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## PIC TOOLKIT Mk2

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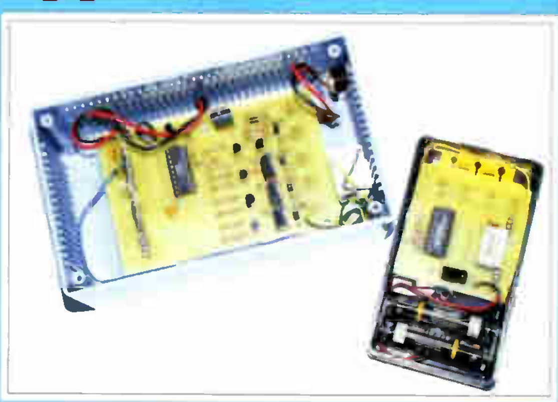
## VERSATILE AM/FM REMOTE CONTROL SYSTEM Uses DTI approved modules



## PC ENGINES

From 4004 to Pentium III

## MIDI "HANDBELLS"

Modern equivalent to handbells

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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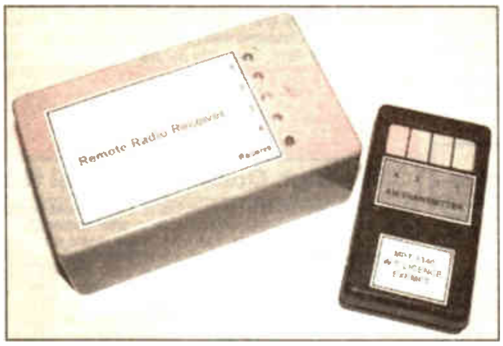


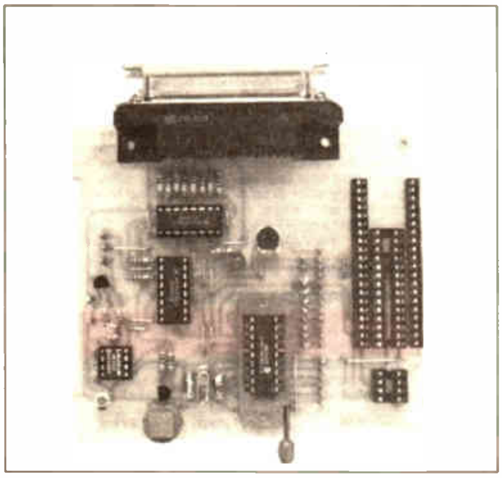

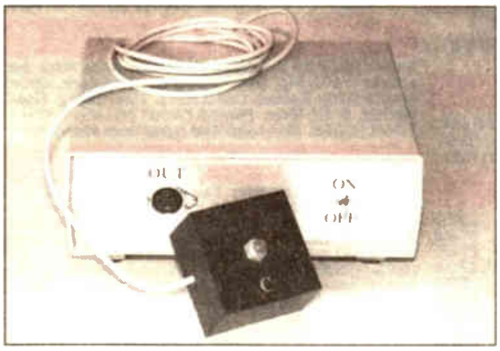


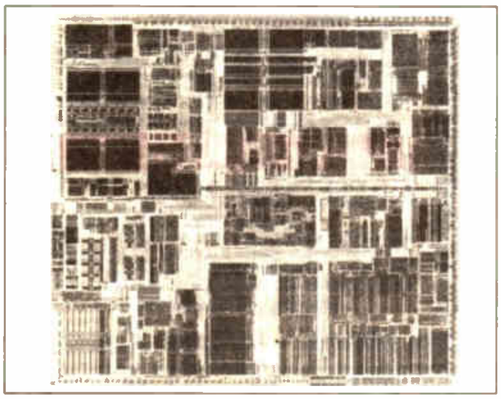



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Ring out thy bells with merry tolling – plus a MIDI PIC-up, of course!

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Coded radio remote control has become straightforward and requires no UK licence

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Ma, it's making eyes at me! The PhizzyBot now has vision – here's how ...

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Expanding Toolkit Mk1 to include the new PIC 16F87x devices as well as the familiar 'x84s, plus many more features!

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***FREE***

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***Our June '99 issue will be published on Friday, 7 May 1999. See page 315 for details.***

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# NEXT MONTH

## *MUSICAL SUNDIAL*

*TRAVESTY – that's the word, it's an absolute and utter travesty – this Sundial thingy, it's a gross and total misuse of sophisticated electronics. Well, think about it – In the Beginning was the Big Shout that echoed throughout the Multiverse: "Let there be Light", and so it was, and so came about shadow where light could not reach. And man saw the shadow and how it moved when the light moved, and thus he saw the motion of time and that it can be measured in its motion beneath the plants and trees around him, and thus the sundial was there for his enlightenment from the beginning.*

*And what happens? Aeons later along comes a bright spark who says to himself "Electronics can tell the time from the motion of sunlight", and set about to prove it. But why he should bother was never questioned – and it should have been; the sundial already IS and needs no improvement, and it certainly doesn't need to be made with technology.*

*Nonetheless, it's been done and we feel you should know about it, perhaps even build it and marvel at how petty we humans can be at trying to replicate what nature has already achieved without even thinking about it.*

*So what does this Musical Sundial contraption actually do? It monitors the motion of the sun of course – a pointer casts a shadow which rotates with the sun. Sensors in an arc detect the position of the shadow and when a sensor is completely covered by the shadow, electronically generated musical chimes and pips mark the hour of the event, one pip for each hour past. Then . . . and then, you get a tune played! And what tune might it be – what else but something that might perhaps remind you of the old classic "You are my Sunshine" (although a real musician wouldn't think so)!*

*But that's not all – on any day when the weather's changeable, with the sun coming and going, appropriate phrases of the "tune" mark the disappearance or re-appearance of the sun.*

*So that's what you do next month, build our Sundial (never mind what the neighbours might say about your sanity!). We provide the info, where you find the sun is up to you!*

**STARTER PROJECT**

***Next month we commence publishing a series of "Starter Projects" designed with the novice in mind. They are all easy to build and inexpensive, the first one is a***

## *CLIPPING VIDEO FADER.*

*Many camcorders include a video fader facility, but this is often in the form of a pushbutton control with a fixed rate of fade. A fader of this type is certainly usable, but offers no creative control to the user. This extremely simple video fader project has a conventional control knob that offers precise control over the fade characteristic. It provides what is virtually a conventional fade to black action, but the fading is provided by asymmetric clipping of the picture modulation rather than by attenuating it.*

*This method of fading operates in a different manner to a conventional fader, and it produces a different effect on-screen when the picture is faded. With the clipping method the brightest parts of the picture are faded first, then the mid-tones, and finally the darker areas. The picture collapses rather than fades from the screen. This project offers an interesting alternative to a conventional video fade effect, and it costs very little to build.*

## *ALAN DOWER BLUMLEIN – A TOUCH OF MAGIC*

*Many readers will have never heard of Alan Dower Blumlein, we hope we can put that right next month. He either originated or made profound contributions to Telephony, Monaural and Stereo Recording, Television, Radar, Amplifier Technology, and Signal Processing circuits.*

*Few will ever match A. D. Blumlein in his insight, breadth of knowledge or ability to solve problems in electronics and electrical engineering. If one defines genius as "original thought" then Blumlein had genius in abundance. In a life that was cut short during the second world war, he created more in a career lasting only 17 years than the vast majority do collectively in a lifetime. In all, Blumlein held 128 patents – on average one for every six weeks of his working life.*

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## OSCILLOSCOPES

| | |
|---|---|
| **Beckman 9020** – 20MHz – Dual Channel | £150 |
| **Cossor 3102** – 60MHz Dual Channel | £250 |
| **Gould OS 245A/250/255/300/3000/3351/4000** | from £125 |
| **Hewlett Packard 180A/180C/181A/182C** | from £200 |
| **Hewlett Packard 1740A, 1741A, 1744A**, 100MHz dual ch | from £350 |
| **Hewlett Packard 54100D** – 1GHz Digitizing | £1500 |
| **Hewlett Packard 54200A** – 50MHz Digitizing | £500 |
| **Hewlett Packard 54201A** – 300MHz Digitizing | £1250 |
| **Hitachi V152F/V302B/V302F/V353F/V550B/V650F** | from £125 |
| **Hitachi V650F** – 60MHz Dual Channel | £295 |
| **Hitachi V1100A** – 100MHz 4 Channel | £950 |
| **Intron 2020** – 20MHz Digital Storage (NEW) | £450 |
| **Iwatsu SS 5710/SS 5702** – 20MHz | from £125 |
| **Meguro** – MSO 1270A – 20MHz Digital Storage (NEW) | £450 |
| **Nicolet 310** – L.F. D.S.O. with twin Disc Drive | £400 |
| **Nicolet 3091** – L.F. D.S.O. | £750 |
| **Lecroy 9450A** – 300MHz/400 Ms/s D.S.O. 2 ch | £2250 |
| **Panosonic VP5741A** – 100MHz – Dual Channel D.S.O. | £1750 |
| **Philips PM 3055** – 50 MHz DUAL Timebase | £450 |
| **Philips PM 3211/PM 3212/PM 3214/PM 3217/PM 3234/PM 3240/PM 3243/PM 3244/PM 3261/PM 3262/PM 3263/PM 3540** | from £125 |
| **Philips PM 3295A** – 400MHz Dual Channel | £1750 |
| **Philips PM 3335** – 50 MHz/20Ms/s D.S.O. 2 ch | £1500 |
| **Tektronix 434** – 25MHz – 2 Channel Analogue Storage | £250 |
| **Tektronix 454** – 150MHz – 2 Channel | £400 |
| **Tektronix 455** – 50MHz Dual Channel | £0000 |
| **Tektronix 464/466** – 100MHz An storage | from £0000 |
| **Tektronix 465/465B** – 100MHz dual ch | from £0000 |
| **Tektronix 468** – 100MHz D.S.O. | £650 |
| **Tektronix TAS 475** – 100 MHz – 4 Channel | £995 |
| **Tektronix 475/475A** – 200MHz/250MHz Dual Channel | from £0000 |
| **Tektronix 485** – 350MHz – 2 channel | £750 |
| **Tektronix 2213** – 60MHz Dual Channel | £375 |
| **Tektronix 2215** – 60MHz Dual trace | £400 |
| **Tektronix 2220** – 60MHz Dual Channel D.S.O. | £1250 |
| **Tektronix 2221** – 60MHz Digital Storage 2 Channel | £1250 |
| **Tektronix 2225** – 50MHz dual ch | £395 |
| **Tektronix 2235** – 100MHz Dual trace | £600 |
| **Tektronix 2335** – Dual trace 100MHz (portable) | £600 |
| **Tektronix 2440** – 300 MHz/500 Ms/s D.S.O. 2 Ch | £2950 |
| **Tektronix 2445** – 150 MHz – 4 Channel + DMM | £1200 |
| **Tektronix 2445A** – 100 MHz – 4 Channel | £900 |
| **Tektronix 2445A** – 150 MHz – 4 Channel | £1250 |
| **Tektronix 5403** – 60MHz – 2 or 4 Channel | from £200 |
| **Tektronix 7313, 7603, 7613, 7623, 7633**, 100MHz 4 ch | from £225 |
| **Tektronix 7704** – 250MHz 4 ch | from £450 |
| **Tektronix 7904** – 500MHz | from £600 |
| **Trio CS-1022** – 20MHz – Dual Channel | £125 |

**Other scopes available too**

**SPECIAL OFFER**

| | |
|---|---|
| HITACHI V212 – 20MHZ DUAL TRACE | £160 |
| HITACHI V222 – 20 MHZ DUAL TRACE + ALTERNATE MAGNIFY | £180 |

## SPECTRUM ANALYSERS

| | |
|---|---|
| **Ando AC8211** – Spectrum Analyser 1.7GHz | £2250 |
| **Anritsu MS62B** – 10KHz – 1700MHz | £2250 |
| **Anritsu MS341A + MS3401B** – (10Hz – 30MHz) | £3995 + £4500 |
| **Anritsu MS610B** – 10KHz – 2GHz – (Mint) | £4750 |
| **Anritsu MS710F** – 100KHz – 23GHz Spectrum Analyser | £5950 |
| **Avcom PSA65 S** – 1000MHz – portable | £850 |
| **Hameg 8028/8038** – Spectrum Analyser/Tracking Gen +100MHz Oscilloscope | £1250 |
| **Hewlett Packard 182T** with 8559A (10MHz – 21GHz) | £3750 |
| **Hewlett Packard 182T + 8558B** – 0.1 to 1500MHz | £1750 |
| **Hewlett Packard 853A + 8558B** – 0.1 to 1500MHz | £2500 |
| **Hewlett Packard 8591A** – 9KHz – 1.8GHz with Option 10 Tracking Generator | £6500 |
| **Hewlett Packard 8594E** – 9KHz – 2.9GHz | £7000 |
| **Hewlett Packard 35601A** – Spectrum Analyser Interface | £1000 |
| **Hewlett Packard 3561A** – Dynamic Signal Analyser | £4750 |
| **Hewlett Packard 3562A** Dual Channel Dynamic Sig. Analyser | £6500 |
| **Hewlett Packard 3580A** – 5Hz-50KHz | £995 |
| **Hewlett Packard 3582A** – 0.02Hz – 25.6KHz (dual ch.) | £2000 |
| **Hewlett Packard 3585A** – 20Hz – 40MHz | £4500 |
| **Hewlett Packard 8753A** – Network Analyser | £4995 |
| **Hewlett Packard 8753B** – Network Analyser | £6500 |
| **IFR 7750** 10KHz – 1GHz | £2500 |
| **Marconi 2370** – 110MHz | £500 |
| **Marconi 2371** – 30KHz – 2000MHz | £750 |
| **Meguro MSA 4901** – 1-300GHz (AS NEW) | £850 |
| **Meguro MSA 4912** – 1-1GHz (AS NEW) | £1250 |
| **Rohde & Schwarz** – SWOB 5 Polyskop 0.1 – 1300MHz | £1500 |
| **Takeda Riken 4132** – 1.0GHz Spectrum Analyser | £2500 |
| **Tektronix 7L18** with mainframe (1.5-60GHz with external mixers) | £2000 |
| **Tektronix 495P** – 100Hz – 1.8GHz programmable | £4950 |
| **Tektronix 496P** – 1KHz – 1.8GHz Spectrum Analyser | £4500 |

## MISCELLANEOUS

| | |
|---|---|
| **Adret 740A** – 100KHz – 1120MHz Synthesised Signal Generator | £800 |
| **Anritsu MG 360A** Signal Generator 0.1-1040MHz | £1500 |
| **Anritsu ME 462B** DF/3 Transmission Analyser | £2500 |
| **Anritsu MG 645B** Signal Generator 0.05-1040MHz | £850 |
| **Boonton 92C** R/F Millivoltmeter | £250 |
| **Boonton 93A** True RMS Voltmeter | £250 |
| **Dranetz 626** – AC/DC – Multifunction Analyser | £600 |
| **EIP 331** – Frequency counter 18GHz | £600 |
| **EIP 545** – Frequency counter 18GHz | £1250 |
| **EIP 575** – Frequency counter 18GHz | £1450 |
| **Eltek SMPS** – Power Supply 60v-30v | £400 |
| **ENI 550L** – Power Amplifier (1.5-400MHz) 50W | £1500 |
| **Farnell TSV-70 MKII** Power Supply (70V – 5A or 35V – 10A) | £250 |
| **Farnell DSG-1** Synthesised Signal Generator | £125 |
| **Farnell ESG-1000** Synthesised Signal Generator 1GHz (as new) | £995 |
| **Farnell AP 30250A** Power Supply 3v - 250A | £1750 |
| **Feedback PFG 605** Power Function Generator | £200 |
| **Fluke 5100A** – Calibrator | £2500 |
| **GN ELMI EPR31** PCM Signalling Recorder | £3000 |
| **Guildline 9152** – T12 Battery Standard Cell | £550 |
| **Hewlett Packard 1630D** – Logic Analyser (43 Channels) | £650 |
| **Hewlett Packard 16500A** – Fitted with 16510A/16515A/16530A/16531A – Logic Analyser | £4000 |
| **Hewlett Packard 331A** – Distortion Analyser | £300 |
| **Hewlett Packard 333A** – Distortion Analyser | £300 |
| **Hewlett Packard 334A** – Distortion Analyser | £300 |
| **Hewlett Packard 3325A** – 21MHz Synthesiser/Function Gen. | £1500 |
| **Hewlett Packard 3336C** – Synthesised Signal Generator (10Hz – 21MHz) | £1000 |
| **Hewlett Packard 3437A** System voltmeter | £250 |
| **Hewlett Packard 3438A** Digital multimeter | £200 |
| **Hewlett Packard 3455A** 6½ Digit M/Meter (Autocal) | £600 |
| **Hewlett Packard 3456A** Digital voltmeter | £600 |
| **Hewlett Packard 3488A** – HP – 1B Switch control unit (various Plug-ins available) | £550 |
| **Hewlett Packard 3478A** – Multimeter (5½ Digit) + HP – 1B | £550 |
| **Hewlett Packard 35600A** Dual Ch Dynamic Signal Analyser | £3750 |
| **Hewlett Packard 3586A** – Selective Level Meter | £1000 |
| **Hewlett Packard 3711A/3712A/3791B/3793B** Microwave Link Analyser | £2250 |
| **Hewlett Packard 3746A** – Selective Measuring Set | £750 |
| **Hewlett Packard 3776A** – PCM Terminal Test Set | £1500 |
| **Hewlett Packard 3779A/3779C** – Primary Mux Analyser | from £600 |
| **Hewlett Packard 3784A** – Digital Transmission Analyser | £5000 |
| **Hewlett Packard 3785A** – Jitter Generator + Receiver | £1250 |
| **Hewlett Packard 37900D** – Signalling Test Set (No 7 and ISDN) | £4250 |
| **Hewlett Packard P382A** Variable Attenuator | £250 |
| **Hewlett Packard 4192A** – LF Impedance Analyser | £7000 |
| **Hewlett Packard 4262A** – Digital LCR Meter | £1250 |
| **Hewlett Packard 4279A** – 1MHz C-V Meter | £4500 |
| **Hewlett Packard 4342A** 'Q' Meter | £800 |
| **Hewlett Packard 435A** or B Power Meter (with 8481A/8484A) | from £750 |
| **Hewlett Packard 4948A** – (TIMS) Transmission impairment M/Set | £1500 |
| **Hewlett Packard 4972A** – Lan Protocol Analyser | £1750 |
| **Hewlett Packard 5183** – Waveform Recorder | £1750 |
| **Hewlett Packard 5238A** Frequency Counter 100MHz | £250 |
| **Hewlett Packard 5314A** – (NEW) 100MHz Universal Counter | £250 |
| **Hewlett Packard 5316A** – Universal Counter (IEEE) | £500 |
| **Hewlett Packard 5335A** – 200MHz High Performance Systems Counter | £600 |
| **Hewlett Packard 5370B** – Universal Timer/Counter | £2000 |
| **Hewlett Packard 5384A** – 225 MHz Frequency Counter | £650 |
| **Hewlett Packard 5385A** Frequency Counter – 1GHz – (HP1B) with OPTS 001/003/004/005 | £995 |
| **Hewlett Packard 5420A** Digital Signal Analyser | £350 |
| **Hewlett Packard 6033A** Power Supply Autoranging (20V – 30A) | £750 |
| **Hewlett Packard 6253A** Power Supply 20V – 3A Twin | £200 |
| **Hewlett Packard 6255A** Power supply 40V – 1 5A Twin | £200 |

