low, which turns the device on and allows the internal batteries to take over and power the alarm. Decoupling and a bit of supply reservoir is thrown in, using capacitors C5 and C6 for good measure.

Diodes D2 to D4 stop "back-feeding" of internal battery power that would otherwise continue to hold TR1 turned of. Resistor R2 keeps any static charge off the gate (just being over-cautious!). This is easy work for the electrically-big MOSFET and the alarm drains little current, so no heatsinks were needed. There was room inside the alarm case to fit the components "ugly" style, held in place by hot-melt polythene glue.

Godfrey Manning G4GLM, Edgware, Middx.

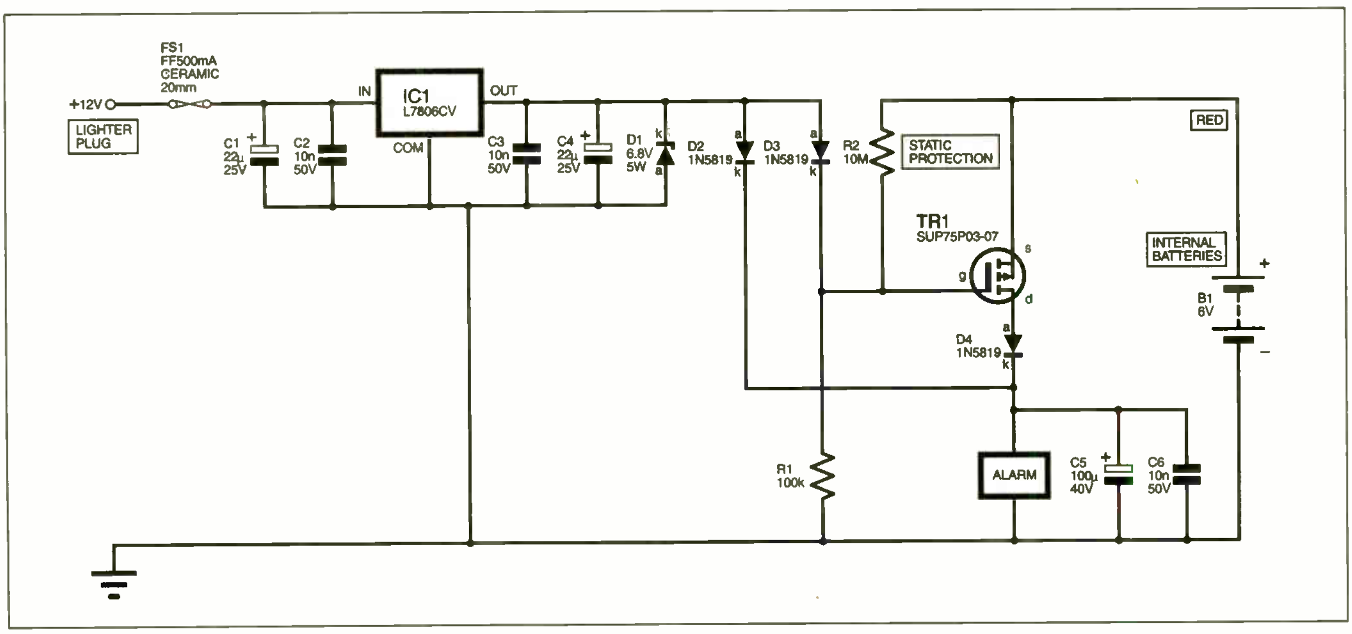


Fig.1. Circuit diagram for the Car Alarm Battery Saver.

PICRONOS L.E.D. WALL CLOCK

JOHN BECKER Part One

Ancient and modern techniques display timely brilliance on a grand scale!

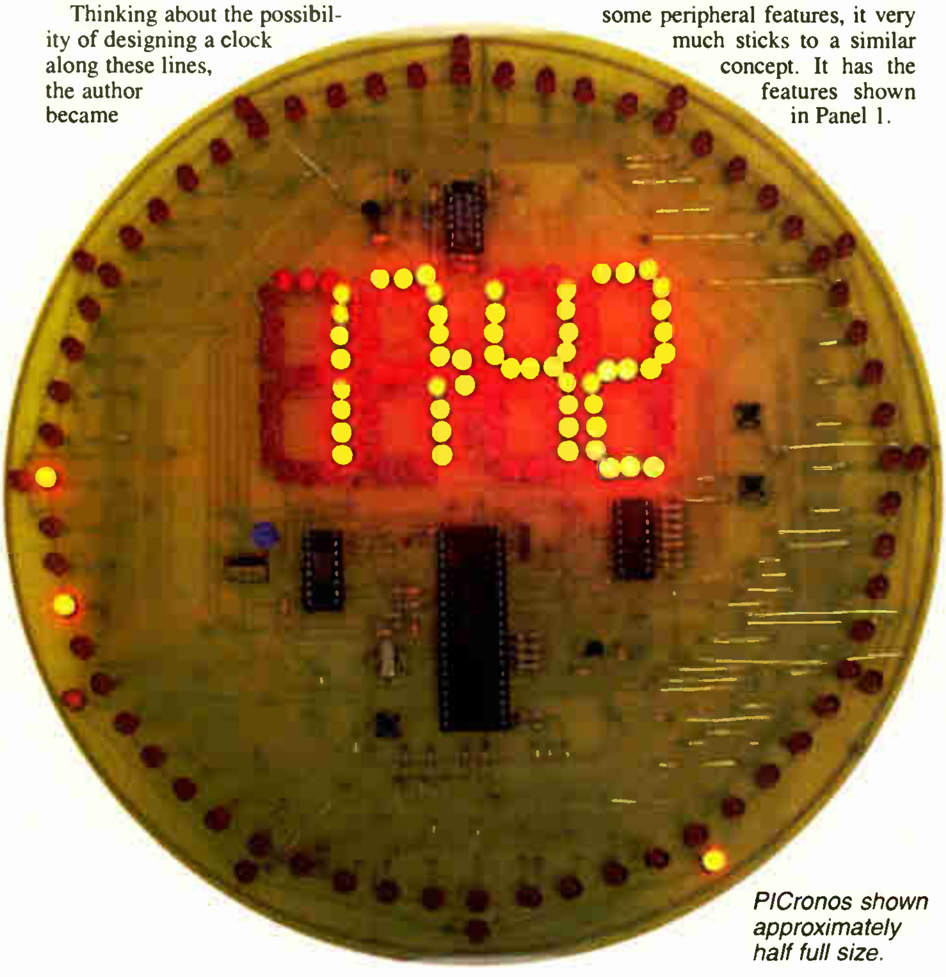
PORTUGUESE reader Fernando Bentes de Jesus emailed us during the Autumn of 2002, saying that his favourite electronically-controlled wall clock had "ticked its last tock" and that it could not be revived. He asked if we knew of anyone who might be interested to design a replacement.

Questioning him further, he explained that in essence his "dream clock" consisted of 60 light emitting diodes, arranged in a circle having a diameter of 24 centimetres, and displayed the seconds count. In the centre were eight digits with each segment comprised of several l.e.d.s. These displayed hours, minutes and calendar information.

Thinking about the possibility of designing a clock along these lines, the author became intrigued by the thought of designing one that embraced both old and new technologies – old in the form of l.e.d.s for the display rather than a liquid crystal screen, and new in the form of a PIC microcontroller (inevitably!).

Making some sketches, he ended up designing the circuit and printed circuit board for one over a weekend! With refinements, and after further discussions with Fernando, plus a *lot* of programming time, the clock presented here is that same one. Its achievement turned out to be a real exercise in multiplexing.

Whilst the design is not exactly the same as Fernando's ideal, which also included some peripheral features, it very much sticks to a similar concept. It has the features shown in Panel 1.



PICronos shown approximately half full size.

PANEL 1 FEATURES

- Crystal controlled
- Circular display having diameter of 9·8 inches (250mm)
- 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 to one decimal place
- Three switches provide adjustment for all display values, and for the precise calibration of the timing accuracy to compensate for normal manufacturing tolerance in the controlling crystal's oscillating rate
- Powered at 9V to 12V d.c. via a mains supply adaptor, with battery back-up
- Current consumption only 65mA (thanks to heavy multiplexing of l.e.d.s)
- Adjustable brilliance of the l.e.d. numerals to suit personal taste

MATRIXED ARRAYS

The use of multiplexing in this design was essential, to cut down on the current consumption and the number of logic gate devices that would otherwise have been required. Additionally, heavy use is made of matrixed arrays. The most significant example of this is in the circle of 60 l.e.d.s., whose array structure is shown in Fig.1.

In this matrix, applying positive power (e.g. +5V) to one of the eight horizontal connections (numbered 9 to 16) allows current to flow through any of the l.e.d.s in that row if its cathode (k) is taken low (e.g. to 0V) via a suitable ballast resistor. The cathodes are also mutually connected in groups of eight columns (numbered 1 to 8). By selecting which row and column are activated, any one (or more) of the l.e.d.s can be turned on.

For instance, applying power between connections 9 and 1 will cause current to flow through the top left l.e.d., D1. So that none of the other l.e.d.s in the other rows are turned on, their anode row connections are held at 0V. Similarly, to prevent other l.e.d.s in a column being turned on, their cathode connections are held positive.