**HEWLETT PACKARD 6261B**
**Power Supply 20V-50A £450** ***Discount for Quantities***

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| **Hewlett Packard 6264B** – Power Supply (0 – 20V. 0 – 25A) | £400 |
| **Hewlett Packard 6266B** Power Supply 40V – 5A | £220 |
| **Hewlett Packard 6271B** Power supply 60V – 3A | £225 |
| **Hewlett Packard 6632A** – Power Supply (20V – 5A) | £800 |
| **Hewlett Packard 7475A** – 6 Pen Plotter | £250 |
| **Hewlett Packard 7550A** – 8 Pen Plotter A3/A4 | £450 |
| **Hewlett Packard 8015A** – 50MHz Pulse Generator | £750 |
| **Hewlett Packard 8152A** – Optical Average Power Meter | £1250 |
| **Hewlett Packard 8158B** – Optical Attenuator (OPTS 002 + 011) | £1100 |
| **Hewlett Packard 8165A** – 50MHz Programmable Signal Source | £1650 |
| **Hewlett Packard 8180A** – Data Generator | £1500 |
| **Hewlett Packard 8182A** – Data Analyser | £1500 |
| **Hewlett Packard 8350B** – Sweep Oscillator Mainframe (various plug-in options available) | £2500 |
| **Hewlett Packard 83554A** – Wave Source Module 26 5 to 40GHz | £3500 |
| **Hewlett Packard 83555A** – Millimeter – Wave source Module 33-50GHz | £4250 |
| **Hewlett Packard 8405A** – Vector Voltmeter | £350 |
| **Hewlett Packard 8620C** Sweep oscillator mainframe | from £250 |
| **Hewlett Packard 8640B** – Signal Generator (512MHz + 1024MHz) | from £850 |
| **Hewlett Packard 8656A** – Synthesised Signal Generator (990MHz) | £1250 |
| **Hewlett Packard 8656B** – Synthesised Signal Generator | £1750 |
| **Hewlett Packard 8657A** – Signal Generator (100KHz-1040MHz) | £2500 |
| **Hewlett Packard 8660D** – Synthesised Signal Generator (10KHz-2600MHz) | £3250 |
| **Hewlett Packard 8750A** Storage normaliser | £375 |
| **Hewlett Packard 8756A** – Scalar Network Analyser | £1500 |
| **Hewlett Packard 8757A** – Scalar Network Analyser | £2250 |
| **Hewlett Packard 8901A** – Modulation Analyser | £2750 |
| **Hewlett Packard 8901B** – Modulation Analyser | £3750 |
| **Hewlett Packard 8903A** – Audio Analyser (20Hz – 100KHz) | £1600 |
| **Hewlett Packard 8903B** – Distortion Analyser | £2500 |
| **Hewlett Packard 8903E** – Distortion Analyser (Mint) | £2000 |
| **Hewlett Packard 8920A** – R/F Comms Test Set | £4995 |
| **Hewlett Packard 8922b** – GSM Radio Comms Test Set | £8500 |
| **Hewlett Packard 8958A** – Cellular Radio Interface | £2000 |
| **Keytek MZ-15/EC** Minizap 15Kv Hand Held ESD Simulator | £1750 |
| **Krohn-Hite 2200** Lin/Log Sweep Generator | £995 |
| **Krohn-Hite 4024A** Oscillator | £250 |
| **Krohn-Hite 5200** Sweep, Function Generator | £350 |
| **Krohn-Hite 6500** Phase Meter | £250 |
| **Leader LDM-170** – Distortion Meter | £350 |
| **Leader 3216** – Signal Generator (100KHz – 140KH z) AM/FM/CW with built-in FM stereo modulator (mint) | £995 |
| **Marconi 2019** – 80KHz – 1040MHz Synthesised Sig. Gen | £950 |
| **Marconi 2019A** – 80KHz – 1040MHz – Synthesised Signal Generator | £1250 |
| **Marconi 2305** – Modulation Meter | £1995 |
| **Marconi 2337A** – Automatic Distortion Meter | £150 |
| **Marconi 2610** – True RMS Voltmeter | £850 |
| **Marconi 2871** Data Comms Analyser | £1000 |
| **Marconi 2955** – Radio Comms Test Set | £2250 |
| **Marconi 6960** – Power Meter & Sensor | from £950 |
| **Philips PM 5167**MHz function gen | £400 |
| **Philips 5190** L.F. Synthesiser (G P I B) | £800 |
| **Philips 5193** Synthesised Function Generator | £1500 |
| **Philips 5518** Synthesised Function Generator | £1500 |
| **Philips PM5519** – TV Pattern Generator | £350 |
| **Philips PM5716** – 50MHz Pulse Generator | £525 |
| **Prema 4000** – 6 ½ Digit Multimeter (NEW) | £450 |
| **Quartzlock 2A** – Off Air Frequency Standard | £200 |
| **Racal 1992** – 1 3GHz Frequency Counter | £800 |
| **Racal 6111/6151** – GSM Radio Comms Test Set | £POA |
| **Racal Dana 9081/9082** Synth. sig gen. 520MHz | from £500 |
| **Racal Dana 9084** Synth. sig. gen 104MHz | £450 |
| **Racal 9301A** – True RMS R/F Multivoltmeter | £300 |
| **Racal Dana 9302A** R/F multivoltmeter (new version) | £375 |
| **Racal Dana 9303** R/F Level Meter & Head | £650 |
| **Racal Dana 9917** UHF frequency meter 560MHz | £175 |
| **Rohde & Schwarz LFM2** – 60MHz Group Delay Sweep Gen. | £1600 |
| **Rohde & Schwarz** Scud Radio Code Test Set | £300 |
| **Rohde & Schwarz CMTA 94 GSM Radio Comms Analyser** | £7500 |
| **Schaffner NSG 203A** Line Voltage Variation Simulator | £950 |
| **Schaffner NSG 222A** Interference Simulator | £850 |
| **Schaffner NSG 223** Interference Generator | £850 |
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## COVER CHANGES

Whilst we have had a number of important changes to our front cover over the last 23 years (from *Everyday Electronics* to *Everyday Electronics and Computer Projects* to *Everyday Electronics and Electronics Monthly* back to *Everyday Electronics*, then to *Everyday Practical Electronics/ETI*) our back cover has only carried one name – Maplin (they first took the *EE* back cover in the Jan 1976 issue). So another era comes to a close, as you will notice, this month.

A number of readers have speculated over the last year or so that Maplin are moving away from the hobby market and, with the cancellation of their regular advertising after so many years on our back cover, we wondered if there was in fact something behind this speculation. With this in mind we wrote to David O'Reilly, Marketing Manager at Maplin Electronics, to ask if Maplin had decided to reduce its support to the hobbyist in the UK. David's reply is reassuring, the relevant part of his letter reads:

"Maplin Electronics is categorically supporting the electronics hobbyist in the UK. We are doing this in a number of ways, most importantly we are developing our e-commerce site to assist retail consumers.

"Both myself and Maplin totally understand the benefits of your magazine, and your company, like ours, is one of the few organisations to continue to support this very important market.

"As with all things, budgets and time constraints mean that all communications to customers have to be constantly reviewed. We have to find the most cost effective method to provide our customers with information on special offers. Sometimes it is more appropriate to invest the time and money in providing good products at good prices, than provide promotional material specifically relating to a catalogue launch.

"I hope you find the points that I have raised in this letter cover your concerns. I cannot stress how important the hobbyist market is to Maplin, it is our heritage, our customer and it is what pays our wages."

## HARD TIME

Maplin Electronics have not had an easy time over the last couple of years, the Saltire company of which they are part lost £5·34 million (pre-tax loss) in 1997 and the interim report for the half-year to July '98 shows a further pre-tax loss of £2·01 million. Their shares were trading at just 4p each at the time of writing, up from a low of 3·5p.

Maplin now have a new MD and hopefully their fortunes will soon change. They are by far the largest supplier of electronic components to hobbyists, but in recent years have been stepping up their services to industry in competition to the likes of Farnell (the largest distributor of electronic components) and RS. It is, however, clear from David's letter that the hobbyist still "pays our wages".

We expect that Maplin will continue to advertise in our pages from time to time, but their regular back page advert has come to an end.

Mike Kenward

### AVAILABILITY

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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*).

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Constructional Project

# MIDI HANDBELLS


## ROBERT PENFOLD


*Ring out thy bells with merry tolling – plus a MIDI PIC-up, of course!*

THIS project was primarily designed with children in mind, and was actually produced in response to a request from a reader who required the gadget for a group of handicapped children. However, it is capable of providing hours of fun for "children" of all ages! It could be regarded as a modern equivalent to a set of handbells.

It is really a form of MIDI interface, and is incapable of making any sound without the aid of a MIDI equipped synthesiser, sound sampler, or other MIDI instrument. The output of the interface connects to the MIDI input of the instrument, which is set to produce a bell sound or any other sound you like. Up to 11 pushbutton switches can be connected to the inputs of the interface.

The general idea is for each player to control one or two pushbutton switches. By operating the switches in the correct sequence and with the correct timing the desired tune can be produced. In other words, the melody is played in much the same way that it would be produced by traditional handbell players.

This simple MIDI method has the advantage of not restricting the players to a single instrument sound, but it also has the drawback of not permitting any control over the dynamics of the instrument. Most MIDI instruments are capable of responding to velocity information, but it is not possible to derive this information from a simple on/off pushbutton switch. All notes, therefore, have the same mid-range velocity value of 64.

A unit of this type is potentially very complex, but the use of a PIC processor in this design minimises the amount of hardware required. In fact, only a handful of components plus the pushbutton switches are required. The circuit is powered from a 4·5V battery which has an extremely long operating life due to the low current consumption of the interface.

The unit should be usable with any MIDI equipped musical instrument, and it connects to the instrument via a standard MIDI cable. Any modern MIDI equipped instrument should be polyphonic, and so is this interface. It should therefore be possible to play several notes at once if desired.

### MIDI BASIC

MIDI is a form of serial interface which operates in conjunction with a standard set of message codes that control the actions of the slave devices. The basic action of this interface is to monitor the 11 pushbutton switches, and to generate the appropriate pulse train each time a switch is pressed or released.

In this case only two types of MIDI message are involved, and these are the note-on and note-off varieties. These both involve the transmission of three bytes of data, and both types of message follow the same general format.

The first byte is the status byte, and this breaks down into two four-bit nibbles. The four most significant bits indicate the type of message involved, and in this case binary values of 1000 (note-off) or 1001 (note-on) are used. Where appropriate, the four least significant bits carry the MIDI channel number. In this case both types of message are of the channel variety, and must include a channel number.

It will not normally matter which channel is used, and the slave device could actually be set to Omni mode so

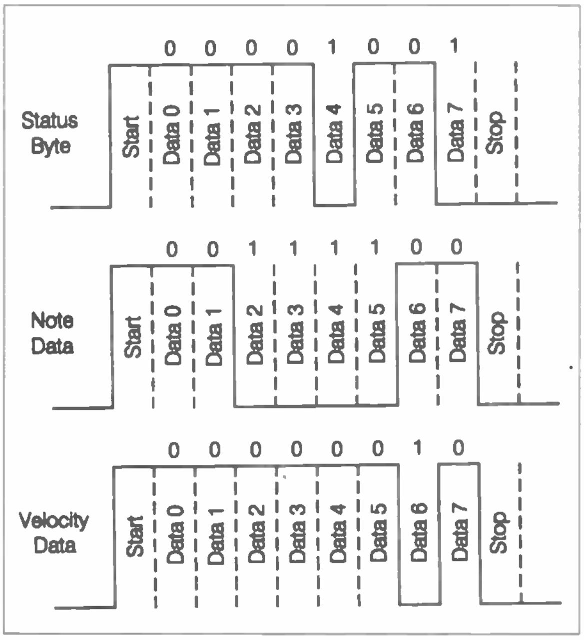
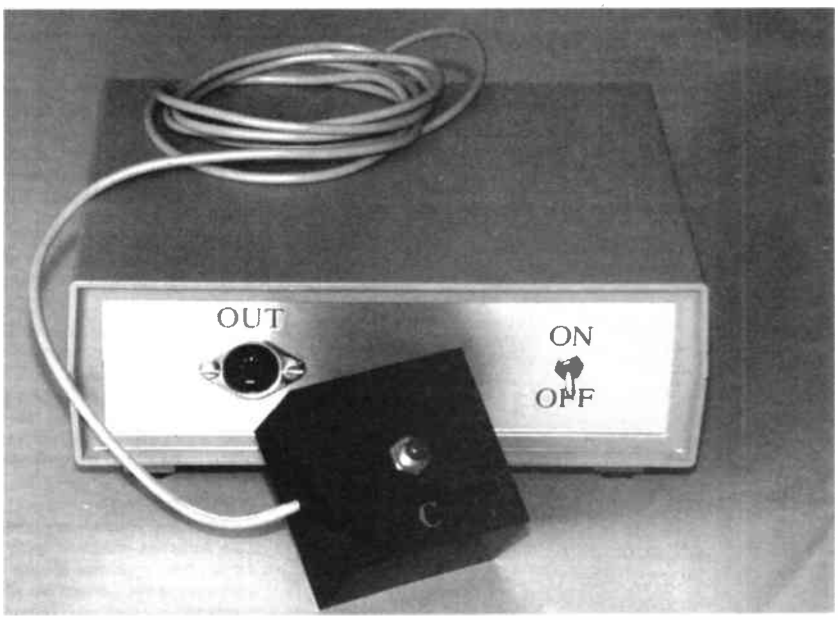



*Fig.1. Example waveforms for a "note-on" message.*




*Completed unit with one "handbell" in the foreground. Eleven such "bells" are required.*

that it responds to messages on any channel. The convention is for devices to default to channel one, which actually requires a binary value of 0000 in the status byte. This anomaly is due to the fact that MIDI channels are, as one would expect, in the range one to 16, whereas the values used in the status bytes are from 0 to 15.

## NOTE VALUE

The status byte is followed by the note value, and like all MIDI data values this is in the range 0 to 127. Middle C is at a value of 60, and the system has a resolution of one semitone. The third byte carries the velocity value, which in a note-on message is a measure of how hard the key of a keyboard instrument has been played, how hard a drum pad has been struck, or whatever. In the current context there is no way of detecting how hard the pushbutton switch has been operated, and the convention is for a dummy value of 64 to be used in these circumstances.

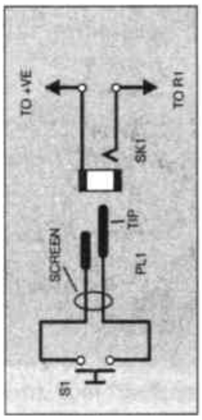
Note-off messages also have a third byte containing velocity information, but this feature is not implemented in many MIDI devices. The third byte must always be included though, and the convention is to use a dummy value of zero where this feature is not implemented.

## NOTE-ON

The illustration in Fig.1 shows the output waveforms needed to produce each byte in a message that will switch on middle C. MIDI is actually a current loop system that operates by switching a 5mA current on and off. This current is used to control the l.e.d. in an opto-isolator at the input of the receiving device. The opto-isolation helps to avoid problems with "hum" loops, and with digital noise leaking into the audio circuits.

Logic 0 and 1 are respectively represented by the current being switched on and off, which respectively require the output of the PIC processor to go high and low. For this reason the waveforms of Fig.1 do not have the expected polarity, and logic 1 is represented by a low voltage.

Under standby conditions the output current is switched off, and the output of the PIC processor is low. At the beginning of a new byte of data the current is switched on for one bit in duration, and




*Circuit alteration for including a jack socket to separate the handbell switches from the main circuit*

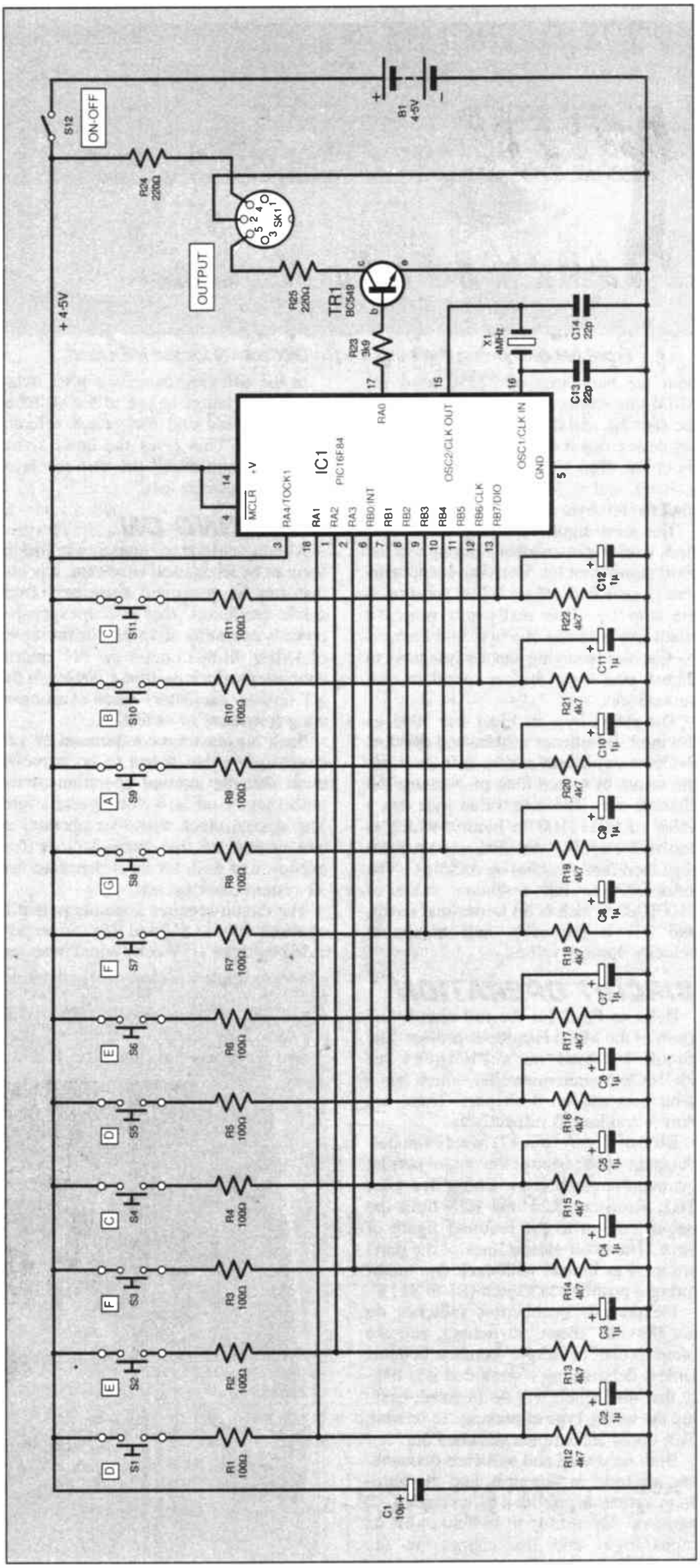
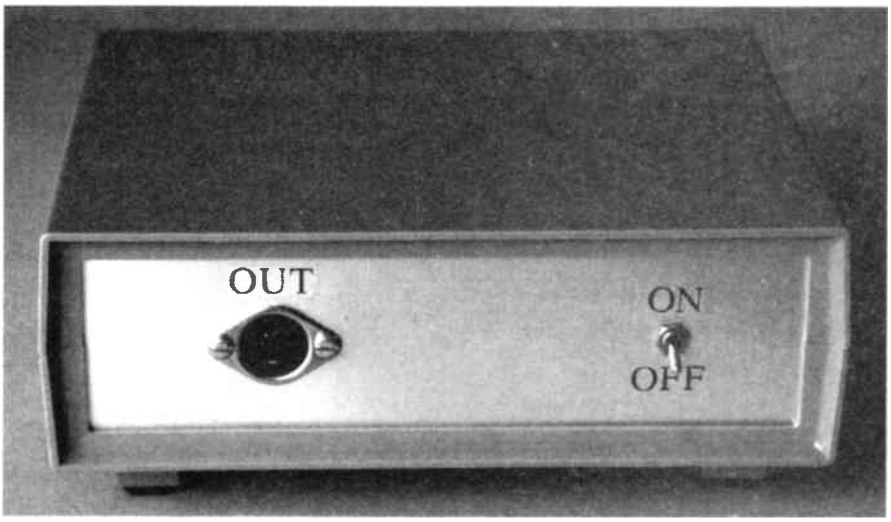



*Fig.2. Complete circuit diagram for the Midi Handbells.*



*Front panel showing the output 5-pin DIN socket for the MIDI lead.*

with the baud rate of 32150 used for MIDI this works out at 32µs. This bit is the start bit, and it indicates to the receiving device that it must test the state of the input line 48µs after the beginning of the start bit, and at 32µs intervals thereafter until the full byte of data has been read in.

The least significant data bit is sent first, working in sequence through to the most significant bit. Then the output current is switched off for 32µs, and this is the stop bit. This really just places a small gap between one byte and the next so that the receiving device has time to digest one byte before another one commences.

The status byte in Fig.1 has 1001 as the most significant nibble, and 0000 as the least significant nibble. It is therefore the status byte in a note-on message on channel one. The note value byte has a value of 00111100 in binary, which is equivalent to 60 in decimal, and the message therefore switches on middle C. The velocity byte has a binary value of 01000000, which is 64 in decimal terms, and this is the usual half maximum velocity dummy value.

## CIRCUIT OPERATION

Refer to Fig.2 for the full circuit diagram of the MIDI Handbells project. The circuit is based on a PIC16F84 (or PIC16C84) microcontroller which has a 4-bit port and an 8-bit port. These are Port A and Port B respectively.

Bit 0 of Port A (pin 17) is set as an output and used to control the output current via common emitter switching transistor TR1. Resistors R24 and R25 limit the output current to the required figure of 5mA. The other eleven lines of the ports are used as inputs, with each one monitoring a pushbutton switch (S1 to S11).

Inexpensive pushbutton switches do not provide "clean" switching, and are often prone to severe contact bounce. Unless debouncing is provided it is likely that the switch will be misread, causing the wrong type of message to be sent. This could leave notes switched on.

Both hardware and software debouncing are used in this unit, and the hardware variety is provided by a simple *C-R* network. Operating a switch pulls its input high, and the charge on the debouncing capacitor prevents any rapid return to the low state.

In the software there is a brief delay between a change in one of the switches being detected and the switch actually being read. This gives the input signal time to stabilise at the correct level before the input is read.

## CLOCKING ON

Although MIDI operates at what might seem to be an unusual baud rate, it is one that can be generated accurately from clock oscillators that use inexpensive crystals operating at 1MHz, or multiples of 1MHz. In this circuit the PIC microcontroller's clock oscillator is used in the XT (crystal oscillator) mode at an operating frequency of 4MHz.

Each bit must have a duration of 128 clock cycles, but it has to be borne in mind that the internal operation of the processor is on a 4-clock pulse cycle. The system clock therefore operates at one quarter of the external clock frequency, and each bit must therefore last 32 system clock cycles.

The circuit requires a supply potential of about 4·5V to 5V, and this can be provided by three 1·5V cells wired in series.

## COMPONENTS

**Resistors**

| | | |
|---|---|---|
| R1 to R11 | 100Ω (11 off) | |
| R12 to R22 | 4k7 (11 off) | |
| R23 | 3k9 | |
| R24, R25 | 220Ω (2 off) | |

All 0·25W 5% carbon film.

See SHOP TALK page

**Capacitors**

| | |
|---|---|
| C1 | 10µ radial elect. 25V |
| C2 to C12 | 1µ radial elect., 63V (11 off) |
| C13, C14 | 22p ceramic plate (2 off) |

**Semiconductors**

| | |
|---|---|
| TR1 | BC549 *npn* transistor |
| IC1 | PIC16F84 or PIC16C84 microcontroller, preprogrammed (see text) |

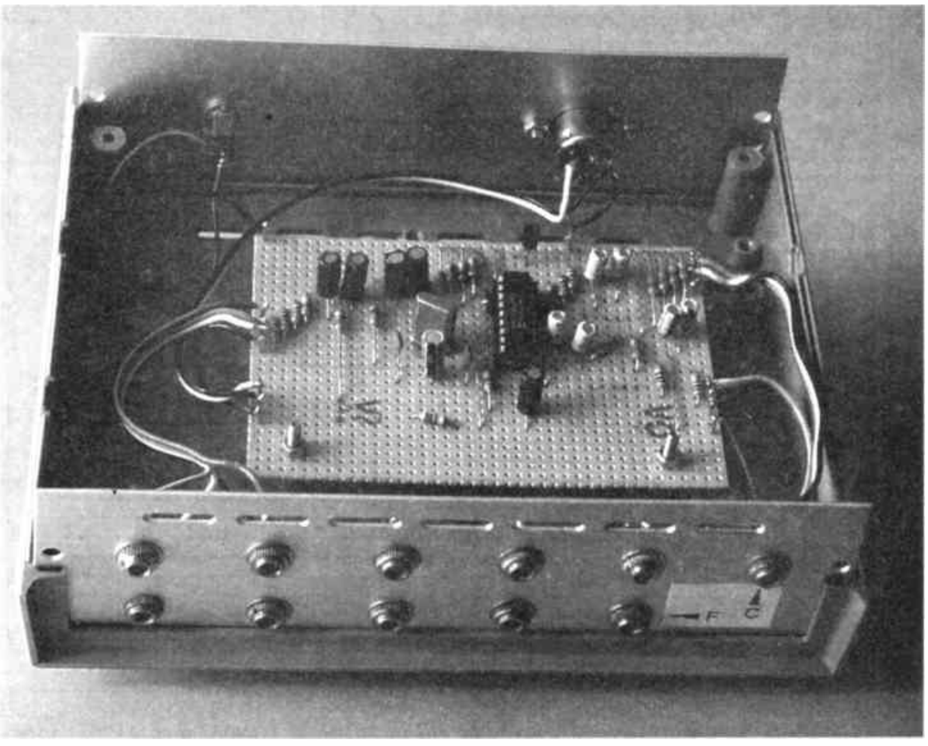
**Miscellaneous**

| | |
|---|---|
| S1 to S11 | Push-to-make switch (11 off) |
| S12 | s.p.s.t. min. toggle switch |
| SK1 | 5-way (180 degree) DIN socket, chassis mounting |
| B1 | AA size 1·5V cell (3 off), plus holder |
| X1 | 4MHz wire-ended crystal |

Plastic case, medium size (see text); plastic case, small (see text) (11 off); 0·1in matrix stripboard, size 40 holes × 27 strips; battery connector, PP3 type; screened connecting cables; connector block or 3·5mm jack plugs and sockets (see text); 18-pin d.i.l. socket; connecting wire; solder pins; solder, etc.

**Approx. Cost Guidance Only £24**

The current consumption is only two or three milliamps under standby conditions, but it increases slightly when the unit is active. Each set of AA size cells should provide several hundred hours of

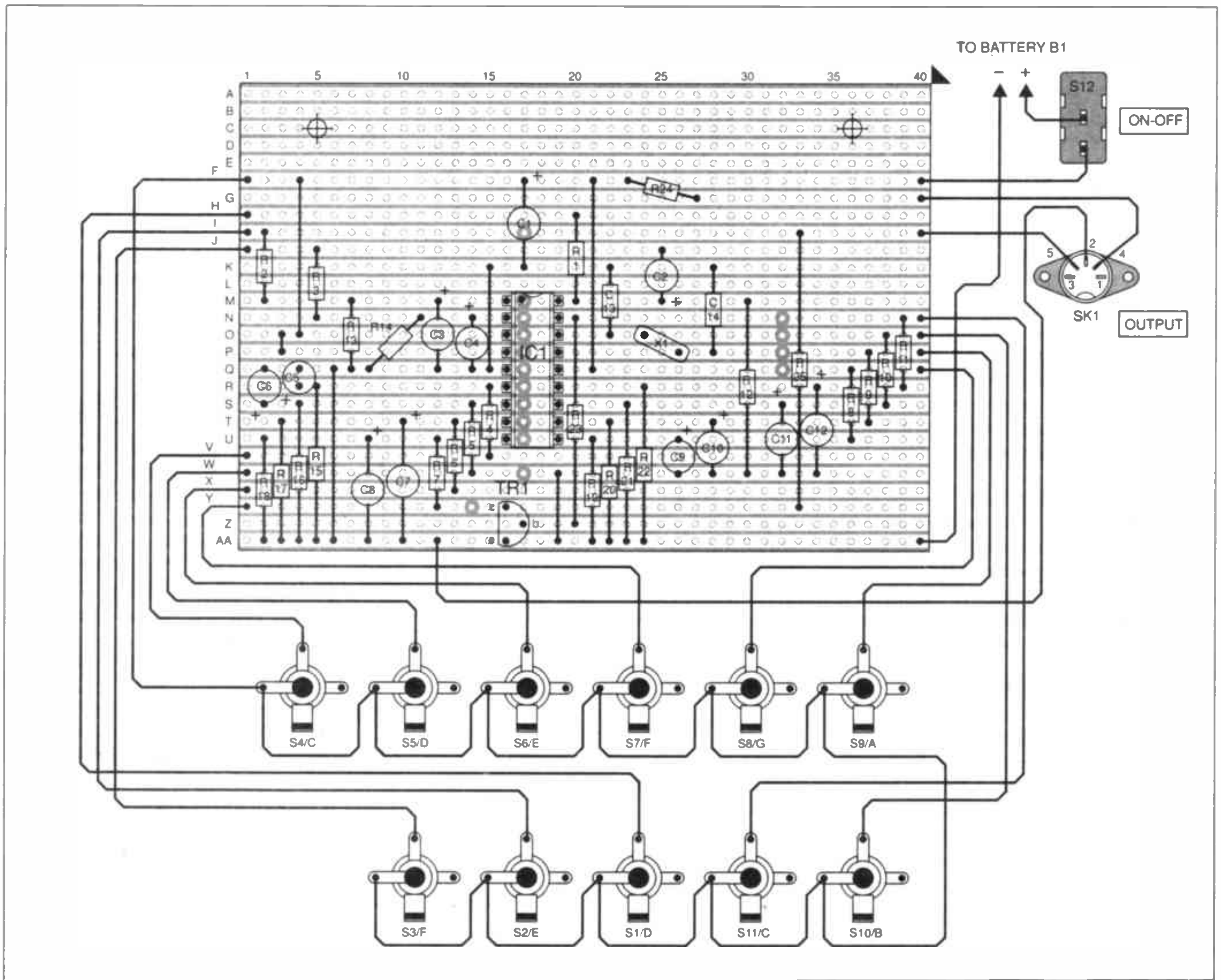

*Interior layout of components and the "handbell" jack sockets mounted on the metal rear panel of the case.*

use, and "bog-standard" batteries are perfectly adequate.

## CONSTRUCTION

The circuit is assembled on a stripboard panel that measures 40 holes by 27 strips. The component layout, interwiring and details of breaks required in the underside copper strips are provided in Fig.3. Construction of the board follows along the normal lines, with the board being trimmed to size, the two mounting holes being drilled, and the breaks being made in the copper strips.

Next the components are added, starting with the small components and link-wires, working through to the larger components such as crystal X1 and the PIC processor (IC1). There are only a few link-wires, but some of them are quite long and it might be worthwhile



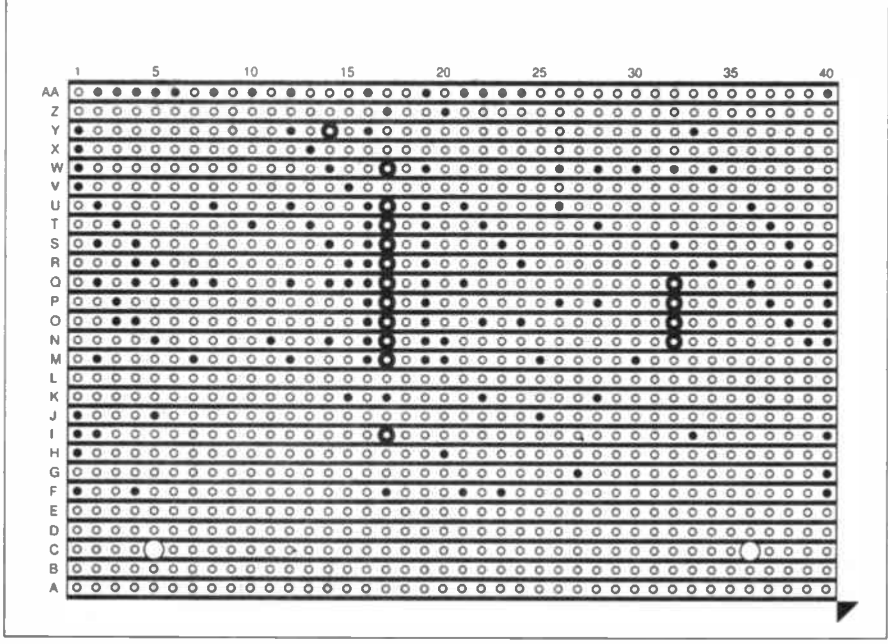



*Fig.3. Stripboard component layout, wiring and details of breaks required in the underside copper strips.*

insulating these with pieces of PVC sleeving. Do not overlook the short link just above C5 and C6.

The crystal must be a miniature wire-ended type having 5mm (0·2 inch) lead spacing if it is to fit into this layout properly. This case style is often referred to as the HC-49/U type in component catalogues. Crystals are slightly less tolerant of heat than most other components, and the two soldered joints must therefore be completed reasonably swiftly.

The PIC processor is a CMOS device, and it is therefore vulnerable to damage from static charges. The usual anti-static handling precautions should therefore be observed, the most important of which is to fit the device in a holder. Do not plug it into the holder until the circuit board and all the wiring have been completed.

Any medium size instrument case or one of the larger plastic boxes will accommodate this project. On/off switch S1 and output socket SK1 are mounted on the front panel. SK1 must be a 5-way

(180 degree) DIN socket connected in the manner shown in wiring diagram Fig.3. The unit can then be connected to the MIDI input socket of the synthesiser via a standard MIDI lead.

## SWITCHES

The main problem with a project of this type is getting the pushbutton switches connected to the circuit board. One solution is to drill eleven small holes in the rear panel for the leads to the switches, and to then connect the leads direct to the circuit board.

This is not a good way of handling things, since anyone tripping over the leads is likely to damage both the interface and themselves. There could also be major problems with the leads getting tangled.

It is much better to connect each switch to the main unit by way of a 3·5mm jack plug at the end of its lead, and matching socket on the rear panel. The only problem with this approach is that the cost of eleven 3·5mm jack plugs and sockets will significantly boost the cost of the system.

However, it is likely to be money well spent as it makes it must easier to sort out tangled leads, and to store the equipment neatly. Also, if anyone should trip over one of the leads the plug will simply pull free from its socket and no harm should be done.

## INTERWIRING

The interwiring shown in Fig.3 assumes that the connections to the pushbutton switches are via 3·5mm open style jack sockets. These have a built-in switch that connects to a third tag, but this extra tag is left unused in this application. The lead connecting all the earth tags (which connect to the positive supply rail in this case) is not needed if the switches are mounted on a metal panel. This connection will then be provided via the panel.

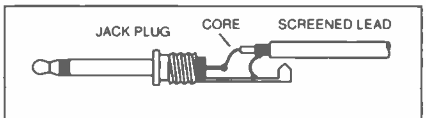



*Fig.4. Connecting a screened lead to a 3·5mm jack plug.*

If you require a cheap alternative to jack sockets, make the connections to the leads by way of a 22-way connector block. It is definitely not advisable to connect the leads direct to the stripboard.

For the system to be usable, the leads will need to be at least two metres long, and something closer to three metres is better. Around 30 metres of cable will therefore be required. Any thin twin cable should be suitable, but an inexpensive audio screened lead is probably the best choice. The screen connects to the positive supply rail, and the inner conductors connect to the inputs of the circuit board (see Fig.4).

In order to make things neater and easier to use, the pushbutton switches should be mounted in small plastic boxes. The cheapest of plastic boxes are adequate, and "potting" boxes (which only have five sides) are a good choice. A type measuring about 48mm × 48mm × 29mm is about right.

## TESTING

Output socket SK1 connects to the MIDI IN socket of the instrument using a standard MIDI lead. At least one lead of this type is normally supplied with a MIDI equipped instrument, and ready-made MIDI leads are readily available.

The interface transmits on MIDI channel one, and the instrument must therefore be set to receive on this channel, or set to Omni mode so that it responds to messages on all MIDI channels.

With everything connected up and switched on, pressing any of the pushbuttons should result in the appropriate notes being played on the instrument. If there are any signs of a problem, switch off at once and recheck the circuit board and all the wiring, etc.

As pointed out previously, the interface is polyphonic, and the maximum number of notes that can be played simultaneously is eleven, or the number supported by the instrument if this is less than eleven. There should be no problem in playing an accompaniment on the keyboard while the instrument is being played via the MIDI interface, provided the instrument can handle all the notes.

## SOFTWARE

For details on obtaining the software and pre-programmed PICs, see *Shop Talk* page.

The PIC's program requires the fuses to be set for crystal clock (XT) operation with the watchdog timer switched off and the power-up timer switched on. The initial part of the program sets RA0 as an output and leaves the other lines of both ports as inputs. Next, the values used in the transmitted bytes of data are stored in file registers. At this stage the file register used to store the note values is left empty, because this cannot be filled until a switch has been operated and the correct note value can be determined.

The program then goes into a loop that checks Port B and then Port A to see if a switch has been operated or released. The same method is used for both ports, which is to compare the previous value read from the port with the new value.

This is done by exclusive ORing (XORing) the two values, which will return a value of zero and set the zero flag if there has been no change. The returned value will be other than zero if a switch has been operated or released. Of equal importance, the bit of the returned value that is set to one indicates which switch has produced the change.

Once a change in the switch settings has been detected a short debouncing delay is provided by an "empty" loop. Then the program branches to a routine that checks each bit of the returned value, one by one, until it finds the bit that has been set to logic 1. The program then branches to the appropriate subprogram where the correct note value is written to file register TRDATA2, which is the one used to store note values.

The relevant bit of the appropriate port is then checked to determine whether it is low or high and, depending on the result, the program branches to a subroutine that produces either a note-on message or a note-off message.

## ROUTINE CALL

The two subroutines operate in the same basic manner, so we will only consider the note-on routine (NTON) here.

First RA0 is set high and a timing loop plus an NOP operation are used to keep it in that state for 32µs. This produces the start bit. The program then moves into a loop where it is looped eight times, as controlled by the value placed in variable CNTR2.

On each loop one of the data bits is generated. First the value for the status byte is complemented (inverted) and loaded into the W register. Remember that the serial data bits use high/on to represent logic 0, and low/off to represent logic 1, making this inversion of the data necessary. The value in the W register is written to Port A, but as only RA0 is set to the output mode, it is only bit 0 that has any affect.

After a simple delaying routine, the data byte is rotated one place to the right, making what was previously bit one the least significant bit. The program then loops back to the beginning of the routine, with the data being complemented and then written to Port A again. This process continues until all eight bits have been output on RA0 for 32µs, and all the data bits have been transmitted. Next RA0 is set low, and a delay of 32µs is provided. This generates the stop bit.

Basically, the same 8-loop routine is then performed again, but this time the note value in TRDATA2 is output on RA0 in serial form. Another loop routine then transmits the velocity data byte stored in TRDATA3. Finally, any stored values that have been altered are restored to their normal values, and the program returns to the main loop where it resumes checking for a change in the switch data.

The note values in the KEY subprograms can be altered to provide any desired notes. The sample values give a C major scale from middle C to the F an octave and a bit higher. A full set of semitones would be a useful alternative.

The PIC16x84 has EEPROM program memory that is easily reprogrammed, making it easy to alter the note data if you have access to a suitable programmer system.