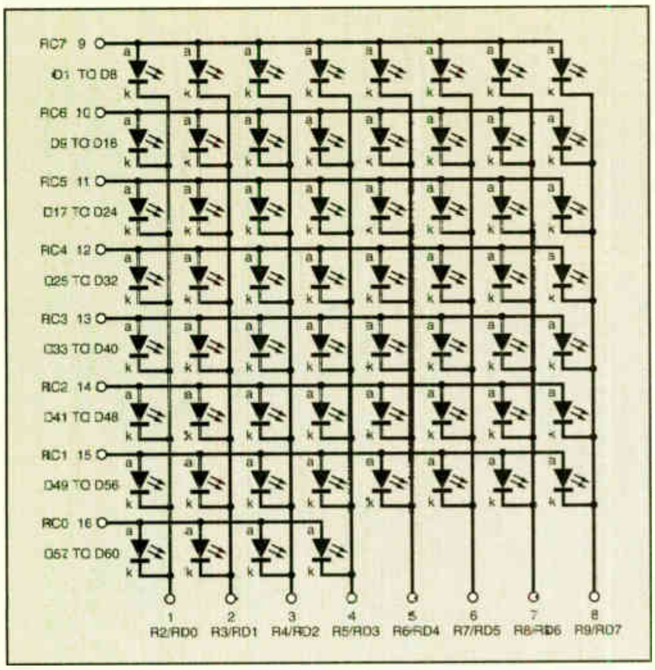


Fig.1. Matrixed array for the l.e.d.s that display minutes and seconds.

In theory, eight rows and eight columns can control 64 l.e.d.s. In this clock, though, only 60 l.e.d.s need to be controlled. Thus the last four positions of the matrix are left unused.

The other notations alongside each row and column (e.g. RC7 and R2/RD0) refer to the control points as shown later in Fig.5.

Multiplex control is used on this matrix. The 60 l.e.d.s are jointly used to show not only a seconds count but also a minutes count. This is achieved by first selecting the matrix co-ordinates for the seconds, turning on the required l.e.d. for a brief period, and then selecting the matrix co-ordinates for the minutes, and turning on that required l.e.d. for the same period. The alternating between the two matrix selections is so fast (around 400Hz) that both l.e.d.s appear to be on at the same time.

A second matrix is used for the l.e.d.s of the analogue hours display, as shown in Fig.2. Seven lines basically control this matrix, although it too is multiplexed by the control source, in conjunction with the 7-segment digits, i.e. as part of a 5-way multiplex switching format.

The basic l.e.d. format of a 7-segment digit is shown in Fig.3, and matrix diagram in Fig.4. Each of the four digits is identically arranged. Three l.e.d.s are connected in series for each of the horizontal segments (segment letters A, G and D), and four l.e.d.s are in series for each of the vertical segments (F, B, E and C). Different values of ballast resistor (R13 to R19) are used for the vertical and horizontal segments to achieve equal brilliance.

All four digits are multiplexed. There are four current source connections, each made to the primary anodes of all seven segments in one digit. The final cathodes of the like-lettered segments of all four digits are connected together (e.g. A to A, B to B). The seven connection paths control current sinking from the segments.

As with the matrix displays, any digit and any of its segments can be turned on as required, in this case using 11 control lines (four source plus seven sink). Again multiplexing is used in the control sequence so that each digit appears to be active simultaneously.

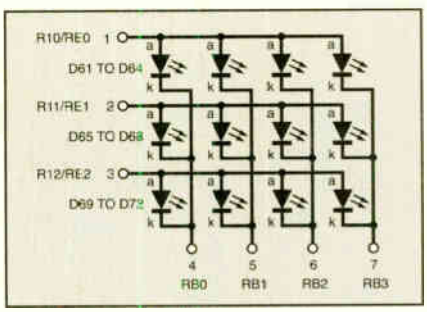


Fig.2. L.E.D. matrix for hours.

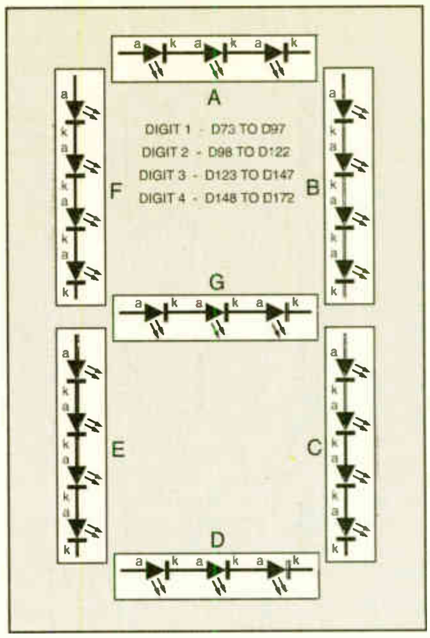


Fig.3. Basic format of a 7-segment digit.

CONTROL CIRCUIT

The control circuit diagram is shown in Fig.5. A PIC16F877 microcontroller, IC1, is the principal component, routing the many multiplex and matrix voltages as required. The PIC is operated at 3·2768MHz, as set by crystal X1.

The circuit should be read in conjunction with the previous illustrations. For example, the matrix display for the minutes and seconds l.e.d.s D1 to D60 that is shown in Fig.1 is represented by the block diagram connected to PIC pins RD0 to RD7 (Port D) and RC0 to RC7 (Port C). Port C provides the current source for the matrix rows, and Port D sinks the current from the matrix columns, via ballast resistors R2 to R9.

Port E is primarily used to provide the power source, via ballast resistors R10 to R12, for the hours matrix in Fig.2. The connection to switch S3 at resistor R11 is discussed later, as are the functions of switches S1 and S2.

The function of Port B is two-fold. In its first role, via pins RB0 to RB3, it provides current sinking from the hours matrix fed from Port E. Secondly it controls the gating of the digital display segments via IC4.

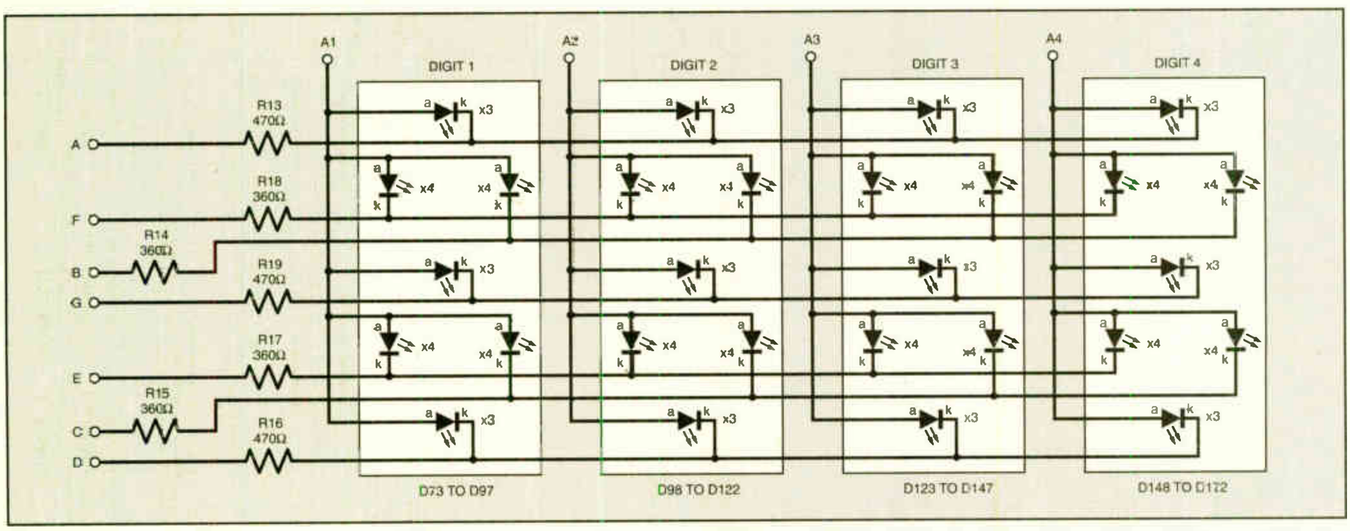


Fig.4. Interconnections between the four 7-segment digits. The x3 and x4 notations indicate the number of l.e.d.s in a segment.