Bear in mind that although MIDI can handle note vales from 0 to 127, most instruments have a more restricted compass. The MIDI implementation chart supplied with MIDI instruments should give details of the note range covered. ☐

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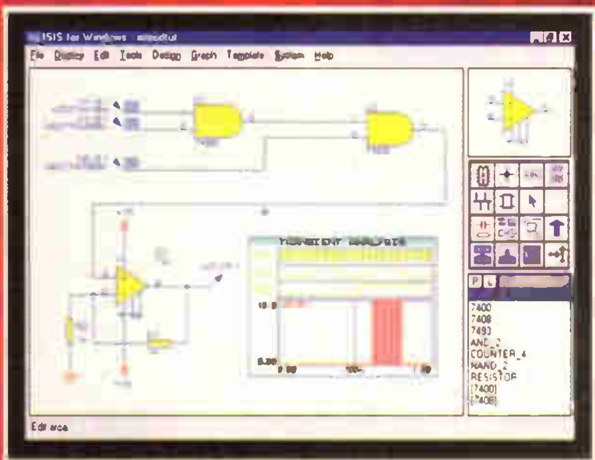

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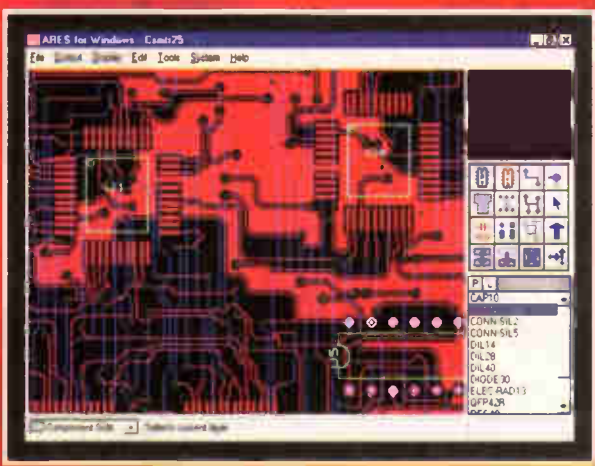

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# News...

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

# YOUR NUMBER'S UP – YET AGAIN!

## *Equal misery is the policy adopted for the forthcoming new telephone number system. Barry Fox reports.*

As a result of piecemeal planning, Londoners must change their telephone numbers and stationery for the third time in ten years. Other areas will suffer too. A cross-party Trade and Industry Select Committee of MPs blames the UK's telecoms watchdog, Oftel, for the inconvenience and cost to users. Oftel admits it "did not do a cost/benefit analysis".

Oftel has adopted the principle of equal misery. Dial codes will be radically changed in cities as they run out of numbers, with capacity for new subscribers created by forcing existing subscribers to use completely different 4-digit prefixes.

The proliferation of direct-dial extensions, mobiles, faxes and modems has created a world shortage of numbers, especially in the UK where codes are tied to geographical location and rural areas have spare capacity.

In May 1990 BT, which was then still in charge of numbering, split London's 01 code into 071 for the centre and 081 the outer zone. In April 1994 Oftel took over and increased the number pool tenfold by adding an extra digit to every number in the country. So London changed to 0171 and 0181.

On 22 April 2000, Oftel creates a completely new 02 range. This re-unites London as 020, with 0207 for the inner city and 0208 for outer zones. Cardiff gets 029, Southampton and Portsmouth share 023, Coventry becomes 024 and Northern Ireland changes to 028.

Oftel decided against the US system of giving new subscribers new range numbers and leaving existing subscribers alone, because some local calls would then need full code dialling.

Says David Rogerson, Principal Consultant at Ovum, the telecoms analyst which in 1989 advised Oftel to introduce 10-digit numbers, "Oftel said that people did not like number changes, or dialling extra digits for local calls. This seemed a perverse conclusion because there are now to be widespread changes with more to come. People don't mind dialling a few extra digits as long as the call costs the same and the digits are familiar".

To smooth the change, the networks will start accepting new 02 numbers as well as old 01s, from 1 June 1999. But the National Code and Number Change steering group warns that this will create problems if payphones, call loggers and routers throughout the UK are not modified before June so that they recognise both old and new codes. So far only one in ten firms has taken any action.

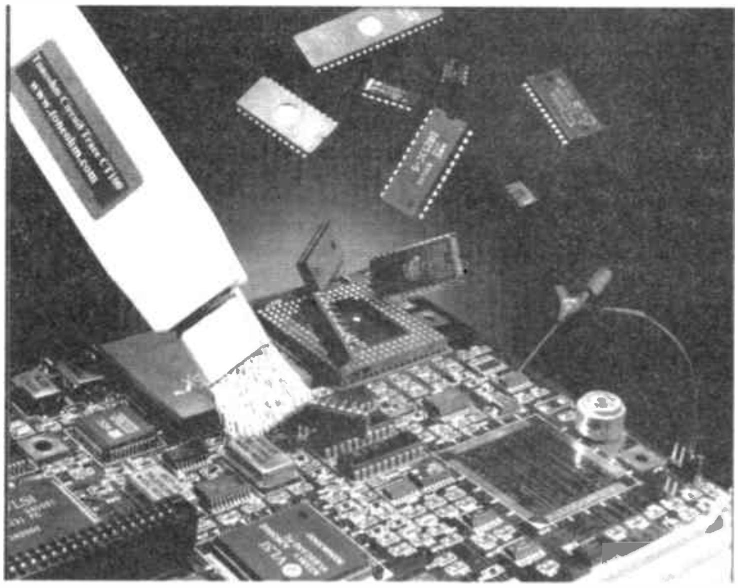
Oftel's Director General David Edmunds argues "There has been full consultation with consumers, business users and telecom companies. If the code changes do not take place London will run out of capacity by summer 2000. Customers need more information."

Oftel is leaving this job to the telecoms operators and their Big Number campaign. A spokeswoman for Big Number admits that there has been no publicity for the June change since last October but the campaign will "soon" run reminder adverts.

Other countries have adopted different approaches. As cities in the US, like New York and Los Angeles, run out of numbers, new subscribers get numbers with whatever new 3-digit prefix is spare. But existing subscribers keep their old numbers.

When French cities started to run out, France Telecom split the country into four zones and added an extra 2, 3, 4 or 5 to the numbers in those zones. It was all done at one fell swoop at 2300 hours on 18 October 1996. Calls dialled to the old numbers simply failed to get through.

## BRUSH-UP YOUR TESTING!



NOW here's a seemingly innovative idea – a p.c.b. test tool that uses a brush-technique to trace connections.

Circuit Trace are the manufacturers, who tell us that they are a start-up company that intends to sell direct via the Web. Their new CT100 is a small handheld connectivity tester that enables users to accurately locate all interconnected points on a p.c.b. within seconds, simply by wiping a conductive brush over the surface of the board and listening for an audible tone.

It seems obvious that this extremely simple approach can be used to significantly reduce fault finding time on any type of p.c.b., regardless of component technology or board complexity. The CT100 has a maximum output of 150mV, making it suitable for testing p.c.b.s containing all types of components, including CMOS devices. A sliding collet enables the stiffness of the conductive brush to be adjusted to suit the type of board being tested. It can also be set to a very loose condition that is ideal for sweeping edge connectors.

The tool is supplied complete with test probes, circuit marker, carrying case and comprehensive user manual. It costs £93.50, including P&P, anywhere in the world. It is available via **http://www.toneohm.com**, or contact Circuit Trace, Dept EPE, PO Box 70, Retford DN22 0SY. Tel/fax: 01777 248993. E-mail: mrbass@globalnet.co.uk.

# DIGITAL RADIO TUNER


ARCAM, the renowned British manufacturer of audio equipment, has announced the introduction of the world's first digital radio hi-fi tuner – the Alpha 10 DRT. It went on sale throughout the UK on 15 March.

Over 60 per cent of the UK is covered by BBC Digital Radio broadcasting and rapid expansion of the network is planned, with Commercial Radio going live in October '99. Digital Radio will eventually replace all current analogue broadcasting.

The Alpha 10 DRT is, say Arcam, the first home DRT to be developed and the first to go on retail sale. It is a standalone unit incorporating radical new technology, and is easily added to any hi-fi system, much as one would add a new CD player. It matches other units in Arcam's range.

The price is around £800 (but the music is free, say Arcam!), and the tuner is on sale nationally through around 100 Arcam hi-fi dealers within range of a BBC Digital transmitter.

For more information, contact your local Arcam dealer, or A&R Cambridge Ltd., Dept EPE, Pembroke Avenue, Denny Industrial Centre, Waterbeach, Cambs CB5 9PB. Tel: 01223 203200. Fax: 01223 863384. E-mail: custserv@arcam.co.uk. Web: www.arcam.co.uk. (For more info on Digital Radio, go to www.arcam.co.uk/news/digiguid.html.)

# MARS EXPRESS

MATRA Marconi Space has been recommended as the Prime Contractor for the Mars Express spacecraft. Its development should now proceed swiftly to meet the deadline of an exceptionally favourable launch window in early June 2003, going into Mars orbit by Christmas of the same year.

Mars Express is the first flexible mission of the revised ESA long-term scientific programme, Horizons 2000. It is designed to be a pivotal element of an international multi-mission for the exploration of Mars. Seven scientific instruments on board will perform a variety of tasks, one of which is to search for sub-surface water. The craft will also provide relay communication services between Earth and the landers and rovers to be deployed on Mars between 2003 and 2007.

On board Mars Express will be the *Beagle 2* lander, a project led by the UK's Open University and the University of Leicester, which will perform exobiology and geochemistry research on the planet's surface, looking for evidence of life.

More information is on web site **http://www.matra-marconi-space.com.**

Another press release informs us that Emkay's microphone technology will be used to detect sound on Mars. Emkay's electret EK-3132 Mars Microphone is onboard NASA's Mars Surveyor mission, launched on 3 Jan '99, with its Mars Polar Lander reaching the Martian surface at the end of this year.

Any sounds which are captured will be sent back to Earth and made freely available on web site **http://sprg.ssl.berkeley.edu/marsmic.** Mark Johnson, Emkay's sales and marketing manager, explains: "Our microphone will pick up not only sounds from the Lander itself, e.g. motors, robotic arm and other mechanical parts, but also sand blown against the Lander and the surrounding terrain, other wind sounds, and possible sounds from electrical discharges in the dust clouds. We may even pick up some unexpected sounds as well!"

Emkay's web site is at **http://www.emkayproducts.com.**

# A Really Smart Card!

## By Barry Fox

TRAVELLERS can now carry a PC database in an electronic credit card. Rex Pro is a PCMCIA memory card that slots into a laptop, or connects to a desktop PC through a docking station. The card sucks address lists, diary entries and to-do notes direct from the PC and stores them in 512K of on-board RAM.

Readout is by a built-in l.c.d., with six buttons to control scrolling and searching. Two button-cells run it for six months; if one cell at a time is changed no data is lost. Size is reduced by forming the chips on the l.c.d. glass. Rex Pro was developed by Franklin Electronic Publishers, Starfish Software and Citizen Watch, made in China and costs £140.

# Antex solders us on web!

WE take it as a compliment that Antex have included the *EPE Basic Soldering Guide* as an active hyperlink within their own Web site. Alan Winstanley's authoring of this guide is increasingly becoming a "standard source" on the subject, referred to and accessed by many in industry and education.

Antex' new web site has much to offer in its own right as well and really should be browsed by anyone who is involved in soldering (and hands up any of you who are not – just as we thought, nil!).

As a leading producer of soldering equipment and accessories for schools and colleges, hobby electronics and product servicing worldwide, they have justifiably included on their site many subjects other than catalogues of equipment.

In addition to our link, the site includes features on a wide range of soldering topics, from selecting products and accessories to techniques, problem solving and safety. There is also a comprehensive list, with Internet links, to the network of distributors worldwide handling Antex products.

The site has been designed for use by visitors of all ages and soldering experience. Enticingly, Antex is offering all visitors the chance to win free, top of the range soldering products. Visit the site! It's at **http://www.antex.co.uk.**

Once in, the route to the *EPE Soldering Guide* is via Technical – Papers – Introduction to Soldering, at the end of which is the hyperlink to us. (You can, of course, also access our *Guide* through the normal *EPE* site **http://www.epemag.wimborne.co.uk.**)

# New Technology Update

*A new bonding technique promises to break the barriers that have held up the progress of IGBTs reports Ian Poole*

INSULATED Gate Bipolar Transistors (IGBTs) are widely used for switching applications in many areas of the electronics industry. One of the main areas where development is focussed for these devices is on improving their speed.

In the past few years a number of improvements have been made in their performance using a variety of new techniques. Now manufacturers are looking to address new market areas where these devices may be used.

In particular, they anticipate that they will achieve large degrees of acceptance in a broad range of power supply applications including uninterruptable power supplies where power MOSFETs and bipolar devices are chiefly used today.

## What Are IGBTs?

The structure of an IGBT is shown in Fig.1. It can be viewed as an SCR (silicon controlled rectifier) with a MOSFET connecting the cathode to the base region. For traditional IGBTs there are two main styles of structure, one vertical and one lateral. In the lateral structure, the anode is situated at the surface, and the *p*-type material in between achieves isolation from the substrate.

The electrodes for these devices are often given different names. Cathode, anode and gate are used by some manufacturers because of the similarity to an SCR, whilst emitter, collector and base are used by others because of the similarities with bipolar transistors. Even the terms drain, source and gate are sometimes seen.

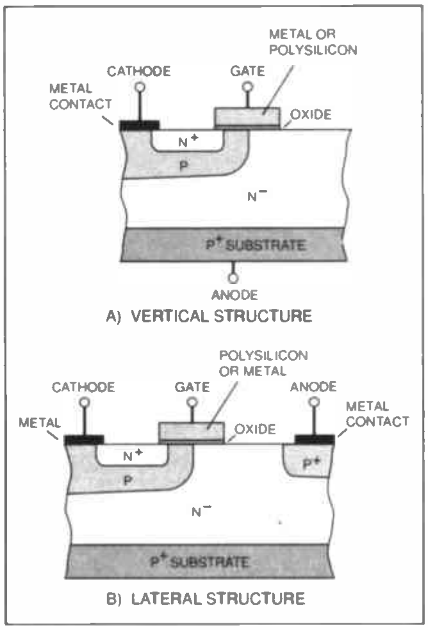



*Fig.1. Structure for an Insulated Gate Bipolar Transistor (IGBT).*

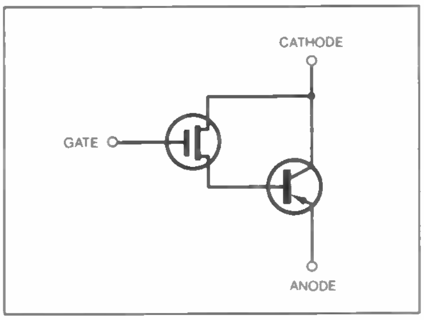



*Fig.2. Equivalent circuit of an IGBT.*

The operation of the IGBT is fairly complicated, although much of its operation can be understood from a view of its equivalent circuit shown in Fig.2. Here it can be seen to be a *pnp* bipolar transistor driven by a MOSFET, in a Darlington type configuration. In this way it is able to switch large voltages and currents by the action of a small input signal.

In operation excess holes are injected from the anode, they are not totally absorbed by the middle p-type region and they contribute to a *pnp* bipolar transistor current. In this way the MOSFET current becomes the base current for the bipolar transistor.

The devices are made from silicon because of the high breakdown voltage and good thermal conductivity of the material. Both of these attributes are required in view of the high current and high voltage applications for which these devices are used.

IGBTs have advantages over both bipolar transistors and power MOSFETs. The IGBT has a much better current density for a given voltage drop. Power MOSFETs come in second, and bipolar transistors are a poor third. The device also has a very high input impedance and low input capacitance as might be expected from the fact that it has an insulated gate input.

However, the main disadvantage of the existing types of IGBT is that they have a relatively low switching speed. To illustrate this, they may typically have a fall time of around 200ns whereas a power MOSFET may be only 50ns.

## Recent Improvements

In recent years, a number of improvements have been made to these devices. In one case a company is developing a device that can switch voltages at rates of 50kHz, but the maximum voltage is limited to 600V. The company hopes that their technology will be able to achieve switching rates of at least 100kHz with some further development.

Another company has released devices where it has been possible to achieve speeds of 150kHz, with currents between 5A and 50A, but again the voltage is limited to a maximum of 600V.

## Direct Bonding

To break the barriers that have been hit by other manufacturers, researchers at Samsung have used a new process called silicon direct bonding (SDB). The process starts with *p*- and *n*- wafers. The *p* wafer is implanted with *p* ions to create a *p*+ wafer, and the *n* wafer is implanted with *n* ions to create an *n*+ layer in the wafer, see Fig.3.

Implantation at this stage is very precise, and this is one of the keys to the success of this method of fabrication. Next, the two wafers are bonded to form a single wafer and an *n* buffer layer is optimised for minority carrier injection into the IGBT's drift region.

This factor means that the switching speed is greatly improved and switching

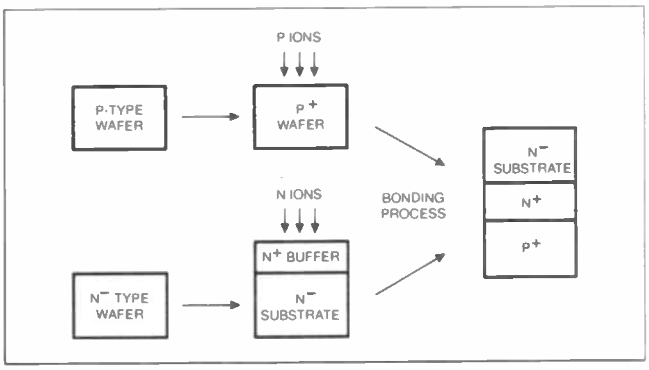



*Fig.3. Block diagram of the silicon direct bonding process.*

losses are reduced. In addition to this the wafer has a very low defect rate and a very uniform doping level, making it ideal for these devices.

Apart from improving the switching characteristics of the device, the short circuit capability has been improved. This has been achieved by including an emitter ballast resistor in the device.

Although these devices cannot withstand indefinite short circuits, their resilience to transient overloads of this nature has been greatly improved.

## Performance

Samsung is offering five devices in the family with current ratings from 5A to 25A in steps of 5A. The devices are fast, offering switching speeds up to 150kHz, all with a saturation voltage of only 2·4V. The reduction in forward voltage drop has resulted in a number of advantages. First, the efficiency of the device is high, and this will enable the systems using these devices to improve their levels of efficiency as well.

A second advantage is that the heat generated in the device is reduced as a result not only of the lower forward voltage drop, but also the increase in switching speed. This has meant that heat-sinking requirements are much less.

In fact, the 1200V 10A version is mounted in a TO3P package and requires no special heat sinking. This fact alone will enable the cost of any units using these devices to be reduced as a result of the simpler, and less costly mounting arrangements.

The switching speed has shown a significant improvement over previous devices. For the 10A version the typical turn on and turn off times for a resistive load are 15ns and 80ns, and even with an inductive load the turn off time is only 100ns.

## Long Term

Plans for the future include a wider variety of devices using the new SDB process. These will include some to operate at lower voltages, although it is hoped to introduce some devices that are able to operate with even higher voltages of 1500V and more.

Other plans include offering the devices in high current modules configured as half and full bridge modules for motor drives and other power applications.

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# SHOP TALK
## with David Barrington

### MIDI Handbells

Thanks to the use of a microcontroller chip, the component count for the *MIDI Handbells* project is fairly small, when you take away the pushswitches and jack sockets/plugs, so we do not expect any real "clangers" when shopping for components. Made up MIDI leads are sold by many of our advertisers.

As usual you will, of course, have to purchase a larger piece of stripboard than you really need and cut it down to size. Also, the open style, chassis mounting, 3·5mm switched jack socket is now regarded as a "commonplace" component and most of our component advertisers, such as **ESR**, **Greenweld**, **Sherwood** and many others should carry stocks or be able to offer an alternative. With eleven required, try for a discount, especially if you include the miniature pushswitches in your order.

The 4MHz clock crystal for this project should be a miniature wire-ended metal can type having 5mm lead spacing. The package style of this crystal is usually referred to as having an HC-49U can case in catalogues and should be widely available.

The choice and size of metal-fronted case is left to the constructor's personal preference, but make sure there is plenty of room for the circuit board and battery holder within it. The small resin potting boxes for the "handbells" are listed in numerous advertisers' catalogues and should be available from local sources.

This just leaves us with the PIC chip. For those unable to program their own PIC16F84, a ready-programmed PIC microcontroller is available from **Magenta Electronics** (☎ ***01283 565435*** or ***http://magenta2000.co.uk***) for the all inclusive price of £5.90 (overseas readers add £1 for postage) – a strong case here for building the *PIC Toolkit Mk2!*

For those who are able to "blow" their own PICs, the software is obtainable from the Editorial Offices on a 3·5in. PC-compatible disk, see *EPE PCB Service* page 389. There is a nominal admin charge of £2.75 each (UK), the actual software is Free. For overseas readers the charge is £3.35 surface mail and £4.35 airmail. If you are an Internet user, it can be downloaded Free from our FTP site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/handbells**.

### PIC Toolkit Mk2

The only component listed in the *PIC Toolkit Mk2* project that is most likely to cause sourcing problems is the regulated +12V charge-pump d.c. to d.c. converter i.c. Currently, the only listing we have found for the Maxim MAX662A is from **Electromail** (☎ ***01536 204555***), code 299-575. It is the CPA (MAX662CPA) version and to obtain a data sheet at the same time also quote code 138-802.

All good PIC micro suppliers should be stocking up on the PIC16F87x devices, including **Farnell**, **RS (Electromail)** and **Magenta**, so supplies should be plentiful. Web users may be interested in checking out Microchip's site for further data (including world-wide agents) on: **http//www.microchip.com**.

The Toolkit Mk2 software is available from the Editorial Offices on a 3·5in. PC-compatible disk, see *EPE PCB Service* page 389. There is a small admin charge of £2.75 (overseas readers £3.35 surface mail and £4.35 airmail). Internet users can download it Free from our FTP site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/PICtoolkit2**.

The printed circuit board is available from the *EPE PCB Service*, code 227 (see page 389).

### A.M./F.M. Radio Remote Control

A number of parts for the *A.M./F.M. Radio Remote Control* project may pose the question "where do I find that?" This applies particularly to the radio modules, the 12-bit HT6014 encoder and HT6034 decoder i.c.s.

Well, starting with the radio modules, we understand that **Maplin** (VY47B-pair) are presently out of stock of the "low cost" pair and cannot give a delivery date for new supplies. Also, we have been informed that the HHR1-418 a.m. receiver module is now discontinued and unobtainable.

The good news is that **RF Solutions** are able to supply readers with the HRR3 replacement a.m. receiver module. They will also supply all the modules, including the f.m. versions, outlined in the article. They can be contacted on ☎ ***01273 488880*** or web site: **www.rfsolution.co.uk** (there is a handling charge).

The only listing for the HT6014 encoder (JA35Q) and HT6034 decoder (JA37S) is Maplin. They also supplied the transmitter case, with pushbuttons (CW26D).

If you elect to use relay outputs, the ones in the model are 12V 10A s.p.c.o. types stocked by **Electromail** (☎ ***01536 204555***), code 350-529. The two printed circuit boards are obtainable from the *EPE PCB Service*, codes 228 (Trans) and 229 (Rec).

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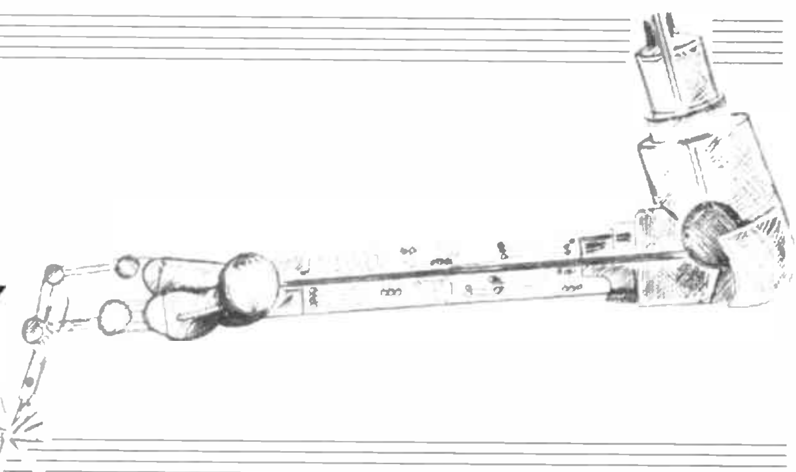
## PLEASE TAKE NOTE

**PC Capacitance Meter** *(Oct '98)*

Page 756. Robert Penfold, the designer, has pointed out that there seem to be slight differences to the Listing program published and one on his current machine. The correct version is as follows:

```
10 REM capacitance meter program
20 PORT1=&H278
30 PORT2=&H279
40 PORT3=&H27A
50 CLS
60 LOCATE 7,30
70 PRINT "RANGE 3"
80 B$= "n"
90 R=1
100 OUT PORT3,35
110 OUT PORT3,33
120 OUT PORT3,35
130 OUT PORT3,34
140 OUT PORT3,35
150 A$=INKEY$
160 IF A$= "1" THEN GOSUB 390
170 IF A$= "2" THEN GOSUB 440
180 IF A$= "3" THEN GOSUB 490
190 IF A$= "4" THEN GOSUB 540
200 IF A$= "s" THEN END
210 FOR D=1 TO 4000
220 OVER=INP(PORT2) AND 128
230 IF OVER=128 THEN GOSUB 360
240 NEXT D
250 X=INP(PORT1)
260 Y=INP(PORT2) AND 16
270 IF Y=16 THEN X=X+256
280 Z=INP(PORT2) AND 32
290 IF Z=32 THEN X=X+512
300 X=X * R
310 LOCATE 5,30
320 PRINT "        "
330 LOCATE 10,30
340 PRINT X B$"    "
350 GOTO 100
360 LOCATE 5,30
370 PRINT "OVERLOAD"
380 RETURN
390 R=10
400 B$= "p"
410 LOCATE 7,30
420 PRINT "RANGE 1"
430 RETURN
440 R=.1
450 B$= "n"
460 LOCATE 7,30
470 PRINT "RANGE 2"
480 RETURN
490 R=1
500 B$= "n"
510 LOCATE 7,30
520 PRINT "RANGE 3"
530 RETURN
540 R=.01
550 B$= "u"
560 LOCATE 7,30
570 PRINT "RANGE 4"
580 RETURN
```

# CIRCUIT SURGERY



ALAN WINSTANLEY
and IAN BELL

***More readers' queries receive attention in our monthly round-up of solutions offered by our team of surgeons.***

REGULAR readers of *Circuit Surgery* will remember previous contributions to this column (e.g. the thorny subject of detecting the number of bats entering a roost!) written by Ian Bell of the School of Engineering at the University of Hull. Ian was one of the co-authors of our tutorial series *Teach-In '98 – An Introduction to Digital Electronics*.

From this month, Ian joins me as co-writer of *Circuit Surgery*. We believe that our individual knowledge and experience of electronics complement one another well and this will allow us to provide a good coverage of topics in this extremely popular column.

## Current Sources

Let's dip into the mailbag. From ***Harsh Mehta*** in India comes this query by E-mail: *"What are current sources and why are they useful in circuits?"*

Current sources are very important in electronic circuit design. Hobbyists probably do not meet them very often, but they are to be found lurking inside almost every analogue i.c., such as operational amplifiers or other linear circuits.

In order to understand the basic concept of a current source, it will help if we first describe *voltage sources*, so we can see some fundamentals in a more familiar context. Fig.1 shows the symbols for voltage and current sources. Most people are familiar with voltage sources (batteries, bench power supplies and the mains are good examples), but unfortunately there is no similar everyday current source.

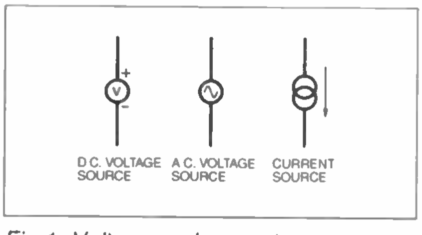



*Fig.1. Voltage and current source symbols.*

A voltage source produces a constant voltage at its output irrespective of the current you draw from it. Well that's not quite true in practice of course – a battery's voltage will *drop* if you connect a heavy load (low resistance), a bench power supply may cut out or limit the current, and a mains supply should blow a fuse before too much damage is done.

An *ideal voltage source* can output any current without the voltage changing or cutting out. Such things do not exist in the real world; however, they can be useful in simplified calculations and simulations. In fact, when analysing circuits we often assume that the power supply is an "ideal" voltage source for simplicity.

## Ohms Law

To pursue this further we need to use ***Ohms Law*** – the basic relationship between current, voltage and resistance. This is $V = I \times R$.

To find the voltage ($V$ in Volts) across a resistor, multiply the current through it ($I$ in Amps) by the resistance ($R$ in Ohms). If we connect a voltage source across a resistor, as shown in Fig. 2, it must produce a current given by $I = V/R$. If we connect a very low value resistor across the voltage source, then it must produce a very high current in order to satisfy Ohms Law.

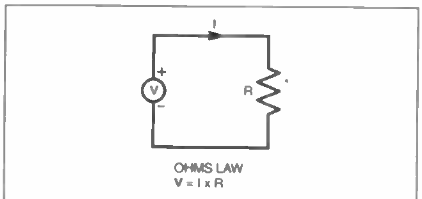



*Fig.2. Ohms Law applied to a fixed resistor R.*

For example, a 9V battery with a 0·5 ohm resistor across it (*do NOT attempt this in practice*) would ideally produce 18A but a small battery such as a 9V PP3 type is just not up to the task! So what happens if the voltage source is not capable of producing the required current? Is Ohms Law broken?

The answer, of course, is no; what happens is that the voltage source pushes out as much current as it can and its output voltage reduces to the point given by Ohms Law for the resistance and current involved. The PP3 battery is no longer a 9V voltage source with a 0·5 ohm load.

## Resistance to Change

We can understand what is going on by using the concept of *internal resistance*. Real voltage sources can be thought of comprising an ideal voltage source (with voltage $V_S$) and a resistor ($R_{INT}$), as shown in Fig.3a.

So when we connect a resistor to a voltage source the current ($I$) flows through *both* resistors with a voltage dropped across each one. The voltage at the terminals of the real source ($V_{OUT}$) therefore becomes smaller when $R$ is reduced and so a greater proportion of $V_S$ is dropped across $R_{INT}$. Note that the internal resistance limits the maximum available output current to $V_S/R_{INT}$, at which point $V_{OUT}$ is zero. In practice we cannot physically separate the voltage source and internal resistance.

A battery's internal resistance is noticeable as a drop in its voltage when we decrease load resistance, and because its internal resistance increases when it becomes exhausted, this becomes worse with older batteries. The effective internal resistance of bench power supplies (and regulator chips) can be made very small using control circuits. These monitor $V_{OUT}$ and effectively change $V_S$ so that $V_{OUT}$ remains constant, compensating for the drop across $R_{INT}$.

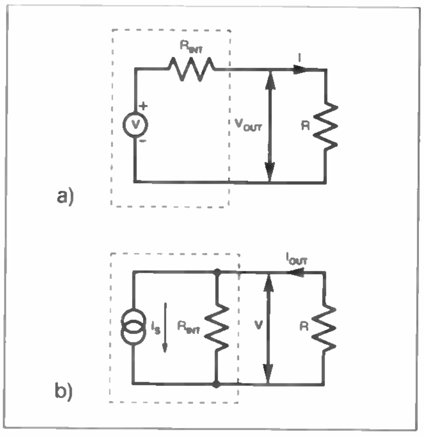



*Fig.3a. Internal resistance $R_{INT}$ of a real voltage source and (b) a real current source.*

This cannot go on forever of course, since at some point we reach the maximum current or voltage rating of one or more of the power supply's internal components. So bench power supplies can sometimes deliver the same voltage (with little "drooping") up to a maximum current at which point they cut out. Due to the active control circuitry, the maximum output current may be much less than that implied by the internal resistance ($V_S/R_{INT}$).

By now you may have guessed that an *ideal* current source outputs a particular current irrespective of the voltage, and that *real* current sources are limited in some way. Real current sources also have internal resistance (see Fig.3b), but it appears in *parallel* with the source and is usually large, unlike voltage sources which have the (usually small) internal resistance in series.

The internal resistance of a current source limits its output voltage to $I_S R_{INT}$, at which point $I_{OUT}$ is zero. Real current sources may also have a limited range of voltages over which they can operate (sometimes called *compliance*), determined by factors other than the internal resistance (like the current range of a bench power supply).

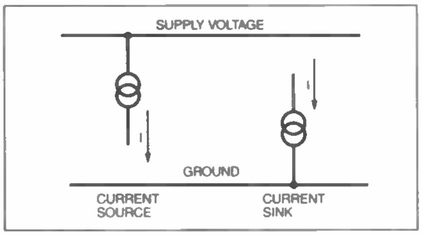



*Fig.4. Current sources and current sinks.*

If we short-circuit a current source then, unlike a voltage source, it has no problem – its output current simply flows through the wire. If we connect a large resistance across a current source, then by Ohms Law it must develop a large voltage across the resistor. For example, if we connect a 1M (megohm) resistor across a 1mA current source it would have to produce 1000V across the resistor to maintain the required current. If a current source is open circuit then it cannot operate (unless it can produce arcing!). Note the opposites here: voltage sources have an easy life with open circuits and a hard time with short circuits, but for current sources it is the other way round.

Current sources connected to ground (0V), through which current flows to ground, are sometimes called *current sinks* (see Fig.4). However, the term *current source* is used in both cases.

## On Stream

Water is sometimes used as an analogy for electricity, and can help us see the difference between a voltage source and a current source. In the water analogy a *voltage source* is a large tank of water suspended above the ground, in which the water is kept at a constant level by some means. The higher the tank then the greater the voltage.

A pipe at the base of the tank allows water (current) to flow – any level of current can flow, depending on the diameter of the pipe. A short circuit would be like the bottom falling off the tank causing a massive flow!

A *current source* is like a pump producing the same rate of flow (current), irrespective of its height above ground (voltage). If we block the pump's output then we get the equivalent of a current source with an electrical open circuit: the pressure builds until something gives up.

The concepts of voltage and current sources are very important in electronics. All real sources of power or signals can be thought of as either voltage sources or current sources with an internal resistance.

We can use this idea further to understand the requirements for circuit designs. For example, if we have a sensor producing an output voltage, but with a large internal resistance, we will need a very high input impedance amplifier to process these signals, to prevent all the source voltage from being dropped across the internal resistance. This can be achieved using a unity gain buffer amplifier or a more sophisticated instrumentation amplifier circuit.

Current sources are important in biasing and obtaining high gains in the analogue circuits used on integrated circuits. They provide very high impedances, which are useful for developing large voltage gains. However, they still allow relatively large bias currents to flow without incurring a large voltage drop.

Next month Ian continues his investigation into current sources with some practical suggestions.

**CIRCUIT THERAPY**

*Circuit Surgery* is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom. E-mail **alan@epemag.demon.co.uk**. Please indicate if your query is not for publication. A personal reply cannot be guaranteed but we will try to publish representative answers in this column.

Special Feature

# PC ENGINES – FROM 4004 TO PENTIUM III


## ERNEST FLINT


*Tracking the Intel microprocessor to its lair!*

### *I'll see your PII and raise you two Celerons!*

IN THE not-so-distant past, very few people had the faintest clue as to which type of microprocessor was ensconced in their personal computer (PC). Instead, in the early days, consumers purchased computers by type, such as an IBM PC-AT or PC-XT. Even for those who did know, the playing field was fairly easy to understand as things tended to progress in a fairly leisurely and obvious manner. Each new generation was faster and better than the one before and, more importantly, each new generation quickly *replaced* the previous one "on the store shelves".

By comparison, it's now hard to turn on the television without being accosted with yet another "Intel Inside" advert. In fact, those little rapscallions at Intel are rolling out new types of microprocessors so fast it makes one's head spin. Even worse, there are now multiple concurrent architectures targeted at different markets.

It was bad enough when all we had to contend with was the choice between a Pentium and a Pentium with MMX. Suddenly, as if from nowhere, we were being barraged with the additional options of Celerons, Pentium IIs, and Pentium II Xeons. And now we are staring Pentium IIIs and Pentium III Xeons in the face, desperately trying not to be the first to blink.

In fact there are now so many flavors of microprocessor on the loose (each of which is available in a range of clock frequencies), that even those of us who are "in the trade" are beginning to lose whatever tenuous grip we once had on reality. So in this article we will rend the veils asunder and expose the horrors within.

## THE EARLY DAYS

Before we plunge too deep into the quagmire of today's microprocessor product offerings, it is advantageous to consider the path by which we arrived at where we are (Fig.1).

The world's first microprocessor – the 4004 – was presented to the market by Intel in 1971 (in fact the 4004 was originally called a microcomputer, and the term microprocessor was not coined until sometime later). The 4004 contained only 2,300 transistors and performed 60,000 operations per second.

The "4"s in the 4004's name were intended to reflect the fact that it had a 4-bit data bus. The 4004 was followed in 1972 by the 8008, which was pretty much the same sort of thing, but with an 8-bit data bus (and 3,300 transistors). The 4004 was also enhanced to form the 4040, which contained additional logical and compare instructions and a small internal stack.

The 4004, 4040, and 8008 were all interesting, but they were also all designed with specific applications in mind, and it wasn't until 1974 that the 4040 and 8008 evolved into the 8080, which contained 4,500 transistors and could perform 200,000 operations per second. The 8080 was the first truly general-purpose microprocessor, and was destined to become the central processor of many early home computers.

By 1978, the 8080 had evolved into the more sophisticated 8-bit 8088 and the 16-bit 8086. The 8088 was to become pivotal in the history of microprocessors as we know it, because IBM decided to use this as the CPU in what is now considered to be the first true PC, which was presented to the market in 1981.

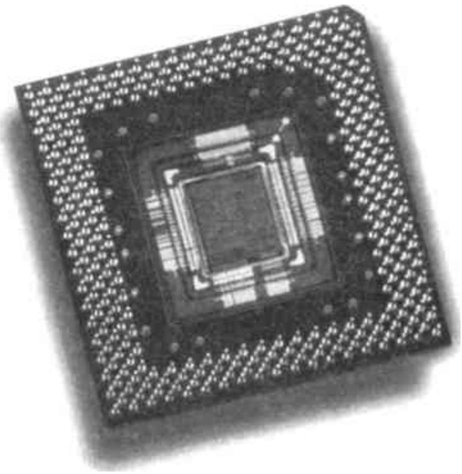


Fig.2. The Pentium processor in a Socket 7 configuration (Photo courtesy of Intel Corp.)

## THE MIDDLE KINGDOM

In 1982, Intel released the 16-bit 286 microprocessor (also known as the 80286). With 134,000 transistors, the 286 sported approximately three times the performance of other 16-bit processors of the time. Amongst other things, the 286 provided "backwards compatibility", which meant it could run programs that had been written for its predecessors. This was considered to be a pretty revolutionary concept at the time.

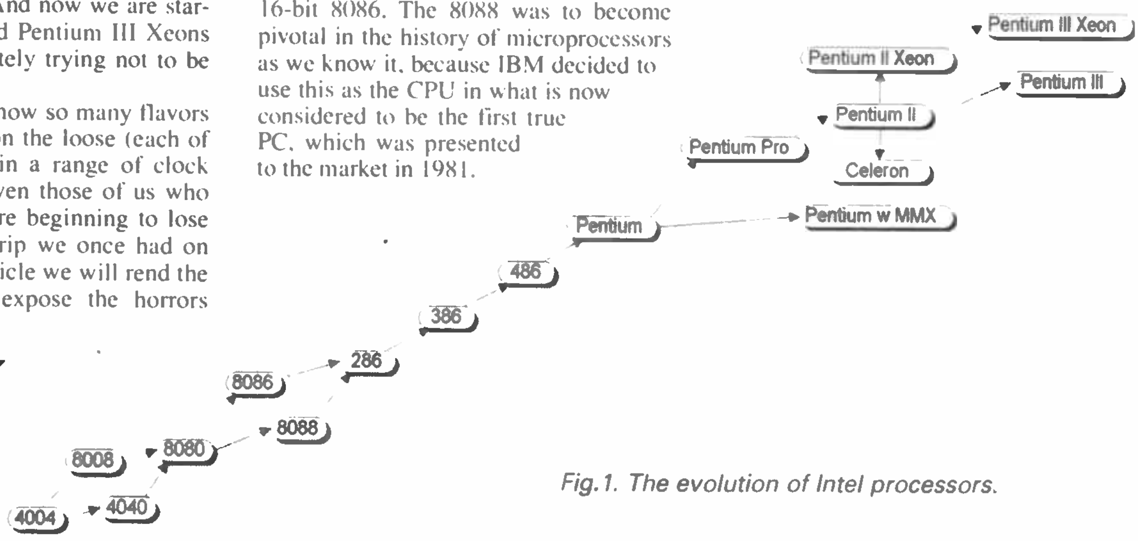



Fig.1. The evolution of Intel processors.