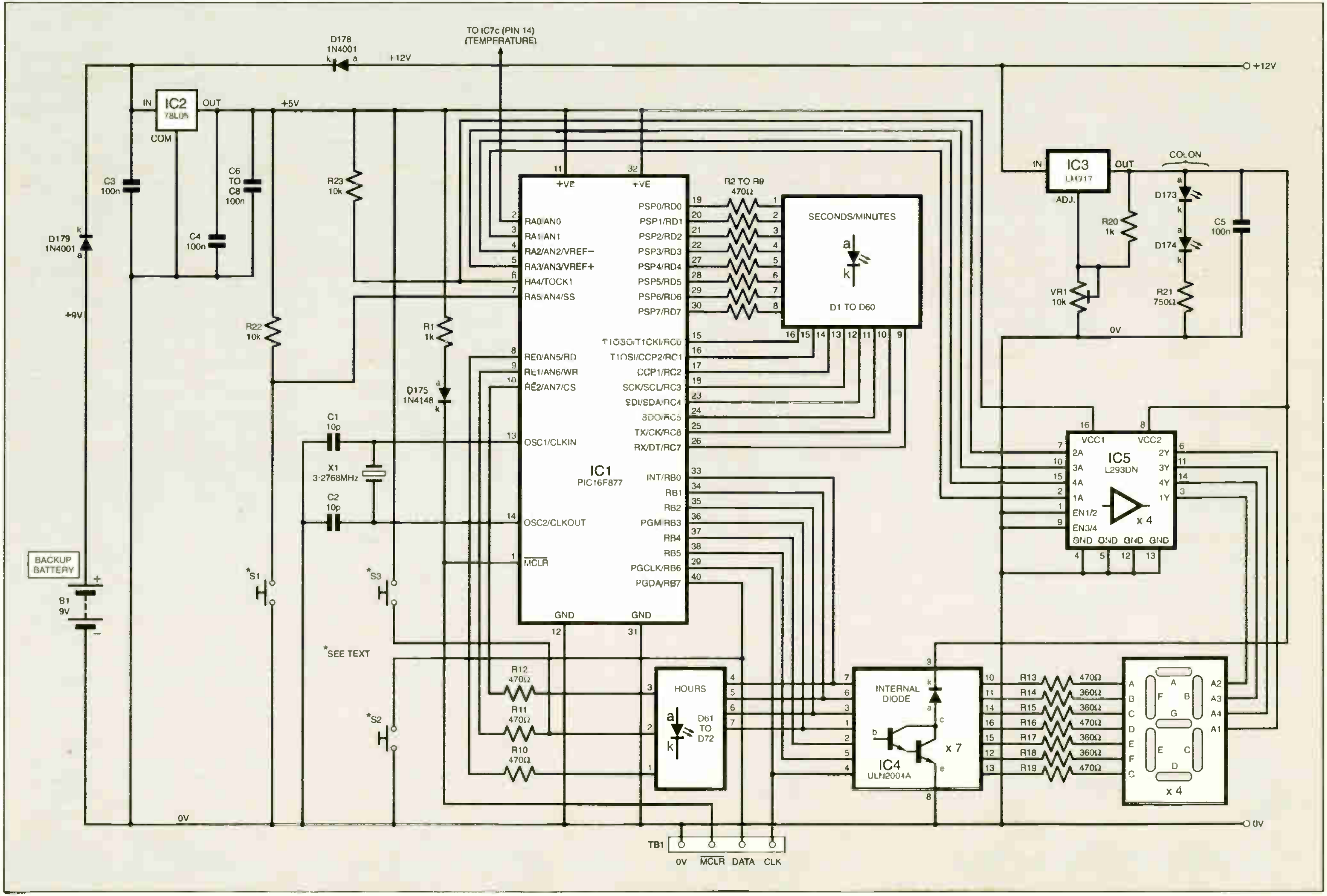


Fig.5. Main control circuit for the PICronos L.E.D. Wall Clock.

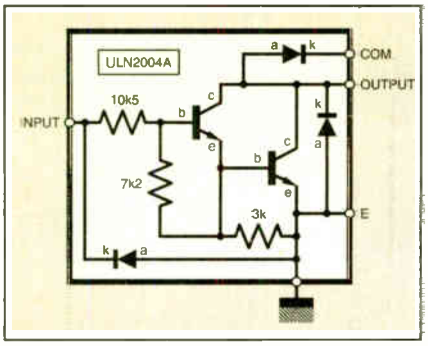


Fig.6. Single Darlington within IC4.

Device IC4 is a type ULN2004A and contains seven Darlington transistors which have open-collector outputs. The schematic diagram for one of the transistors is given in Fig.6.

The input to the base of the first transistor in the pair has an internal current-limiting resistor (10k5Ω) which allows the device to be controlled without the use of an external ballast resistor. The input is also protected against negative-voltages by an internal diode.

The open-collector output from the pair is also provided with internal protection diodes, to make the device suitable for use with inductive loads. Strictly speaking they are not needed in this design, but they have been connected anyway.

The Darlingtons are controlled by Port B (RB0 to RB6), and their outputs sink current from the digital display segments via resistors R13 to R19.

The anodes of the digital displays are indirectly controlled by Port A (RA1 to RA4). Because RA4 has an open-collector output, it is biased to the +5V line via resistor R23.

The digital displays are powered at a voltage higher than the 5V that supplies the PIC. This enables the brilliance of the displays to be more readily placed under external control, as discussed shortly. An interface is required to enable the 5V control voltage from the PIC to select the path through which the higher voltage, up to around 12V, is routed to the display anodes.

4-DIGIT DRIVER

The interface device used is the L293DN type previously chosen for the author's *PIC Big Digit* display (electro-mechanical digits) of May '02 (so too was the ULN2004A). Its internal functions and truth table are illustrated in Fig.7. Although not shown, this device also has internal protection diodes, between the outputs and the two power rails. They are irrelevant to this circuit as the device is not controlling inductive loads.

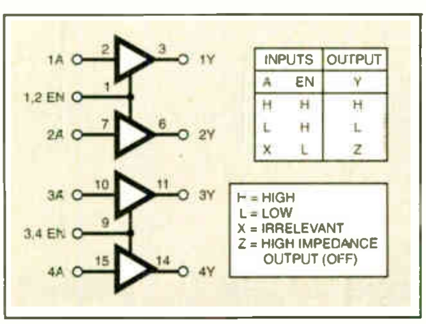


Fig.7. Schematic functions and truth table for IC5.

The L293DN requires two positive power supplies. One needs to be suited to the voltage level swing at the device's inputs, in this case a supply of +5V is fed to VCC1 at pin 16. The output needs the second power source to be suited to the output voltage required by the circuit being controlled. It is supplied via VCC2 at pin 8.

POWER SUPPLY

The design is intended to be powered by an external supply capable of delivering between about 9V and 12V d.c. at about 65mA, via a mains-power adaptor for example. It is recommended that the supply should be capable of delivering at least 100mA to provide plenty of "headroom". Whilst a current of 65mA may seem low for a circuit having nearly 200 l.e.d.s, it is the multiplexing technique that has enabled a low current consumption to be achieved.

Two power supply inputs are provided, via diodes D178 and D179. The connection for the main power supply is via diode D178. The other path is intended for connection of a back-up battery. of 9V at about 30mA maximum. This enables the clock to continue running in the event of a power failure at the main source, but without the l.e.d. digits being active.

If a backup battery capable of being kept on permanent trickle charge is used, a suitable charging resistor could be connected across diode D179. Its value should be chosen to suit the battery concerned (refer to its data sheet).

The principal incoming power supply is directly connected to the input of adjustable voltage regulator IC3. This is an LM317 device whose output voltage is controllable by potentiometer VR1 in conjunction with feedback resistor R20. Its purpose is to allow the brilliance of the 7-segmented digits to be varied, and that of the two l.e.d.s D173 and D174. These two form the "colon" between digits 2 and 3. It is a static colon and is not under PIC control.

Note that the brilliance of the l.e.d.s in the two rings (D1 to D72) is fixed.

If the variable brilliance facility is not needed, omit VR1, R20 and IC3. Then link the IN and OUT pads of IC3's position.

It is worth noting that although red l.e.d.s were used throughout in the prototype, it might be beneficial to make those in the outer hours ring a different colour (e.g. bright green or blue) so that they stand out better from the inner ring when seen from a distance.

When purchasing the l.e.d.s remember that considerable cost savings can be made by buying in bulk. The author paid 6p per l.e.d. by buying 200, even though fewer are actually required. L.E.D.s can be bought at even lower prices from some suppliers, but before buying ensure that their pin spacing and diameter is consistent with the spacing allowed on the board.

For the sake of readers who may wish to modify parts of the software to suit their own needs, resistor R1, diode D175 and connector TB1 allow the PIC to be programmed by a suitable external programmer, such as the author's *Toolkit TK3* of Oct/Nov '01, to which readers are referred for more information (also see later). R1 and D175 should be retained even if the programming option is not required, although TB1 may be omitted.

TEMPERATURE SENSING

A temperature sensing and display facility has been included. Its analogue circuit diagram is shown in Fig.8.

Temperature sensing is performed by the familiar LM35CZ. This basically outputs a voltage that varies by 10mV per degree Celsius. It is used in a configuration given in the device's data sheet, with which two diodes are used in series between the device's negative terminal and the 0V line.

This allows the device to output a voltage relative to negative temperatures. However, it is fully agreed with Fernando that anyone experiencing sub-zero temperatures where this clock is placed should emigrate to a warmer climate. With this in mind, the clock has not been tested for negative temperatures!

The lower-cost LM35DZ could be used instead without circuit modification if the negative temperature option is not needed. It is worth considering though, whether you might like to have the sensor outdoors so you know how cold it is there on a winter's day while you are warm and snug!