The 16-bit 286 was followed by the 32-bit 386 in 1985. This device, which contained 275,000 transistors, was designed to support "multitasking" (running multiple programs at the same time). In turn, the 386 was followed in 1989 by the 486, which contained an amazing (for the time) 1.2 million transistors.

In the early days, complex math functions (multiplication and division) were performed as a series of simple steps, such as "shift-and-add" algorithms. Later schemes employed external math coprocessor devices, which were special units dedicated to performing complex math functions as quickly as possible. The 486's 1.2 million transistors allowed it to include an on-chip math coprocessor as part of the main CPU (this was considered to be mega-cool by those of us who cared).

The first 486s had system clocks (see sidebar) running at 25MHz. These were soon followed by 33MHz and 66MHz versions (and various "clock doublers" appeared later in the market).

## THE GOLDEN AGE

The start of the current golden age of microprocessors (insofar as this article is concerned) occurred in 1993, when Intel first introduced the Pentium processor (Fig.2). With 3.1 million transistors, the Pentium was approximately five times faster than its 486 ancestor. The Pentium sported a 16 kilobyte L1 cache (see sidebar) and up to 512KB L2 cache (this L2 cache was mounted on the main motherboard).

The first Pentiums started with clock speeds of 75MHz, and over time additional options were added to 233MHz (note that the host bus speed remained at 66MHz – see sidebar). Also, the Pentium was presented in a pin grid array (PGA) package, which plugged into an Intel-defined pinout format called "Socket 7."

The next major development occurred in 1995 with the Pentium Pro, which sported a number of innovations and improvements (and a whopping 5·5 million transistors).

Quite apart from anything else, the Pentium Pro was presented as a multichip

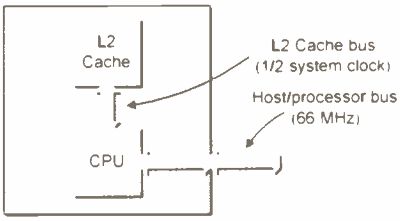



*Fig.3. The Pentium Pro architecture (two chips in a multichip module).*

module package containing two silicon chips: the Pentium Pro processor itself (with a 16-kilobyte on-chip L1 cache) and an L2 cache chip. The original Pentium Pros came equipped with 256KB L2 caches, and 512KB versions became available later. One really cunning innovation associated with the Pentium Pro was that it had two busses (an external processor-to-main-memory (host) bus and an internal processor-to-L2-cache bus) and the processor could access both busses simultaneously (Fig.3).

The original Pentium Pros supported a 150MHz system clock, and this was quickly followed by 200MHz versions. The multichip module of the Pentium Pro allowed the processor core and the L2 cache to be located very close to each other, which in turn facilitated the cache bus running at half the main system clock frequency. (This was much faster than the Pentium's L2 cache, which was located on the motherboard, and which was therefore obliged to run at the 66MHz host bus frequency.)

The end result of this dual-bus architecture (plus other cunning stuff that's too complex to go into here) made the Pentium Pro go "like a bat out of hell." The Pentium Pro module plugged into an Intel-defined pinout format called "Socket 8".

The pace really started to pick up in 1997, when Intel introduced two new developments. The first was the concept of MMX instructions (see sidebar), which first appeared in the "Pentium with MMX." The second was the Pentium II processor (with a mind-boggling 7.5 million transistors), which also included MMX instructions (Fig 4).

At a first glance, the Pentium II appeared

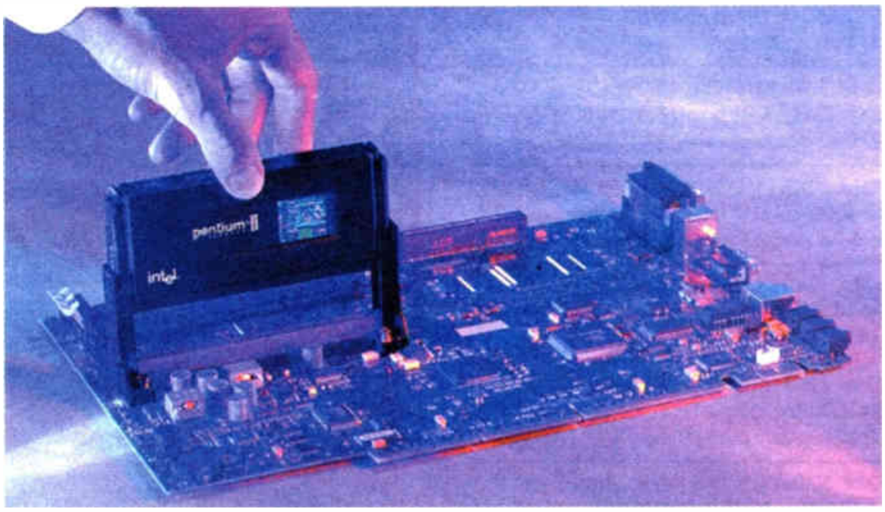



*Fig.4. The Pentium II shown in slot 1 configuration (Photo courtesy of Intel Corp.).*

## TECHNICAL TERMS – A BRIEF OVERVIEW

**During the course of this article, one or two terms are mentioned such as "cache", "host bus," MMX, and so forth. For those amongst us who aren't too familiar with these (and certain other) terms, a brief overview is presented here.**

### SRAM vs DRAM

Semiconductor memory comes in a variety of flavors. The two main categories are read-only memory (ROM) and random-access memory (RAM). (The purists amongst us would prefer to replace the term RAM with read-write memory (RWM), but realistically this is never going to happen).

ROM devices contain instructions and/or data that is "hard-wired" into them during their construction. By comparison, RAM devices only contain whatever data and instructions the computer last wrote into them (and they "forget" their contents when power is removed from the system).

Furthermore, RAM is itself split into two core technologies, which are known as Static RAM (SRAM) and Dynamic RAM (DRAM). Each memory cell in an SRAM device requires between four and six transistors, while each cell in a DRAM device requires only one transistor (so you can get more memory in a DRAM device)

SRAMs are faster than DRAMS, but they use more power, run a lot hotter, and are much more expensive. Thus, the bulk of a computer's main memory is formed from DRAM devices, and SRAMs are only used where extreme speed is required.

### SIMMs vs DIMMS

Multiple memory devices are typically mounted on small p.c.b.s (known affectionately as "sticks" of memory). These are referred to as SIMMs (single inline memory modules) if they only have chips on one side, or DIMMS (dual inline memory modules) if they have chips on both sides.

### FDO vs EDO vs SDRAM vs . . .

As was previously noted, the bulk of a computer's RAM is composed of DRAM devices, but these can be presented in different ways. When you purchased a computer in the not-so-distant past, it came with FDO (fast data out) memory. This was subsequently replaced in later systems by EDO (extended data out) memory, which was in turn superceded by SDRAM (synchronous DRAM) memory.

This is a bit confusing at first, but underneath it's really quite simple. These memory schemes are all basically formed around a core of standard DRAM chips, but each uses a different way of controlling and accessing the devices to squeeze more "throughput" out of them.

Also, note that the term ECC (error correcting and control) memory used in higher-end machines refers to the fact that these memory devices contain additional bits that can be used to detect (and correct) errors in the data.

***continued . . .***

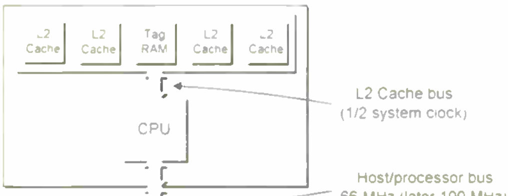



*Fig.5. The Pentium II architecture.*

to be radically different to the Pentium Pro, because it was presented in a relatively large package called a single-edge-connect (SEC) cartridge, which plugged into a new Intel-proprietary socket configuration called Slot 1 on the motherboard.

Internally, the Pentium II is constructed as a hybrid using a printed circuit board substrate. This circuit board contains the processor chip, which is essentially a Pentium Pro with a 32KB L1 cache and MMX instruction support. This board also contains four industry-standard burst-static cache RAM devices and a tag RAM chip, which together form the 512KB L2 cache (Fig.5).

(Note that Fig.5 is only an illustration. In reality the processor core and two of the cache RAM devices are mounted on one side of the board, while the remaining cache RAMs and the Tag RAM are mounted on the other side.)

The first Pentium IIs supported clock frequencies of 233MHz and 266MHz. These were quickly followed by 300MHz, 333MHz, and 350MHz versions, which were in turn superceded by 400MHz and 450MHz versions. This obviously has a huge impact on processor operations, and also cache-intensive operations (because the Pentium II cache is running at half of the main clock frequency). Furthermore, the first Pentium IIs supported a host/processor bus frequency of 66MHz, but this was boosted up to 100MHz in later versions, which dramatically improved access to the main memory.

Last but not least, the Pentium II supported Intel's AGP (advanced graphics port). Actually, to be more precise, it's the Pentium II's supporting chipset that provides AGP capability, but supporting chipsets are part of a completely different discussion, so we'll ignore them in this article (for which you can be truly thankful). The AGP is also outside the scope of this discussion, except to say that it is designed to streamline the transfer of data from the CPU to AGP-compatible graphics accelerator cards.

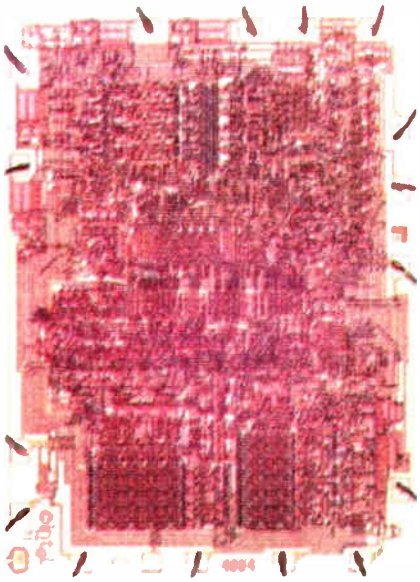
## AND THEN . . .

For a long time things had appeared (at least on the surface) to be relatively well ordered. The 268 was followed by the 386, which was in turn followed by the 468. The 486 begot the Pentium, which led to the Pentium Pro, which in turn paved the way for the Pentium II. And then things began to get more complicated . . .

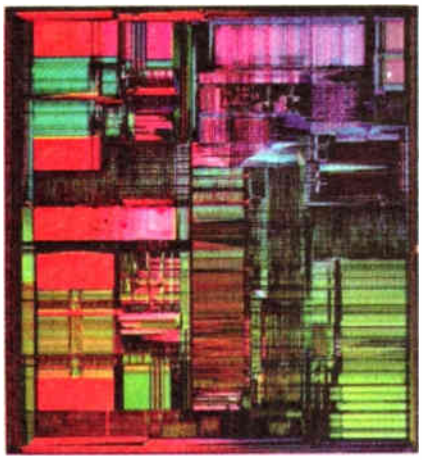
In 1998, Intel introduced the Celeron processor, which was based on the Pentium II. The first Celerons didn't have any L2 cache at all, which caused

**Table 1: Intel microprocessor development**

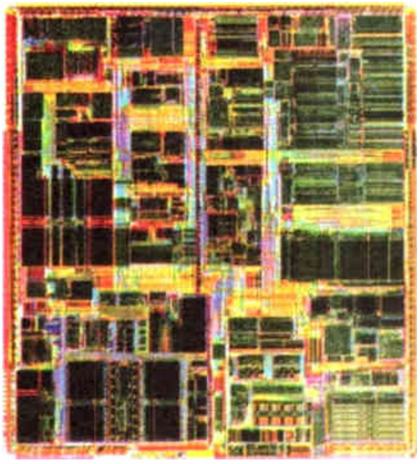
| | | |
|---|---|---|
| 1971 | 4004 | 2,300 transistors, 4-bit, 60,000 operations per second |
| 1972 | 8008 | 3,300 transistors, 8-bit |
| 1972 | 4040 | 4-bit (like a 4004 but with additional instructions) |
| 1974 | 8080 | 4,500 transistors, 8-bit, 200,000 operations per second |
| 1978 | 8088/8086 | 8-bit/16-bit (the 8088 was used in the first IBM PC) |
| 1982 | 286 | 134,000 transistors, 16-bit |
| 1985 | 386 | 275,000 transistors, 32-bit (multitasking) |
| 1989 | 486 | 1.2 million transistors, 32-bit (first math coprocessor)<br>25MHz system clock (-> to 66MHz over time) |
| 1993 | Pentium | 3.1 million transistors, 32-bit, 16KB L1, 512KB L2 (external)<br>75MHz system clock (-> 233MHz), 66MHz host bus, Socket 7 |
| 1995 | Pentium Pro | 5.5 million transistors, 32-bit, 16KB L1, 256KB L2 (internal)<br>150MHz system clock (-> 200MHz), 66MHz host bus<br>L2 Cache bus runs at 1/2 main system clock, Socket 8 |
| 1997 | Pentium II | 7.5 million transistors, 32-bit, 32KB L1, 512KB L2, MMX<br>233MHz system clock (-> 500MHz), 66MHz host bus (-> 100MHz)<br>L2 Cache bus runs at 1/2 main system clock |
| 1998 | Celeron | 7.5 million transistors, 32-bit, 32KB L1, 0KB L2 (later 128KB L2), MMX<br>266MHz system clock (-> 400MHz), 66MHz host bus<br>L2 Cache (when provided) bus runs at 1/2 main system clock |
| 1998 | Pentium II Xeon | 7.5 million transistors, 32-bit, 32KB L1, 512KB / 1MB / 2MB L2, MMX<br>400MHz system clock (-> 500MHz), 100MHz host bus<br>L2 Cache bus runs at FULL main system clock |
| 1999 | Pentium III | 7.5 million transistors, 32-bit, 32KB L1, 512KB L2, MMX II<br>500MHz system clock (-> 550MHz), 100MHz host bus<br>L2 Cache bus runs at 1/2 main system clock |
| 1999 | Pentium III Xeon | 7.5 million transistors, 32-bit, 32KB L1, 512KB / 1MB / 2MB L2 MMX II<br>500MHz system clock (-> 550MHz), 100MHz host bus<br>L2 Cache bus runs at FULL main system clock |



*Bare (unpackaged) silicon (die) for the 4004 processor.*



*The Pentium die.*



*The Pentium II die.*

*(The photos above are courtesy of Intel Corporation).*

some observers to refer to them as "brain dead Pentium IIs." Subsequent implementations had 128KB L2 caches, and versions with larger cache configurations wouldn't be too surprising.

Later on in 1998, just to make life interesting, Intel Introduced the Pentium II Xeon. This little rascal arrived in a yet bigger package, which plugged into a new Intel-proprietary socket configuration called Slot 2 on the motherboard.

The Pentium II Xeon contains two devices: the main processor and a honking big new L2 cache device. One key point about the Xeon (apart from its high price) is that its L2 cache, which is available in 512KB, 1MB, and 2MB options, runs at the same frequency as the main processor clock. (Remember that the cache bus on the standard Pentium II runs at half the main clock frequency.) This high-speed cache can have a significant effect for certain high-end applications such as database hosting and other server-bested applications.

And last but not least (as we pen these words), Intel have just announced the Pentium III and the Pentium III Xeon processors. These are essentially the same as their Pentium II forebears, but with higher clock frequencies (commencing at 500MHz and 550MHz as they launched), including a special CPU ID, and supporting MMX II instructions (see sidebar).

Each Pentium III has a unique ID number hardwired into it, which is intended to allow querying software to positively identify the CPU (note that the CPU does not "broadcast" the ID, but instead programs have to actively read it). Intel's main (stated) goal was to provide increased security for electronic transactions (E-commerce) over the Internet. There are a number of other possible uses for such an ID, ranging from identifying stolen processors, to locking (licencing) applications to a specific machine.

An unexpected result (for Intel) is that a variety of civil liberties groups are currently "up in arms" campaigning about possible invasion of privacy issues. In response, Intel is providing a utility that will allow users to enable and disable the CPU ID at will, and the majority of machines will be shipped with the ID disabled by default (which sort of makes you wonder if it was worth it in the first place).

## WHICH SIZE FITS YOU?

So which processor is right for you? This is a tricky one, because it can be difficult to separate the "hype" from the reality. Let's start with the Celeron, which is essentially a Pentium II with a smaller L2 cache (*whatever you do, don't buy one of the earlier Celerons without any L2 cache at all*).

Intel's marketing position is that the Celeron is intended for home use (games, entertainment, simple word processor-type applications) by the more cost-conscious buyer. In reality, Intel would probably have preferred not to have introduced the Celeron at all – they main-

## L1 vs L2 CACHE

Modern semiconductor memories are extremely fast, but computer programs typically perform a humongous amount of memory accesses (reads and writes), so anything that can be done to speed things up is generally considered to be very desirable.

If we analyse programs, we tend to find that they are often composed of blocks of instructions, where each block may be performed multiple times before moving on to the next block. A key point is that these blocks of instructions tend to be relatively small compared to the size of the total program.

Computer designers can take advantage of this knowledge by creating a special "chunk" of high-speed memory called the cache. When the CPU starts running a program and it reads an instruction (or data) for the first time, in addition to processing that instruction it also stores it in the cache. The next time the CPU attempts to read that instruction, it first checks to see if it's already in the cache – if so it can read it from the cache much faster than it could from the main memory.

The cache is formed from the fastest SRAM devices available, so the designer (who would ideally prefer as large a cache as possible) has to keep it smaller than he or she would like to balance cost and performance.

In fact computer designers use a hierarchy of memory. The L1 ("Level 1") cache is very small, but very, very fast, because it is constructed as an integral part of the CPU itself (on the same silicon chip). The L2 ("Level 2") cache is significantly bigger than the L1 cache, but it's father away from the CPU and thus not as fast. In fact some computers have L1, L2, and L3 caches between the CPU and the main memory!

## SYSTEM CLOCK vs HOST BUS

The main system clock is used to synchronize the internal actions of the CPU and also the rest of the system. The CPU communicates with the rest of the system by means of the main system bus, which may also be referred to as the "host bus", the "processor bus", or the "front bus."

Increasing the frequency of the system clock increases the rate by which the CPU performs its internal actions. However, the frequency of the host bus is not directly related to the frequency of the main system clock.

## OVERCLOCKING

In order to understand the concept of overclocking, we first need to know that computer motherboards are designed to support a range of system clock frequencies. This allows a Pentium II motherboard, for example, to support say 350MHz, 400MHz, and 450MHz versions of the processor. Theoretically, this allows end-users to upgrade their main processor (although this rarely happens in practice).

Most Intel processors are reasonably robust. One by-product of this is that it is possible to take a processor rated for one clock frequency, say 350MHz, and "tweak the jumpers" or otherwise modify the motherboard to clock the processor at a higher frequency.

There are a number of sites on the web with instructions on how to tweak different motherboards to overclock different processors. One downside of this is that the processor will run hotter than it's rated for (and than the computer's cooling system is expecting), which may cause problems. Another thing to bear in mind is that if you do this you've just waved goodbye to any warranty that came with your system (assuming they find out what you did).

## MMX vs MMX II

In 1997, Intel introduced the Pentium II and a new version of the Pentium, both of which boasted something called MMX. After wading through the "razzmatazz", we find that MMX Stands for "MultiMedia eXtensions", which are actually a group of 57 special SIMD (single instruction multiple data) instructions.

To understand what this means, we first need to understand that many applications like to use data in small "chunks." For example, multimedia and image processing programs largely view the world as a series of picture elements (pixels), where each pixel consists of red, green, blue, and alpha (transparency) values (abbreviated to RGBA). Furthermore, many applications use 8-bits to represent each of these values, which makes it easy to pack all four values into a single 32-bit word (the size currently used by the Pentium, Pentium Pro, Pentium II, and so forth).