If the latter technique is used, it might be worthwhile adding the resistors and capacitors (RT, CT1, CT2) shown in Fig.9. These help to keep the input signals stable for long cable lengths, and should be mounted at the board end. They will need

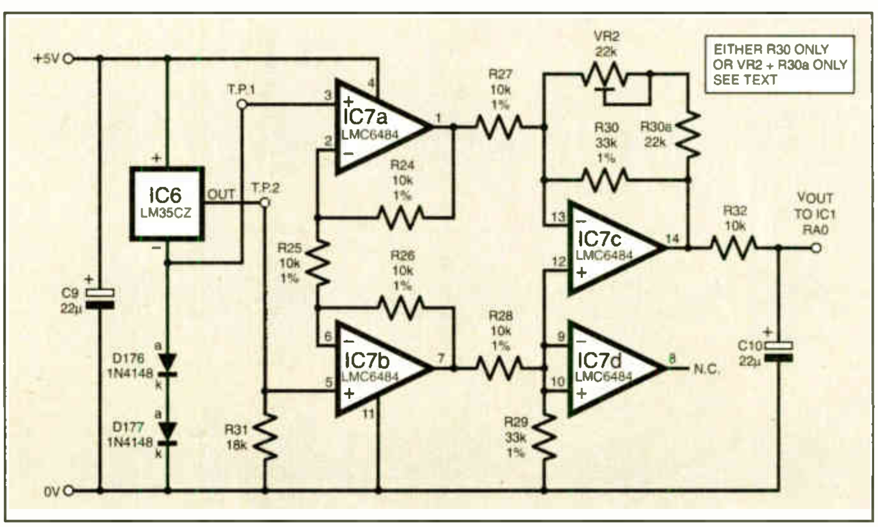


Fig.8. Temperature sensing circuit.

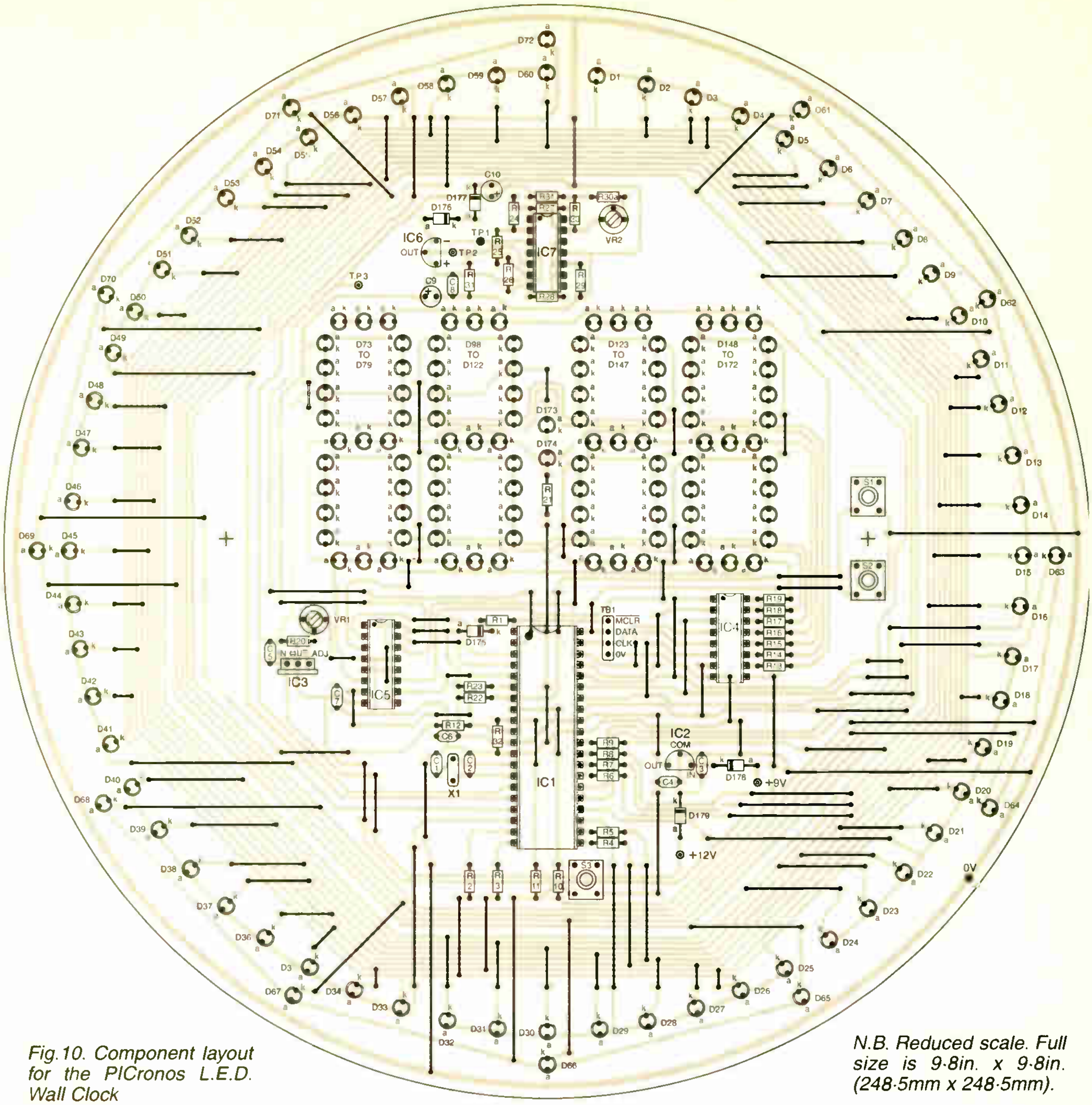


Fig.10. Component layout for the PICronos L.E.D. Wall Clock

N.B. Reduced scale. Full size is 9·8in. x 9·8in. (248·5mm x 248·5mm).

COMPONENTS

Resistors

R1, R20	1k (2 off)
R2 to R13, R16, R19	470Ω (14 off)
R14, R15, R17, R18	360Ω (4 off)
R21	750Ω
R22, R23, R32	10k (3 off)
R24 to R28	10k 1% 0·25W (5 off)
R29, R30	33k 1% 0·25W (2 off)
R30a	22k (see text)
R31	18k

All 0·25W 5% except where stated.

See **SHOP TALK** page

Potentiometer

VR1	10k min. round preset
VR2	22k (or 25k) min. round preset (see text)

Capacitors

C1, C2	10p disc ceramic, 0·5mm pitch (2 off)
C3 to C8	100n disc ceramic, 0·5mm pitch (6 off)
C9, C10	22µ radial elect. 10V (2 off)

Semiconductors

D1 to D60, D73 to D174	red l.e.d., 5mm dia. ultrabright (162 off)
D61 to D72	red l.e.d., 5mm dia, ultra-bright (see text) (12 off)
D175 to D179	1N4148 signal diode (5 off)
D178, D179	1N4001 rectifier diode (2 off)
IC1	PIC16F877-4 microcontroller, pre-programmed (see text)
IC2	78L05 +5V 100mA voltage regulator
IC3	LM317 adjustable voltage regulator
IC4	ULN2004A 7-way Darlington line driver
IC5	L293DN 16-pin Half-H driver
IC6	LM35CZ temperature sensor
IC7	LMC6484 quad op.amp, rail-to-rail

Miscellaneous

S1 to S3	min. push-to-make switch, p.c.b. mounting (3 off)
TB1	1mm pin-header, 4-way (optional)

Printed circuit board, available from the *EPE PCB Service*, code 395; 22s.w.g. tinned copper wire, solid (for link wires); 14-pin d.i.l. socket; 16-pin d.i.l. socket (2 off); 40-pin d.i.l. socket; 1mm terminal pins or pin headers; connecting wire; solder, etc.