The interesting point is that these applications often want to perform operations on pairs of 32-bit RGBA values, such as adding two of them together. However, the application doesn't simply want to add these two values as 32-bit quantities. Instead, it wishes to add the two 8-bit R values together, and likewise for the two 8-bit G values (and the B values and the A values).

The old way of doing this required multiple operations to separate out each of the 8-bit values, perform the requisite function, and then "munge" the results back together. Hence the introduction of MMX instructions, which direct the CPU to treat the data as four 8-bit chunks (but to still perform all four additions in a single clock beat!).

Of course these instructions are only of value if you have applications that make use of them. But once they became available, application developers began to take advantage of them, and MMX versions of certain programs do go substantially faster than their non-MMX counterparts.

The original MMX instructions only worked on integer data representations. However, the new Pentium III and Pentium III Xeon processors have been enhanced to support MMX II. Also known as SSE (for "Streaming SIMD Extensions"), MMX II comprises around 70 additional instructions that allow operations to be performed on four floating point numbers simultaneously. Future applications that take advantage of these instructions (such as analytical programs, graphics applications, and 3D games) will see a major speed increase.

ly did so in response to other processors from manufacturers like AMD, which were starting to "eat Intel's lunch" at the home consumer end of the market.

Pentium IIs (and now Pentium IIIs) are primarily targeted towards the high-end consumer and professional desktop (although television adverts often position them for home entertainment machines also). By comparison, Pentium II Xeons (and now Pentium III Xeons) are typically presented as being the processors of choice for high-end technical and professional applications.

In reality, Xeons typically only deliver approximately five percent performance boost for many applications at a very significant cost premium over their non-Xeon counterparts. Where the Xeons really score (especially with the larger cache versions) is in server-type applications.

## BOILING IT DOWN

Thus, for the majority of home users, the choice really boils down to one between a Celeron, a Pentium II, and a Pentium III. Let's see if we can reduce this choice a little further. In reality, the vast majority of home users won't be able to spot any difference in performance between a Celeron (with 128KB L2 cache) and a Pentium II (with 512KB L2 cache) running at the same frequency. However, the Celeron will be several hundred pounds cheaper, and you can invest some of this money on additional RAM, which can provide a *HUGE* speed increase for memory-intensive applications. In fact some savvy users purchase a Celeron-based machine and then overclock it (see sidebar), which provides the increased performance associated with higher clock frequencies.

Of course for those users who want (nay NEED) to live on the cutting edge of technology, only a Pentium III processor will suffice (and there aren't any Pentium III-based versions of the Celeron to play with). Sad to relate, however, the Pentium III won't actually perform any faster than a Pentium II running at the same clock frequency (at least not today). This is because the only real difference between the two processors (apart from the fact that the Pentium III has a CPU ID) is the presence of MMX II streaming SIMD instructions in the Pentium III.

The problem is that it will take time for mainstream applications to be upgraded to take advantage of these instructions (and then you'll have to purchase these upgraded versions). Another consideration is that, in the same time-frame, you'll be able to get even faster processors for less money (see the next section). But it was always thus, and at the end of the day it's a case of "you pays your money and you takes your choice" as the old saying goes.

## AS FOR TOMORROW

"And what about tomorrow?" – you ask – "What new wonders are heading our way?" Well there are a whole host of exciting developments racing towards us.

First, processor clock frequencies are going to rise yet higher. Internet newsgroups are confidently predicting 600MHz clocks by the end of 1999, 700MHz clocks by mid-2000, and 1GHz clocks soon thereafter.

Next, Intel are working furiously on a 64-bit processor (the current generation all work with 32-bit wide chunks of data), which should give another huge performance boost (when applications are rewritten and/or recompiled to take advantage of this feature).

Also, new integrated circuit production technologies are allowing increasing numbers of transistors to be squeezed onto each chip. In the foreseeable future it will be possible to cram 100 million transistors onto a single device. What will all of these transistors be used for? Well in addition to making the processors more powerful, it will be possible to dramatically increase the sizes of the local memory caches and locate the caches on the core CPU device, which will significantly improve the processor's performance.

Meanwhile, processors will be able to handle ever larger amounts of memory (which shall hopefully continue its trend to become even cheaper). Some high-end Intel-based professional workstations can already access 3GB of RAM or more (which makes the author's 64MB look positively measly by comparison). Also, Intel are working on bringing a next-generation memory system called Direct RAMBUS to the market, which will dramatically speed up processor-to-memory accesses.

It's also worth noting that, despite the Intel-centric focus of this article, Intel aren't the only game in town. There are a number of other players developing processors that look set to give Intel a run for their money.

Last but not least, there are a whole host of technologies that are outside the scope of this article, including optical fiber-based disk drives, and ..... but that would be telling, wouldn't it? Suffice it to say that, for those of us who love computers, the future promises nothing less than faster, better, and cheaper, and who amongst us can find fault with that?

## FURTHER READING

The hybrid and multichip module packaging technologies mentioned in this article are described in detail in an amazingly useful book called *Bebop to the Boolean Boogie (An Unconventional Guide to Electronics)*. For those who want to understand more about how microprocessors work, *Bebop BYTES Back (An Unconventional Guide to Computers)* is jolly good. By some strange quirk of fate, both of these tomes are available from the *EPE Direct Book Service*.

For those who want the inside scoop on the latest breaking news in the processor wars, an excellent place to start is Tom Pabst's web site at **www.tomshardware.com**

### INTEL WHO?

There are many fine microprocessors around, including those from Motorola (as found in Apple's Macintosh machines), AMD, Cirrus, and others. So why has this article concentrated on those from Intel (you may ask)?

Strange to relate, Intel never really intended to manufacturer microprocessors – their original goal was to supply the world with semiconductor memory devices. So it rather took them by surprise when one of their design teams created the world's first microprocessor – the 4004. In fact the fate of the 4004 was precarious at best, and one of the main reasons that persuaded Intel's management to invest in continued development was the argument that the availability of microprocessors would help them to sell more memory devices.

In the mid-1970s, Intel considered adding a keyboard and a monitor to a board containing their 8080 microprocessor to sell it to the home user, but no one could think of a use for it (apart from something for housewives to keep recipes on) so they dropped the idea.

Some time later IBM decided that there was a market for computers for the small business user, so they set about creating the world's first PC. At that time, the two main contenders to supply the CPU for this PC were Intel's 8088 and Motorola's 6800. Had IBM opted for the Motorola device, we would all now doubtless have "Motorola Inside" logos tattooed on our foreheads.

Why did IBM choose Intel over Motorola? Who knows? Who Cares? The decision was made, with the result that Intel Corporation are now arguably the best known manufacturer of microprpcessprs on the face of the planet.

*The Pentium III is home to 7·5 million transistors! (Courtesy Intel Corp.)*

# A.M./F.M. RADIO REMOTE CONTROL

MAX HORSEY

*Coded radio remote control has become straightforward and requires no licence.*

REMOTE control systems are increasingly popular, and the introduction of pre-tuned radio modules, and their steadily falling prices has made radio a viable alternative to infra-red control. The advantage of radio is the ability of the signal to pass through objects and walls. Its range is also impressive, 100 metres or more (in free space) being typical.

No licence is required in the UK, providing the radio modules operate on the 418MHz waveband, and there are a number of conditions, one of which is that setting up and tuning is carried out by a DTI (Department of Trade and Industry) approved company. Hence if the module is purchased from such a company the home constructor can enjoy the benefits of radio remote control.

The DTI regulations also include limitations regarding the antenna (aerial) dimensions and mandatory labelling. This is to ensure that interference is not caused to other radio users. The basic requirments under these regulations are given at the end of the article. Leaflets giving further information are available from the DTI.

This article describes how to use the radio modules in a similar way to those in the *Reliable Infra-red Remote Control* system which was published in *EPE* Oct/Nov '98. We will examine both a.m. and f.m. (amplitude modulated and frequency modulated) systems, and begin with a brief outline of the difference between these.


## A.M./F.M. PRINCIPLES

In order to carry useful information, radio waves must be modulated, in other words the required signal must be superimposed on the radio wave (known as the *carrier wave*).

With Amplitude Modulation transmissions, it is the *amplitude* of the carrier wave that is made to change in accordance with the required signal. It is reasonably easy to generate, but can suffer from interference.

With Frequency Modulation transmissions, it is the *frequency* of the carrier wave that is made to change in accordance with the required signal. The f.m. modules described here tend to be more expensive than the a.m. modules, but they are almost immune to interference, can carry a higher data rate and have a longer range.

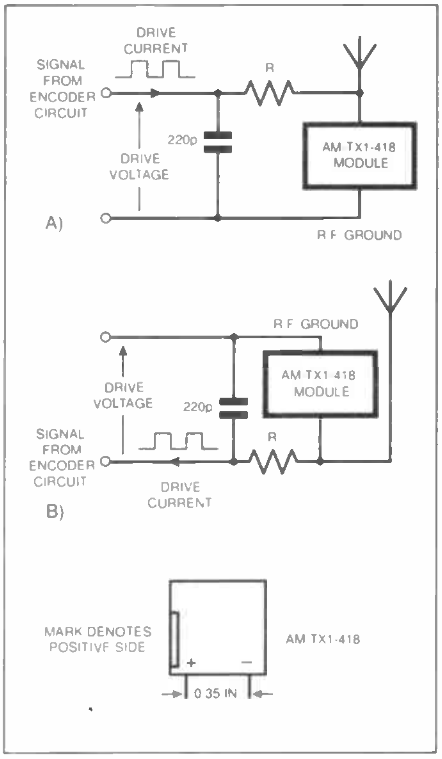



*Fig.1. AM-TX1-418 transmitter driven from (a) +ve supply and (b) –ve supply.*

Both types operate at 418MHz and have been tested for the purpose of this article, and the a.m. system proved very reliable with an impressive range. However, we will describe how to use both systems.

A number of a.m. 418MHz modules are available, but we have chosen two transmitters and one receiver. The cost of these modules has fallen in recent months and a transmitter/receiver pair can be obtained for less than £8.

## TRANSMITTER AM-TX1-418

The RF Solutions a.m. transmitter module type AM-TX1-418 is a 2-pin device, and looks like a capacitor. It is very simple to use – the basic arrangement is shown in Fig.1.

There are two circuits shown: (a) allows the encoder signal (i.e. the message being sent) to drive the positive side of the radio module; (b) allows the encoder signal to drive the negative side

**Table 1. Resistor selection for AM-TX-418 module**

| Supply voltage | Resistor value |
|---|---|
| 12V | 2k2 |
| 9V | 1k8 |
| 6V | 1k |
| 4·5V or 5V | 470Ω |
| 3V | 100Ω |

Current consumption: 2·5mA (typical)
CMOS/TTL compatible input
Data throughput: 1200 baud

of the radio module. The only additional components required are a capacitor and resistor. The value of the resistor (R) is chosen according to the supply voltage employed in the circuit (between 3V and 12V), as shown in Table 1.

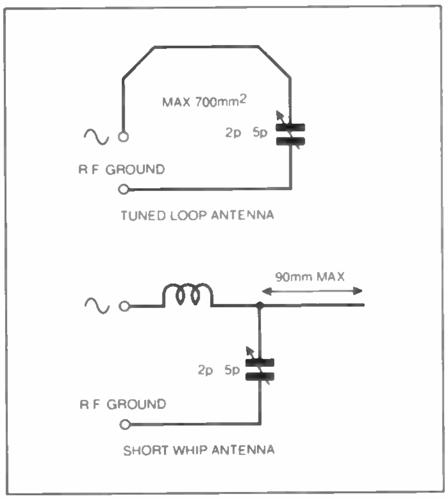
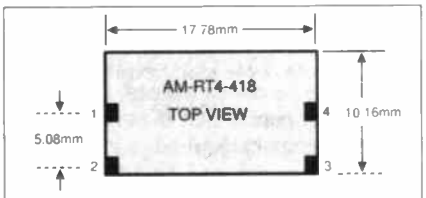



*Fig.2. Two possible alternative antenna arrangements.*

The module requires an antenna which is a little more complicated to set up than the transmitter module described later. Two possible arrangements are shown in Fig.2. A variable capacitor having a 2pF to 5pF range is also required, and must be adjusted to provide the strongest signal. In practice, this is not easy to check, and the practical project described now employs a transmitter module which requires no such adjustment.

## AM-RT4-418 TRANSMITTER

An alternative 418MHz a.m. transmitter module is the RF Solutions type AM-RT4-418. It is a d.i.l. device and its mechanical dimensions and pin descriptions are given in Fig.3.




| PIN NO | FUNCTION |
|---|---|
| 1 | $V_{CC}$ |
| 2 | GND |
| 3 | DATA IN |
| 4 | ANTENNA |

*Fig.3. Pinouts of the d.i.l. version of the AM-RT4-418 transmitter.*

Note that an RF Solutions type AM-RT5-418 is also available. The only difference is that it is supplied in a s.i.l. (single-in-line) package, i.e. its pins are arranged in a straight line.

Apart from the fact that the RT4 operates at 418MHz, the other main operational factors are:

Operating voltage: 2V to 14V
Current consumption: 4mA
Maximum data rate: 4kHz.

The antenna used with this module could be a "whip" type or a helical coil. The latter consists of a coil made of 34 turns of enamelled copper wire (diameter 0·5mm), close wound on a 2·5mm diameter former. The helical coil consumes much less space than a whip antenna, but its performance may be a little lower, and small adjustments may be needed to its length for best results.

A whip is the simplest antenna for use with the RT4 transmitter. It can simply be a straight piece of rigid wire (or p.c.b. track) 17cm long. It works very well in practice, though it should not be close to metal objects. The wire should be as straight as possible.

The simplicity and reliability of this arrangement is the reason for the choice of this particular radio module in the constructional project about to be described.

In tests, this transmitter was able to cover a range of 100m in open space. Note that unlike the previous radio module (AM-TX1-418), the AM-RT4-418 is permanently connected to the power supply, but if no switch is pressed the current consumption is virtually zero.

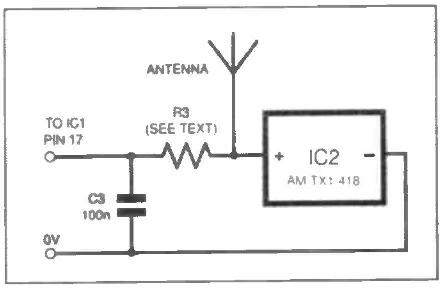



*Fig.5. Insertion circuit of alternative AM-TX1-418.*

12V, and it does not produce a modulated output. In other words, the i.c. encodes the signal but modulation is performed inside the radio module.

The circuit diagram for the encoded Radio Remote Control A.M. Transmitter module is shown in Fig.4. It uses the AM-RT4-418 a.m. radio module (IC2) and the HT6014 encoder (IC1). The module can send up to four encoded signals, or

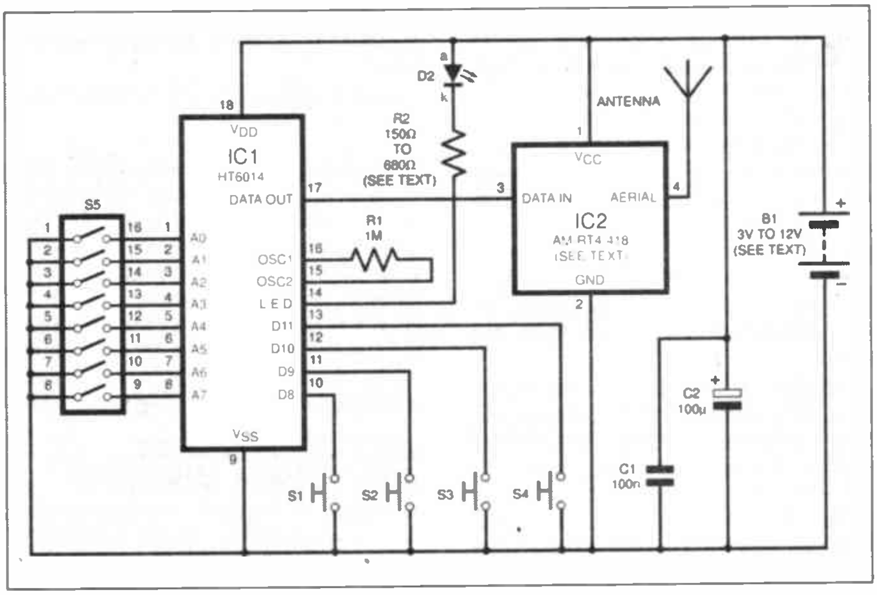



*Fig.4. Circuit diagram for the encoded Radio Remote Control A.M. Transmitter module.*

## CODED TRANSMITTER

All remote control systems are more reliable if a coded message is sent, and the use of an encoder integrated circuit (i.c.) is suggested, such as the Holtek HT6014. This is similar to the type HT12B used in the *Reliable Infra-red Remote Control* system, except that it can operate at up to

combinations of signals. Whenever one of the switches, S1 to S4, is pressed the circuit becomes active. If no switch is pressed, the circuit virtually shuts down — hence saving battery power.

The optional light emitting diode (l.e.d.) D1 lights when any switch is pressed. The value of its ballast resistor (R2) depends on the power supply used, typical values being 680Ω for a 9V or 12V supply, 150Ω for 3V. If the l.e.d. is not required, R2 can be omitted.

An AM-TX1-418 transmitter module can be substituted for the AM-RT4-418 as shown in Fig.5.

## CODING SWITCH

The transmitter is encoded by means of the multiple switch S5, which comprises eight independent on-off switches in a d.i.l. (dual-in-line) package. The purpose is to allow any or all of IC2's pins labelled A0 to A7 to be connected to 0V, the pattern of connection setting the code

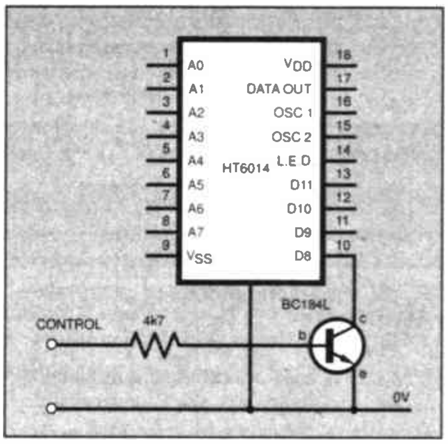



*Fig.6. Transistor coupling a control input.*

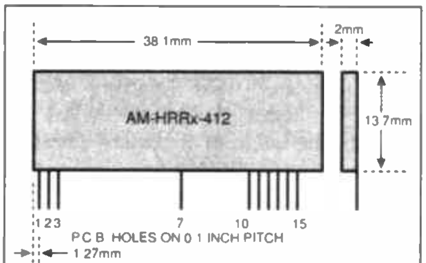
to be transmitted. The transmitted signal will only be decoded by a receiver's decoder which has a similar combination of pins connected to 0V.

This technique is useful if you wish to control a door lock (for example) — it would be difficult for an intruder to match the particular combination you may have chosen.

The d.i.l. switches allow you to change the combination whenever you wish. However, in practice you may never need to change the combination, and it is easier and cheaper to permanently connect one or more of A0-A7 pins to 0V, using link wires. *It is essential to have the same combination of pins connected to 0V on both the transmitter and receiver.*

Capacitors C1 and C2 are included for decoupling purposes; C1 removes any voltage spikes on the supply rails, and C2 removes slower voltage fluctuations.

If you wish to interface the circuit to an input module, Fig.6 shows how a transistor may be employed (no provision for this has been made on the p.c.b., however). When the control input is at about 0V, the *npn* transistor is turned off and the effect is similar to the equivalent hardware switch in Fig.4 (S1 in this case) not being pressed.




| PIN NO | FUNCTION |
|---|---|
| 1 | RF $V_{CC}$ |
| 2 | RF GND |
| 3 | ANTENNA |
| 7 | RF GND |
| 10 | AF $V_{CC}$ |
| 11 | AF GND |
| 12 | AF $V_{CC}$ |
| 13 | TEST POINT |
| 14 | OUTPUT |
| 15 | AF $V_{CC}$ |

*Fig.7. Pinouts for the AM-HRR1-418 receivers.*

When the control input is made positive (i.e. more than about 0·7V) the transistor turns on and data input D8 is connected to 0V — like pressing S1 in Fig.4. Each of the four data inputs may be treated in the same way if required.