Approx. Cost Guidance Only **£45** *excl. batts*

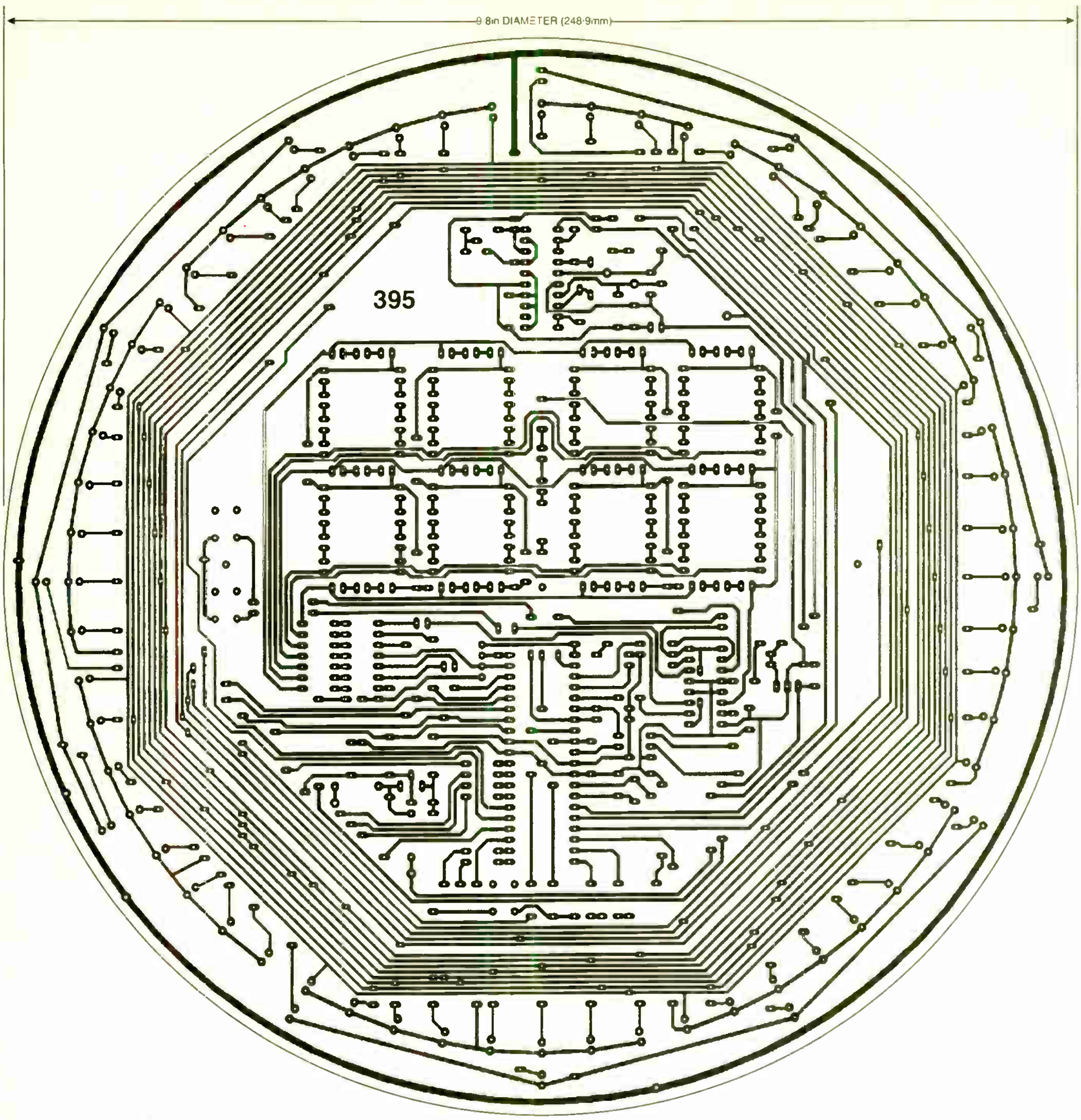


Fig.11. Reduced scale copper foil track pattern for the PICronos L.E.D. Wall Clock. This should be enlarged on a photocopier to 9·8in. x 9·8in. (248·5mm x 248·5mm) or purchase a board from the EPE PCB Service.

to be hardwired as no provision for them has been made on the board. The principle was discussed in *Teach-In 2002* Part 5 (with reference there to Fig.5.6 page 194). The values shown in Fig.9 provide a cut-off frequency of 166Hz.

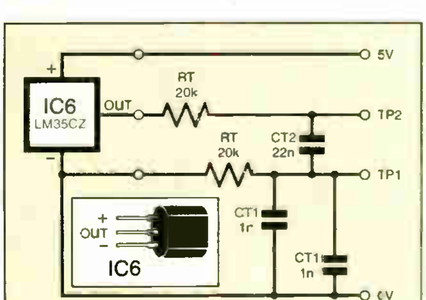


Fig.9. Additional components suggested if external temperature sensing is required.

Between them, IC7a to IC7c form a standard differential amplifier providing a d.c. gain of ×10. Resistors of one per cent tolerance are specified for all resistors except R31 and R32 (which may be five per cent). This close tolerance allows the amplifier to provide an output voltage swing that linearly tracks the output of the sensor by a factor of 10.

By calculation, the gain of the amplifier is actually ×9·9 (×3 via IC7a/b and ×3·3 via IC7c – see *Teach-In 2002* Part 5 for explanation). It was felt that this was close enough to 10 to be acceptable. For those readers who wish to be more precise, resistor R30 should be *omitted*, and resistor R30a plus VR2 should be inserted *instead*, adjusting VR2 to provide the exact gain needed.

Note that software allows the set range width (but not the gain) of the output voltage to be raised or lowered in response to pushswitch control (see later).

CONSTRUCTION

Printed circuit board (p.c.b.) component and track layout details are shown in Figs. 10 and 11. This board is available from the *EPE PCB Service*, code 395.

Both figures are shown to a reduced scale. The full size is 9·8in. × 9·8in. (248·5mm × 248·5mm). If you wish to make your own p.c.b. using Fig.11, the image should be enlarged on a good quality photocopier.

The board supplied by the *EPE PCB Service* is in the round format and has pilot holes drilled for the two mounting holes as shown in Fig.10 and Fig.11.

There are over 130 link wires that need to be made on the board. The cost of producing a plated-through-hole (pth) board was considered to be prohibitive. The use of a double-sided board with interconnecting pins was also felt to be just as taxing in construction as inserting link wires.

Make the link wire connections first, especially noting that some go under d.i.l. (dual-in-line) i.c. positions. The links are best made using solid tinned copper wire of 24 s.w.g. (a roll of which should be part of anyone's toolkit).

Next insert all the d.i.l. i.c. sockets. Do not insert the i.c.s themselves, or the temperature sensor, until the board has been fully checked for poor soldering, incorrect component positioning, and the correctness of the power supply has been determined. Regulator IC3 can be mounted with its back against the board to keep the board's profile low.

Next insert the resistors, diodes (but not l.e.d.s), capacitors and voltage regulators in order of ascending size. Ensure the correct orientation of the semiconductors and electrolytic capacitors.

Finally, insert the l.e.d.s. Note that those in the two "rings" all have their cathodes (k) pointing towards the centre. Those in the horizontal segments all have their cathodes to the right, while the cathodes of those in the vertical segments all face downwards.

To assist in the best alignment of the l.e.d.s, initially just solder one leg of each so that it is easier to re-position a misplaced one by having to unsolder only one lead. The l.e.d.s will have small spigots close to the body end of each lead, allowing their insertion depth to be maintained consistently.

Those who have good quality printed circuit board assembly frames with clip-on foam "lids" will find the entire p.c.b. assembly far easier than those who do not. The author's frame accepts p.c.b.s of 10in × 18in (254mm × 457mm) and the PICronos board was designed to just fit it.

It may be of interest to know that the author has used this frame for over 20 years and it considerably assists in the assembly of all the boards he designs.

It is strongly recommended that if you do not have an assembly frame, you should buy one. But only get a good quality one – those at the cheaper end of the selection may prove more trouble than they are worth, as the author once found to his detriment. Those in the professional class are the best.

Using this frame, assembly of the PICronos board took around four hours.

The author did not provide the clock with an enclosure and no recommendation for using one is offered.

SOFTWARE

The software for the clock is available on a 3·5in disk (Disk 6) from the *EPE* Editorial office (a small handling charge applies), or as a *free* download from the *EPE* ftp site. The easiest way into the latter is via the main *EPE* website page at **www.epemag.wimborne.co.uk**. and click on the ftp site link at the top. Then click on down through folders PUB, PICS and then into the PICronos folder.

There are two files – ASM (source code in TASM grammar) and HEX (in standard MPASM format). The HEX file is the code file to be sent directly to the PIC via a suitable programmer (e.g. *TK3*). It contains embodied configuration and data EEPROM values.

For those whose programmers cannot handle embedded data, the configuration values must be set separately. The values are XT crystal, WDT off, POR on. All other factors should be off. Data EEPROM values can be set by switches during clock adjustment and calibration, as discussed next month. Note that unexpected display results may occur until the values have been set.

Pre-programmed PICs can also be purchased – for details of this and on obtaining the software disk, read this month's *Shoptalk* page.

NEXT MONTH

In the final part next month, the clock's software and setting-up are discussed.

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 ★

Dear EPE,

Thanks again for some really great articles and projects. The *Earth Resistively Logger* (Apr/May '03) has some really great potential and is certainly timely, given all the attention archaeology is given across our country. It is these kinds of projects that stimulate ideas across disciplines and in my humble opinion, help us as a collective whole move to the next big idea.

I've been thinking of how I could use the unit for more than one thing, and I came across an idea that might work. I wonder if it could be adapted to use with a seismograph (**www.njsas.org/projects/tidal_forces/magnetic_gravimeter/baker/**), as I think that along with the ground waves common with earthquakes a possible resistivity change caused by micro movement of the surrounding earth structure may also occur.

What I find is a need for a simple serial port datalogger that will collect and display ±5·0V d.c. changes in voltage levels collected by my existing seismograph and associated ADC, plus output from the ER unit. I currently use a small test software application from Iguana Labs (**www.iguanalabs.com/adc2051.htm**), and it works ok for a single input, but if a way could be found to develop a simple serial port datalogger to use inputs from both the ER system and the seismo, and then generate a comparison chart, it could be interesting and a logical extension of the ER idea.

Do you think there be any value in a simple serial port reader application capable of simultaneously reading, comparing, and displaying data inputs on COM1 and COM2?

I like the projects in *EPE*. I've been working on mixing and matching a couple of project circuits – nothing unique – and imagineering other possible uses for things I'm doing with your circuits. Thanks for the wonderful work you are doing; lots of folks look at your magazine but not all write or acknowledge.

Dave Mynatt, Manchaca, Texas, USA

Nice to hear from you again Dave. Let us know when you find anything interesting!

Regarding seismo – yes, I have in mind to do a solid-state one at some time (I did a mechanical unit many years back). It would use data logging techniques along the lines of ER. But I do not know if it would be of use to archaeologists to have seismic conditions recorded at the same time. In the UK it is rare for us to be knowingly shaken (or stirred!). The aim of my ER is to show relative *differences in sub-surface conditions, not their absolute values.*

Twin serial input via COM1 and COM2 – it seems that multiplexing data into one serial port will be just as good. In fact on my forthcoming Weather Centre, *I'm multiplexing nine data sources into one output. Another good reason for not using two COMs ports is that many PCs are now being produced with only COM1, with USB as the second option.*

PATTING ER

Dear EPE,

Earth Resistivity Logger (Apr/May '03) – a brilliant project, I've been playing in this area of surveying for years but never with this level of sophistication!

Project built and running exactly as described. Multiple pats on the back all round!

Barry Benson, via email

Thank you Barry, that's great news! I am really pleased to hear it. A lot of effort and field work has gone into producing ER. All the best – tell us when you find the next long-lost Roman city!

INDUCTIVE SURVEYING

Dear EPE,

Maybe the *Earth Resistivity Logger* could be combined with an Induced Polarization (IP) instrument. I believe that IP uses the same ground probes but inject a current at several different frequencies. The signal is ON+, OFF, ON–, OFF, over the timed period. When the signal is shut off IP instruments read the voltage while it is decaying. The measurements are of time domain and also frequency domain. Interfacing ER to a GPS handset would also be useful.

Here is a link that deals with IP: **www.geop.ubc.ca/ubcgif/tutorials/resip/ip.html**.

Neil Pagel, via email

I've looked at the IP site you quote, Neil. It's interesting but I'm not sure how the technique might benefit amateur archeologists. Readers – your opinions please!

I'm currently in the middle of doing a PIC interface for use with GPS and things like ER and magnetometry – stick around!

SONIC FISH

Dear EPE

Just a word on the Babel Fish letter in *Readout* April '03 and hoping it wasn't intended as a joke . . . I remember one of the gadgets in my boyhood. The Tandy 75-in-1 kit was a Sonic Fish Caller – simply a low frequency oscillator, with the loudspeaker waterproofed and suspended in the water. It claimed that fish were attracted to the sound and that professional fishermen used similar devices. I was never interested in fish, but did try it once in a newt-pond. It didn't work – just like most of my projects.

Nigel Rushbrook, via email

Well, Nigel, there was humour in what was being said by those who offered comments, but it was not intended to be a commemoration of April 1st! The questioner was really looking for a circuit for a form of depth sounder. Years ago I designed one for use when scuba diving, but the special transducer was too expensive to offer the design for publication.

Better luck with future projects you build!

REVERED CHEERS FOR ALAN

Dear EPE,

Readers everywhere will surely be sad to see the retirement of Alan Winstanley from *IU*. Over the years, Alan gave the column a common look and feel, and a lighthearted touch, that made it a pleasure to read. It was Alan and *IU* who introduced me to constructional articles, and I know that there are others whose "careers" in electronics were profoundly influenced by him and the column.

So a big thank you Alan, and long live *IU*.

Rev. Thomas Scarborough, South Africa, via email

Three cheers for Alan, indeed, Thomas. It is the end of a significant era and Alan's seat will be hard to fill. It is colleague Dave Barrington and I who shall be attempting to continue where Alan left off.

Keep those IUs *coming in folks – we want to share your ideas with others!*

BOAT ALARM

Dear EPE

In Graham Johnston's *Letter of the Month*, March '03, he suggested an idea for a boat alarm that sent a message to his mobile phone. This is a good idea, one which a friend of mine thought of about three years ago (although not just for a boat). I designed the electronics for him and he went on to patent the idea (which he still holds). These devices are on the market to protect houses, boats, cars and industrial sites, the latter use radio PIRs and can protect a site of vast area.

I think *EPE* is invaluable and have gained most of my electronic knowledge from it. This brought about the confidence that I had when my friend asked me if I would be able to help him. I undertook the task not knowing whether I had bitten off more than I could chew but I surprised myself and went even further than he had asked. I put that down to reading *EPE* on a regular basis for years.

Keep up the good work guys and if by chance Graham or anyone else wants one of these devices they could contact my friend Roger Clifford at **roger@clifford.freeserve.co.uk**.

Michael Read, via email

Thanks Michael for the kind words and the information, plus Roger's address.

Enjoy your electronics – and EPE!

UNPIC-ING DOS

Dear EPE,

I am currently using PIC Basic PRO and a John Morrison designed software/programmer to develop PIC software. The solution has served me well, but the limitations of the DOS environment are getting painful. Can you recommend a suitable replacement for both the development and the programming which are completely Windows compatible and allow 18, 28 and 40 pin PICs to be programmed?

I am an avid reader of *EPE* and enjoy it thoroughly. I feel, however, that there could be more detail in your circuit descriptions. In terms of the circuit detail, it might help if I explained that I am a qualified but not practicing electronics technician. I qualified about 15 years ago and really have not used my skills (with the exception of some PIC programming) for the past 10 years. So I use *EPE* to keep in touch not only with modern technology but also with some of the principles which, like my hair, are getting a little grey now.

I am always thinking about what currents are flowing and what voltages I would expect at certain points in the circuit and what would happen if we used a different value capacitor here, etc. I'm sure I get it wrong a lot so it would be useful to know the correct answer. It would also be helpful to know alternative components which could be used (e.g. a 2N3904 where a BC108 is suggested). I appreciate I may be asking a lot and the above may be beyond the scope of *EPE*, but I hope feedback of any kind is not completely useless.

Simon Smyth,
Dublin, via email

Well Simon, feedback is always welcome. Taking your first comment first – you could go the full hog and get Microchip's own system (browse ***www.microchip.com****) or consider my* Toolkit TK3 *of Oct/Nov '01. Various advertisers also do good programming facilities, as many readers will confirm – browse the adverts. Texts of* TK3 *are available from our Online Shop via* ***www.epemag.wimborne.co.uk****, or on our* PIC Resources *CD-ROM advertised in this issue.*

I appreciate what you are suggesting, but it would be complex for us to add that extra info as designs are from the readership who don't usually give us that degree of detail. This is why we periodically publish tutorials such as our Teach-In *series every two years, and of course our monthly* Circuit Surgery. *Regarding substitutes, we try to ensure that components are readily available and prefer readers to use those specified by the author.*

STEPPING RIGHT

Dear EPE,

I'm trying to develop a machine which needs several stepper motors and a couple of sensors to make it operate. I'm thinking of controlling (been advised) said machine with a PIC microcontroller. I'm also relatively new to electronics/engineering so I need to know before buying if a PIC is the right way to approach controlling my machine.

I have programmed in BBC Basic a long time ago and would welcome any advice on which programming languages are now available and/or would be easiest, viz a PIC. I also have an Acorn RISC PC as well as a Windows PC. Which would be best to use?

John Amps,
via email

It's a matter of portability, John – it can be portable with a PIC, but not with a PC. Certainly a PIC is the route I would take.

With your previous programming experience you should have no difficulty learning about using PICs. The rest is then just down to you as an electronics designer, and your ability to think straight on software writing!

In terms of PCs I only use Windows and cannot comment on other systems.

PIC16F62x AND ADC

Dear EPE,

I have recently been working on a circuit requiring analogue to digital conversion. Having seen the PIC16F627 in the Maplin catalogue with pins labelled AN, I had been planning on using this. I have since read the Microchip datasheet for this PIC, and from this understand these pins to be only comparator pins and not strictly A/D. I therefore changed to the PIC16C710, and have written the program to suit.

Since this will be my first PIC project I would rather use a Flash PIC. So I then looked around for methods of programming PICs and discovered *EPE*. Upon reading the April issue I found the *Intelligent Garden Lights Controller* was using the PIC16F627, and from what I can tell it is being used for ADC. Could you please tell me how this PIC can be used in this way?

Joe Dowsett,
via email

Disappointingly, Joe, you are right about the PIC16F627 not providing true ADC. In the Garden *unit, the PIC's comparator can only be set to one of 16 different analogue input trigger levels, which is very limited. However, the PIC16F87x family have true ADC, providing 1024 levels of conversion. Read Part 3 of my* PIC Tutorial V2 *in this current issue.*

AUTOMATED SURVEYING

The following are extracts from a series of threads that appeared towards the end of March on our Chat Zone *following publication of the* Earth Resistivity Logger, *started off by Robin Turk:*

Robin Turk: I am an archaeology student in UCC Ireland. I was interested to see the *Earth Resistivity Logger* in *EPE* but I am interested in making an automated system for surveying an area, i.e. some kind of radio controlled vehicle for positioning and inserting the probes in the correct positions on the grid and subsequently logging the reading and moving on to the next position.

This would avoid the tedious and time consuming process of positioning probes etc. The actual mechanics of positioning the probes and inserting them would be relatively simple (some probe configurations would be easier than others) but I would need a relatively accurate way to make the device follow a grid pattern over the area to be surveyed. I was thinking maybe GPS or something. I would be grateful for any ideas on the matter!

John Becker: A fascinating subject is this "seeing beneath the soil" and what has been proved with my own tests and the surveys by friend Nick Tile (who has professional experience of seismic surveying on land and at sea) encourage me to take the subject further. The next step is probe-less surveying using magnetometry – early field tests on the prototype have started. I have a further idea for remote sensing for a later investigation (following a fair bit of research).

Robin Turk: Thanks for cool plan, John. I had another look at Anthony Clarke's *Seeing Beneath the Soil* book the other day and realised that he and others had done work in semi-automated surveys and continuous trace probing methods. In fact using an automated roving device one could achieve an almost continuous trace using either separate probes (in any configuration) with a short distance between each movement, or with probes attached to wheels or tracks (as Miguel suggests below and Clarke used in his design) using the twin electrode method. I look forward to a design for a magnetometry surveying device. It would be nice to be able to incorporate this into a rover as well!

BWTS: The roving logger could have a simple representation of the ground to be covered stored in its memory. This representation could be as simple as a rectangle. Each time you want it to go over a piece of ground you enter the dimensions of the rectangle. The logger then trundles off probing every so many metres (or feet if you prefer) in let's say the X direction. Getting to the end of one length it turns 90 degrees, let's say right to avoid confusion, takes a "step" forward in let's say the Y direction, turns another 90 degrees right so it's now facing the direction it came in from.

It repeats the process until it gets to the end of another length and this time turns left, takes a "step", turns left again and repeats the whole thing until it has gone as far in the Y direction as you specified in the first place.

This would avoid the need for external sensors or GPS if the ground to be covered was relatively clear of trees and so on. The hardware would be kept to a minimum and the only input you would have to make would be the X and Y dimensions.

Robin Turk: Yes this method would be probably the simplest but it would rely heavily on the accuracy of the measurement of the distance travelled by the rover. These errors would get progressively worse the further it travelled. There would also be problems in achieving an accurate 90 degree turn without the use of some kind of inertial guidance system, although a relatively straight line could probably be achieved by use of a gyro.

Max: I think GPS at its most accurate can only pinpoint its location to within about 20cm (I think – but that's plenty accurate enough for its normal uses!), a most accurate way would probably be to use ultrasonic or infra-red sensing to judge the vehicle's position to some fixed markers at the edges of the area being surveyed. It would be a lot easier (and cheaper) than GPS, but would probably need some serious hardware/software to control it, but then I guess it would take a lot of complicated interfacing to get something to interface with a GPS handheld thingy (a technical term).

A fascinating set of chats (of which there were more, but no space here). As a postscript, by the time you read this I hope to have a GPS input for ER Logger *completed. Stay tuned!*

UPGRADING ATMOSPHERICS MONITOR

Dear EPE,

Regarding my *Atmospherics Monitor* (April '03), during late March/early April atmospheric pressure was very high at 1024mb to 1030mb. Under these conditions, Russian beacons above 9kHz become audible. I have re-worked the aerial input and the first IC1a stage of the monitor. This modification provides a better signal-to-noise floor, improving the resolution of atmospheric signals. The frequency response curve peaks at 7kHz, rolling off steeply above, and provides a gain lift at 2kHz. The modification is as follows:

- Amend C5 to 100nF
- Completely remove C7
- Amend C2 to 22nF and fit 10kΩ resistor in parallel with it
- Remove link wire connecting between stripboard tracks C and I at column 3 and replace by a 220kΩ resistor
- Amend R2 to 390kΩ
- Amend R3 to 470kΩ
- Amend R5 to 3k3Ω
- Amend R6 to 39kΩ
- Add a 47pF capacitor between stripboard tracks F and B in column 1 (between coil wire hole and track to collector of TR1/IC1 pin 5)

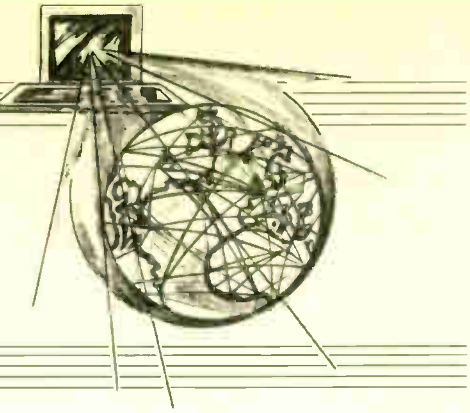
After modifying the circuit, the bias will need re-adjustment. With power supply at 9·0V, set VR1 for 4·5V at IC1 output pin 7.

Brian Lucas,
Jersey, via email

Thanks Brian. Readers, this is the same information as was placed on our Chat Zone *in late March.*

A few of you have commented that PIC subjects are dominant in Readout. *That's because most letters received are about PICs. If you want other matters covered please write to us about them.*

NET WORK



ALAN WINSTANLEY

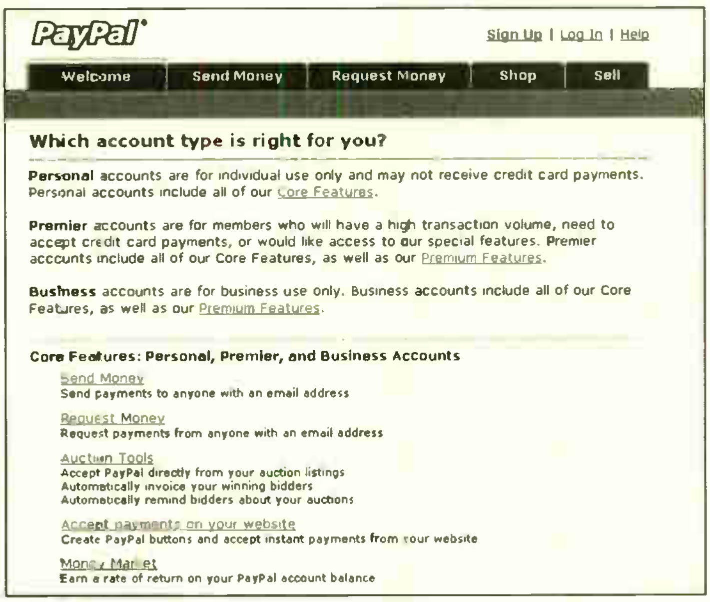
Credit When It's Due

WHEN setting up a business that will sell products via the Internet, one of the first obstacles to overcome is that of credit card processing. Much has been written over the past few years about the perils of buying over the Internet: consumers are warned about using only "secure" web sites and not sending credit card numbers through ordinary email.

So far so good, but for the uninitiated Internet user there is still plenty that can go wrong. Faced with the prospect of saving money (lots of money, sometimes), then, when it comes to buying a juicy-looking bargain online, a fool and his money are soon parted, and fools can get their fingers burned very easily. A number of users have been the victims of Internet fraud, losing thousands of pounds through bogus web sites created by fraudsters.

There is a flip side to all this: when opening up an online shop, it is probably the *owner of the business* that faces the greatest challenges from credit card fraud. Flinging open his virtual shop window, orders arrive literally through the ether, sent by customers whom the business will never meet in person. However, when things go wrong the online store faces the risk of losing both the goods as well as the money.

Problems start when the trader sends out the merchandise in good faith, only to learn a month later that the credit card number had actually been stolen or forged. The credit card company might have charged an innocent person's account, which then has to be refunded.



Paypal is an account-based online payment system that lets you send or receive money online.

This cash is clawed back from the trader who is compelled to provide the refund (called a chargeback in the trade). This is bad news because the trader has then lost both the goods as well as the cash. Too many chargebacks, and the trader risks losing his merchant account altogether. Security and online vetting procedures are tightening all the time to help avoid this.

Jump To It

In the UK, a trader (merchant) first needs an "Internet merchant account" to be able to receive credit card (CC) payments online. In practice these accounts are usually arranged via the trader's bank. In addition there are a number of online credit card processing organisations including Netbanx, SecPay, Secure Trading and WorldPay (which in the UK is now part of RBS/Natwest) all of whom can process credit cards for a fee.

Add in standard bank charges as well, and the online business could see no less than three percentages deducted from every deal. Things are somewhat different in the USA where a trader's credit card processing business can be sub-contracted out to any number of competing independent sales organisations.

In view of the almost paranoid risk of chargebacks, money laundering, fraud and theft, it is not surprising that many UK traders are forced to jump through hoops before acquiring an Internet merchant account. Some alternatives include using a CC processing company (e.g. WorldPay or Netbanx) to handle the transaction in its entirety, i.e. paying a net amount directly into the trader's bank account. It costs money to set up, the interest rates are higher and (worse still) the trader has to wait up to four weeks before receiving his cash, rendering this type of "bureau account" completely unfeasible for many Internet traders who would have to send out the goods but wait a month for their cash to arrive.

Pay-up Pal

So the viable trading alternatives start to run out. One very tempting option is to use Paypal (**https://www.paypal.com**) to handle all online credit card transactions. The online auctioneer eBay (**www.ebay.com**) now owns this American credit card processing and payment company, which is why Paypal has been heavily integrated into eBay's checkout system.

On the surface, Paypal appears to be the perfect solution to almost every trader's credit card processing requirements. Paypal claims there are 20 million users in over 30 countries that entrust credit card payment processing to them. Its account-based system lets you send or receive money using a credit card or cheque (checking) account.

It is free to open a Paypal account. "Members" can sign up online in a simple-looking process but finer details become apparent the deeper you dig. In order to validate your details, Paypal makes a $1.95 test transaction to a designated credit card account: a nice little earner. A Member ID number is printed alongside the transaction details that appear on the credit card statement, which has to be entered back into the Paypal web site. That is how Paypal confirms your details and you then become a verified member.

By upgrading to a Premier account and entering your bank account details, you suddenly gain the ability to accept credit card payments, because Paypal can process the CC transaction for you and pay the balance straight into your bank account. More accurately, Paypal actually pays the cash into your *Paypal member's account*, from where you can withdraw it into your designated bank account. Paypal deal in several currencies including US$, Sterling and Euros.

Apart from one glitch when Mastercard locked up my credit card following a series of "suspicious looking" $1 Paypal payments, I have purchased a number of items using Paypal without any problems. Other users have not been so lucky, especially when they rely on Paypal for their business income. As long as you are mindful of the pitfalls, Paypal may or may not be an ideal solution for the budding Internet start-up or small enterprise.

Next month I'll look in more detail at Paypal, and also show you how you can set up a simple online shop for yourself, using Paypal's selling tools to handle payments. If you have any comments on this topic, you can email me at **alan@epemag.demon.co.uk**.

PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for *airmail* outside of Europe. Remittances should be sent to **The PCB Service, *Everyday Practical Electronics*, Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. Tel: 01202 873872; Fax 01202 874562; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.wimborne.co.uk/shopdoor.htm.** Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only).**

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.

Back numbers or photostats of articles are available if required – see the *Back Issues* page for details. We do not supply kits or components for our projects.

Please check price and availability in the latest issue.

A number of older boards are listed on our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE		Order Code	Cost
Hosepipe Controller	JUNE '01	301	£5.14
Magfield Monitor (Sensor Board)		302	£4.91
Dummy PIR Detector		303	£4.36
★PIC16F87x Extended Memory **Software only**		–	–
Stereo/Surround Sound Amplifier	JULY '01	304	£4.75
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MSF Signal Repeater and Indicator			
Repeater Board		306	£4.75
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★PIC to Printer Interface		308	£5.39
Lead/Acid Battery Charger	AUG '01	309	£4.99
Shortwave Loop Aerial		310	£5.07
★Digitimer – Main Board		311	£6.50
– R.F. Board		312	£4.36
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Perpetual Projects Uniboard–3 Loop Burglar Alarm, Touch-Switch Door-Light and Solar-Powered Rain Alarm	SEPT '01	305	£3.00
L.E.D. Super Torches – Red Main		313 } Set	£6.10
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– White L.E.D.		315	£4.28
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PIC Toolkit Mk3		319	£8.24
Perpetual Projects Uniboard–4. Gate Sentinel, Solar-powered Bird Scarer and Solar-Powered Register		305	£3.00
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Capacitance Meter – Main Board (double-sided)		323 } Set	£12.00
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★★PIC Toolkit TK3 – **Software only**		–	–
4-Channel Twinkling Lights	DEC '01	325	£6.82
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★PIC Magick Musick		332	£5.87
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★PIC Spectrum Analyser	FEB '02	334	£7.13
Versatile Current Monitor		335	£4.75
Guitar Practice Amp		336	£5.39
★PIC Virus Zapper	MAR '02	337	£4.75
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★PIC Mini-Enigma – **Software only**		–	–
★Programming PIC Interrupts – **Software only**		–	–
★PIC Controlled Intruder Alarm	APR '02	339	£6.50
★PIC Big Digit Display	MAY '02	341	£6.02
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Audio Circuits–1 – LM386N-1		343	£4.28
– TDA7052		344	£4.12
– TBA820M		345	£4.44
– LM380N		346	£4.44
– TDA2003		347	£4.60
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Frequency Standard Generator – Receiver		353	£4.12
– Digital		354	£6.82
★Biopic Heartbeat Monitor		355	£5.71
Simple Audio Circuits – 3 – Dual Output Power Supply	JULY '02	356	£4.60
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★EPE StyloPIC		359	£6.50
Rotary Combination Lock – Main Board		360	£5.39
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★Using the PIC's PCLATH Command – **Software only**		–	–
Big-Ears Buggy	AUG '02	362	£5.71
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Simple Audio Circuits–4 – Low Freq. Oscillator		364	£4.44
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Vinyl-To-CD Preamplifier	SEPT '02	366	£5.71
★Freebird Glider Control		367	£4.91
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Headset Communicator	OCT '02	369	£4.75
EPE Bounty Treasure Hunter		370	£4.77
★★Digital I.C. Tester		371	£7.14
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Transient Tracker	NOV '02	372	£4.75
★PICAXE Projects–1: Egg Timer; Dice Machine; Quiz Game Monitor (Multiboard)		373	£3.00
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Owen Bishop

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160 pages **Order code BP413** £6.49

DISCOVERING ELECTRONIC CLOCKS
W. D. Phillips

This is a whole book about designing and making electronic clocks. You start by connecting HIGH and LOW logic signals to logic gates. You find out about and then build and test bistables, crystal-controlled astables, counters, decoders and displays. All of these subsystems are carefully explained, with practical work supported by easy to follow prototype board layouts.

Full constructional details, including circuit diagrams and a printed circuit board pattern, are given for a digital electronic clock. The circuit for the First Clock is modified and developed to produce additional designs which include a Big Digit Clock, Binary Clock, Linear Clock, Andrew's Clock (with a semi-analogue display), and a Circles Clock. All of these designs are unusual and distinctive.

This is an ideal resource for project work in GCSE *Design and Technology: Electronics Product*, and for project work in AS-Level and A-Level *Electronics and Technology*.

194 pages, A4 spiral bound **Order code DEP1** £17.50

DOMESTIC SECURITY SYSTEMS
A. L. Brown

This book shows you how, with common sense and basic do-it-yourself skills, you can protect your home. It also gives tips and ideas which will help you to maintain and improve your home security, even if you already have an alarm. Every circuit in this book is clearly described and illustrated, and contains components that are easy to source. Advice and guidance are based on the real experience of the author who is an alarm installer, and the designs themselves have been rigorously put to use on some of the most crime-ridden streets in the world.

The designs include all elements, including sensors, -detectors, alarms, controls, lights, video and door entry systems. Chapters cover installation, testing, maintenance and upgrading.

192 pages **Order code NE25** £17.95

MICROCONTROLLER COOKBOOK
Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages **Order code NE26** £21.99

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages **Order code BP332** £5.45

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** £5.49

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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Computing & Robotics

WINDOWS XP EXPLAINED
N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and Home editions.

The book was written with the non-expert, busy person in mind. It explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, Notepad and Paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; How to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows set-up, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

268 pages **Order code BP514** £7.99

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages – large format **Order code BP901** £14.99

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision Command System

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using Lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

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.

298 pages **Order code BP902** £14.99

PIC YOUR PERSONAL INTRODUCTORY COURSE SECOND EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised second edition covers the popular reprogrammable EEPROM PICs: P16C84/16F84 as well as the P54 and P71 families.

270 pages **Order code NE36** £13.99

INTRODUCTION TO MICROPROCESSORS
John Crisp

If you are, or soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors. assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern microprocessors.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages **Order code NE31** £18.99

Theory and Reference

ELECTRONICS MADE SIMPLE
Ian Sinclair

Assuming no prior knowledge, *Electronics Made Simple* presents an outline of modern electronics with an emphasis on understanding how systems work rather than on details of circuit diagrams and calculations. It is ideal for students on a range of courses in electronics, including GCSE, C&G and GNVQ, and for students of other subjects who will be using electronic instruments and methods.

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

SCROGGIE'S FOUNDATIONS OF WIRELESS AND ELECTRONICS – ELEVENTH EDITION
S. W. Amos and Roger Amos

Scroggie's Foundations is a classic text for anyone working with electronics, who needs to know the art and craft of the subject. It covers both the theory and practical aspects of a huge range of topics from valve and tube technology, and the application of cathode ray tubes to radar, to digital tape systems and optical recording techniques.

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.

400 pages **Order code NE27** £21.99

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** £4.49

PRACTICAL ELECTRONIC FILTERS
Owen Bishop

This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.

The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.

Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.

188 pages **Order code BP299** £5.49

PREAMPLIFIER AND FILTER CIRCUITS
R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases). The preamplifier circuits featured include: Microphone preamplifiers (low impedance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A. equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Mixers. Volume and balance controls.

92 pages **Order code BP309** £4.49

Project Building

ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold

Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different.

The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages **Order code BP371** £5.45

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold

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

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

All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** £5.45

ELECTRONIC MUSIC AND MIDI PROJECTS
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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 the individual constructors to sort out, simply because the vast majority of project builders prefer to do their own thing.

None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit.

138 pages **Order code PC116** £4.95

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
NEW LOW PRICE

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.

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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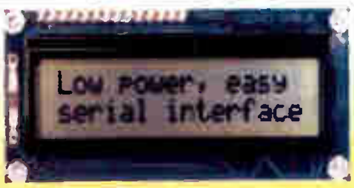

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