## A.M. RECEIVER

Only one type of receiver is described, although three versions are available.

They have the same pin layouts and can be interchanged with each other in your circuit. The three versions are:

- AM-HRR1-418: This is inexpensive (e.g. less than £3) and although superseded by the next type, it works very well.
- AM-HRR3-418: As above, but laser trimmed for accuracy
- AM-HRR5-418: As above, but very low current consumption (0·5mA)

The receiver modules have the following specifications:

Supply voltage: 4·5V to 5·5V
Supply current: 2·5mA (HRR5 version: 0·8mA)
Output is compatible with CMOS/TTL
Maximum data rate: 2kHz.

The pin layout is shown in Fig.7. Note the slightly odd numbering used, and the way in which the r.f. (radio frequency) ground is separate from the a.f. (audio frequency) ground. Although both grounds should be connected to 0V in the circuit, it is best to use separate tracks on the p.c.b., with separate decoupling capacitors. A look at the receiver p.c.b. will illustrate this (Fig.12 later).

## DECODING A.M. RECEIVER CIRCUIT

Details of how the receiver module may be used with an HT6034 decoder to make up the A.M. Receiver circuit are shown in Fig.8.

Signals detected by the receiver module IC1 are output to the decoding device, IC2. The signal is only decoded if the settings on the d.i.l. switch S1 match those of the transmitter.

When a correctly coded signal is received, the pin labelled VT on IC2 switches to positive. The VT pin only remains positive for the duration of the decoded signal (i.e. for as long as the appropriate switch is pressed on the transmitter).

During this period, the data outputs (D8 to D11) copy the logic level at the data inputs of the transmitter. They will normally be positive, but if (for example) the switch (S1) connected to data pin D8 on the transmitter is pressed, this pin will be pulled to 0V and will make data pin D8 on the receiver switch to 0V.

The same applies to the other data switches (S2 to S4) and associated pins (D9 to D11). Note that this is different to the encoder/decoder system used previously on the infra-red modules.

The data outputs can be used to drive logic gate inputs (TTL or CMOS), or can be connected to transistors as described later.

As with the transmitter module, the purpose of the d.i.l. switch (S1) is to allow any or all of IC2's pins labelled A0 to A7 to be connected to 0V, allowing you to change the combination whenever you wish. As before, you may use link wires instead of a switch if you prefer. Again note that it is essential to have the *same* combination of pins connected to 0V on both the transmitter and receiver.

## INTERFACE CIRCUIT

Most of the rest of the circuit in Fig.8 (to the right of the dotted line) shows how IC2's VT and data outputs can be interfaced in order to allow the module to control l.e.d.s, buzzers, relays, motors, solenoids etc. If all the output options are not required many components can be omitted.

The VT pin is connected via resistor R10 to the base of TR1. This can be a TIP122 (or TIP121) *npn* Darlington transistor, enabling higher-current devices (such as those above) to be controlled. A small-signal transistor (such as a BC184L) could be substituted for the TIP122 if only a small buzzer or l.e.d. is required.

A relay coil (RLA1) is shown as the driven load for TR1. A motor or solenoid could be connected here if preferred. Diode D1 removes any back e.m.f. spikes produced by the relay/motor etc (which could damage the transistor). An l.e.d. D2 serves as an indicator whenever a signal is received. Any or all of these components may be omitted if not required.

## DATA OUTPUT INTERFACING

The fact that each data output switches to 0V when the appropriate transmitter button is pressed causes a slight complication at this stage. It is possible to switch on a *pnp* transistor with a 0V signal, but if the transistor is also being used as an interface between two voltage levels then this option is difficult. Hence additional transistors TR2 to TR5 are used to invert the logic level.

For example, if data output pin D11 is positive (no signal received), TR2 will be switched on, and its collector will be at 0V. This will switch off TR6. If output D11 switches to 0V, then TR2 will be switched off, and its collector will be pulled to 5V via resistor R6. Consequently, Darlington transistor TR6 will switch on, causing l.e.d. D4 to light.

As with TR1, a relay (RLA2) is the driven load for TR6. Other higher current devices may be driven instead. Diode D3 removes any back e.m.f. If only an l.e.d. or small buzzer is required, a low-power *npn* transistor such as a BC184L can be substituted for the TIP122.

The other three data outputs are interfaced in the same way.

## POWER SUPPLY

As shown in Fig.8, the power supply for the receiver is a 12V battery, since many applications will require the circuit to drive 12V relays/solenoids etc.

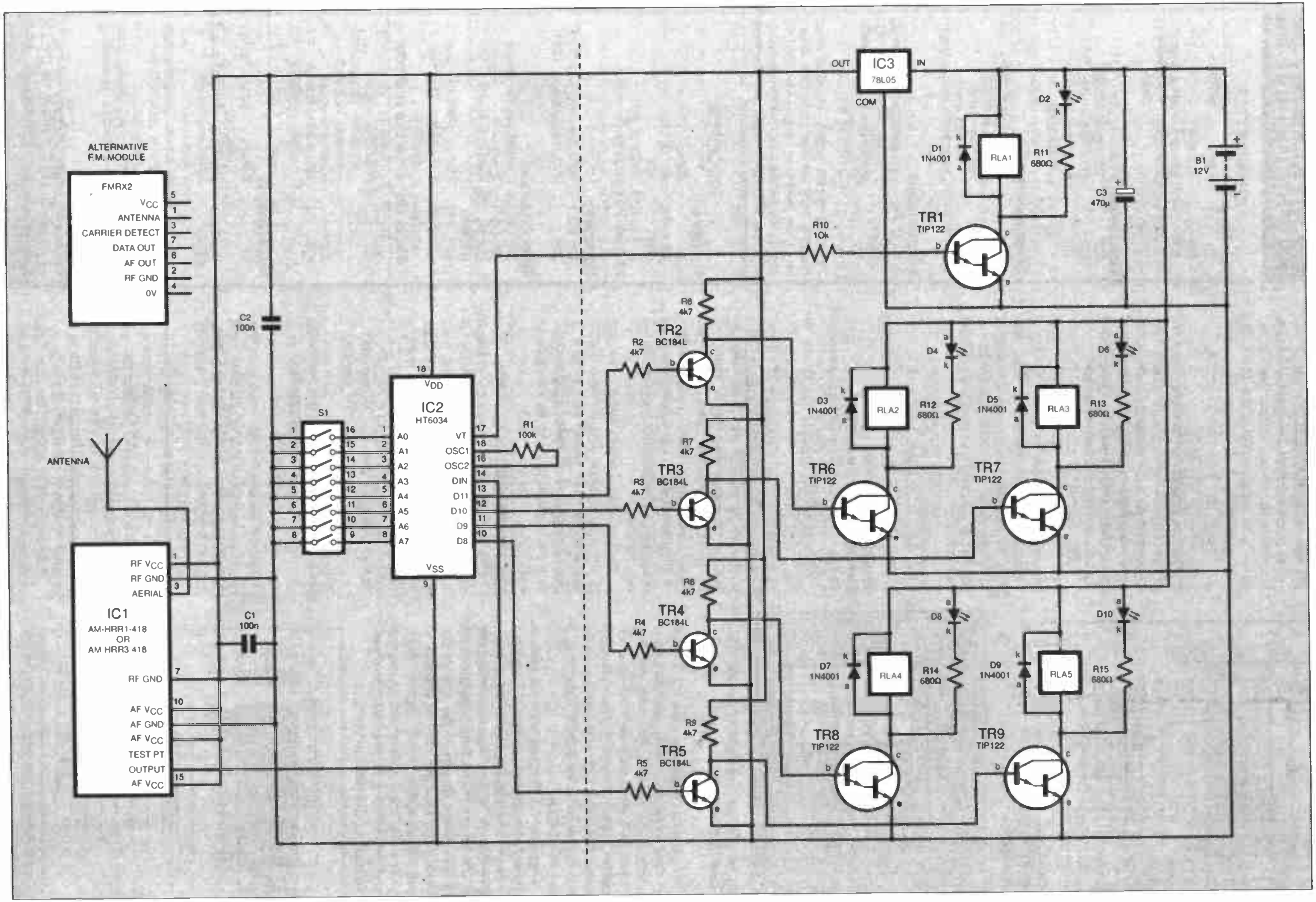
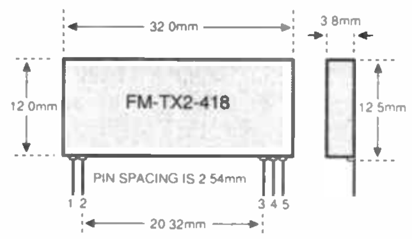



Fig.8. Complete circuit diagram of the decoding receiver.




| PIN NO | FUNCTION |
|---|---|
| 1 | RF GND |
| 2 | RF OUT |
| 3 | $V_{CC}$ |
| 4 | 0V |
| 5 | DATA IN |

*Fig.9. Pinouts for the FM-TX2-418 transmitter.*

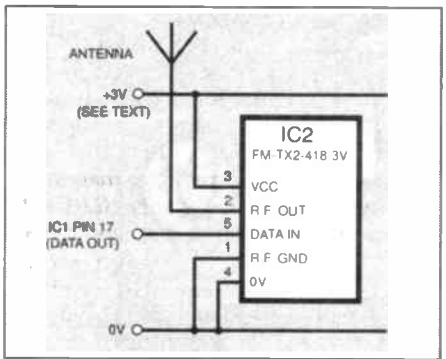
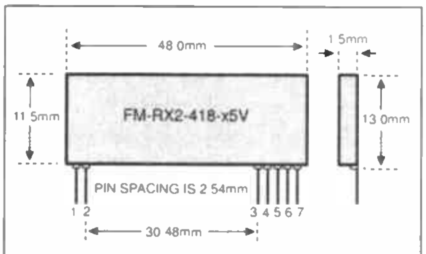



*Fig.10. Circuit connection for the FM-TX2-418 transmitter.*

However, whereas the HT6034 decoder chip IC2 will operate on a supply of 3V to 12V, the radio receiver module IC1 must only be used on a 5V supply. Hence the inclusion of the 5V voltage regulator IC3. If the entire circuit is to be powered by a 4·5V battery, IC3 may be omitted.

Capacitor C1 decouples the r.f. section of the radio module, while C2 and C3 decouple the main part of the circuit. Note that on the printed circuit board the r.f. 0V supply line is kept separate from the 0V power supply to the rest of the circuit. The two are only connected to each other at the power supply input point. This helps reduce the chance of interference being induced into the sensitive parts of the radio module.




| PIN NO | FUNCTION |
|---|---|
| 1 | ANTENNA |
| 2 | RF GND |
| 3 | CARRIER DETECT |
| 4 | 0V |
| 5 | $V_{CC}$ |
| 6 | AF OUT |
| 7 | DATA OUT |

*Fig.11. Pinouts for the FM-RX2-418-A5V/F5V receiver.*

## *F.M. MODULES*

For readers wishing to employ an f.m. transmitter/receiver combination (instead of an a.m. combination), the following will be helpful.

### F.M. TRANSMITTER

The f.m. transmitter module suggested is type FM-TX2-418-3V, since it is able to operate on a 3V supply (as its reference code implies). This can be provided by two AAA cells, which fit neatly inside the recommended transmitter case.

A 5V module is also available, code FM-TX2-418-5V. Note that the f.m. transmitter module is designed for a particular voltage, unlike the a.m. version which can operate on a range of voltages. Apart from that, the module is similar to use, and its specification is as follows:

| | |
|---|---|
| Supply Voltage | 2·2V to 4V (3V version)<br>4V to 6V (5V version) |
| Supply Current | 6mA |
| Data Rate | up to 40k bits/s |
| Range | 300m in open ground |

Pinouts for the module are shown in Fig.9 and circuit connection details are shown in Fig.10. It is similar to the 4-pin a.m. transmitter module described earlier, except that a fifth pin is included so that the r.f. ground and the 0V supply to the rest of the module can be separated. This reduces the problem of interference.

The transmitter p.c.b. layout has been designed to accept either the a.m. or the f.m. module.

The f.m. module costs about twice that of the a.m. module, but it has a higher specification and greater range. If it is chosen in preference to the a.m. module, then the receiver must be an f.m. type as well.

### F.M. RECEIVER

The f.m. receiver module is much more expensive than the a.m. version. It is available in 3V and 5V versions, both of which are available as two Data Rate versions, standard and fast. The specifications are as follows:

| | |
|---|---|
| Supply Voltage | 3V to 4V (3V version)<br>4V to 6V (5V version) |
| Supply Current | 13mA |
| Data Rate | 40k bits/s (fast version)<br>14k bits/s (standard version) |

The 5V version of the module is the most convenient in this application, and the standard version is denoted FM-RX2-418-A5V while the fast version is coded FM-RX2-418-F5V.

The pin layout of the module is shown in Fig.11. It features a similar arrangement to the a.m. module, but note that pin 6 provides an analogue output, while pin 7 provides a digital output. In this application we use the digital output which is a squared version of the signal at pin 6.

The application circuit for the f.m. receiver is virtually identical to the a.m. circuit shown in Fig.8. As with the trans-

## COMPONENTS

### TRANSMITTER

**Resistors**

| | |
|---|---|
| R1 | 1M |
| R2 | see text |
| R3 | see text |

All 0·25W 5% carbon film or better.

See SHOP TALK page

**Capacitors**

| | |
|---|---|
| C1 | 100n ceramic disc |
| C2 | 100μ radial elect., 25V |
| C3 | 100n ceramic disc (see text) |

**Semiconductors**

| | |
|---|---|
| D1 | red l.e.d. (see text) |
| IC1 | HT6014 encoder |
| IC2 | AM-RT4-418 or AM-TX1-418 or FM-TX2-418 (see text) |

**Miscellaneous**

| | |
|---|---|
| S1 to S4 | min push-to-make switch, p.c.b. mounting (4 off) |
| S5 | 8-way d.i.l. s.p.s.t. switch (see text) |

Printed circuit board, available from the EPE PCB Service, code 228; antenna, 17cm wire (see text); AAA-size 1·5V cell (2 off); plastic case, 105mm × 60mm × 25mm with four integral push buttons; connecting wire; solder, etc.

### RECEIVER

**Resistors**

| | |
|---|---|
| R1 | 100k |
| R2 to R9 | 4k7 (8 off) |
| R10 | 10k |
| R11 to R15 | 680Ω (5 off) |

All 0·5W 5% carbon film or better.

**Capacitors**

| | |
|---|---|
| C1, C2 | 100n ceramic disc (2 off) |
| C3 | 470μ radial elect., 16V |

**Semiconductors**

| | |
|---|---|
| D1, D3, D5 D7, D9 | 1N4001 rectifier diode (5 off) |
| D2, D4, D6, D8, D10 | red l.e.d. (5 off) |
| TR1, TR6 to TR9 | TIP122 or TIP121 *npn* Darlington (see text) (5 off) |
| TR2 to TR5 | BC184L *npn* transistor (4 off) |
| IC1 | AM-HRR1-418 or FM-RX2-418 transmitter module (see text) |
| IC2 | HT6034 decoder |
| IC3 | 78L05 +5V 100mA voltage regulator |

**Miscellaneous**

| | |
|---|---|
| S1 | 8-way d.i.l. s.p.s.t. switch (see text) |
| RLA1 to RLA5 | 12V relay, contacts to suit application (5 off) (see text) |

Printed circuit board, available from the EPE PCB Service, code 229; antenna, 17cm wire (see text); 12V mains adaptor plus socket to suit; plastic case, 148mm × 90mm × 54mm; connecting wire; solder, etc.

**Approx. Cost Guidance Only £54 excl. batt & p.s.u.**

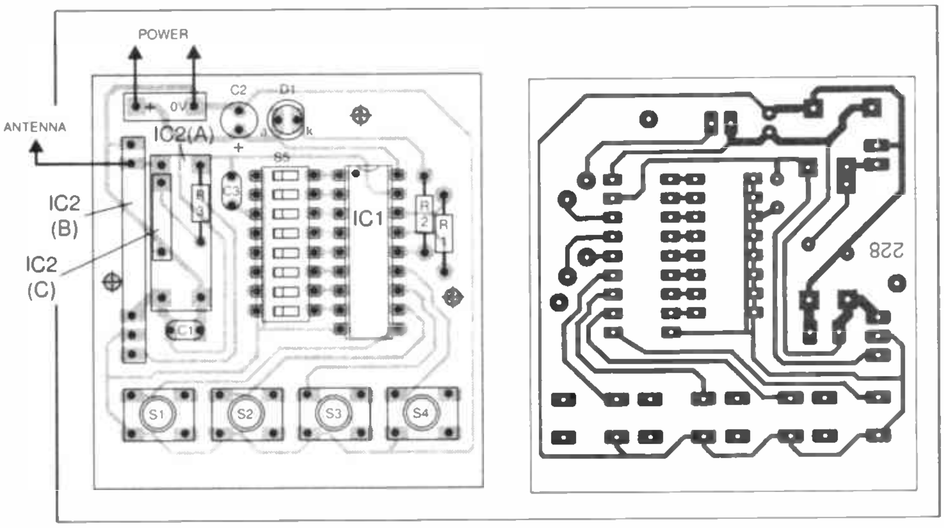



*Fig.12. Component layout and master track foil pattern for the Transmitter p.c.b.*

mitter, the receiver p.c.b. has provision for either the a.m. or f.m. modules.

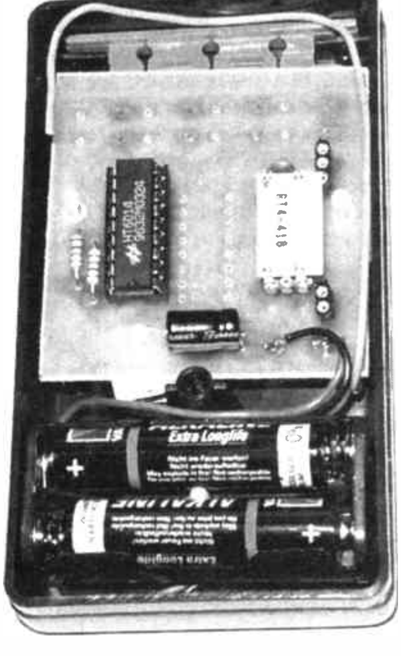
## PRACTICAL SYSTEM

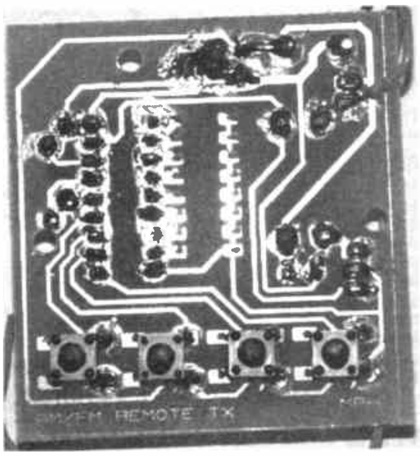
Emphasis has been placed on a transmitter circuit designed around the AM-RT4-418 a.m. module, and in tests it performed extremely well, and the antenna arrangement is straightforward, with no adjustable components.

It is this circuit for which the transmitter p.c.b. has been designed. However, provision has been made on the p.c.b. for the AM-TX1-418 module plus its extra resistor (R3) and capacitor (C3). The same board will also accept the f.m. transmitter module as an alternative.

The radio modules can be used in all sorts of ways, and so as much flexibility as possible has been allowed for. The remote control system can be a single momentary signal, i.e. when any switch is pressed on the transmitter, a single action occurs at the receiver; when the switch is released the action stops.

In this context the word *action* means that (a) an l.e.d. can light, (b) a buzzer can sound, (c) a relay can be activated etc.






There is provision for any or all of these options on the p.c.b.. If a single way momentary system is required, it is necessary to fit only one switch – ideally one near the centre of the p.c.b., say S2 or S3.

There is provision for up to four latching ways. Pressing another switch unlatches the previous one. For example, if two switches are fitted on the transmitter p.c.b., say S1 and S4, then S1 can be used to latch the appropriate output. When S4 is pressed, the output unlatches. Note that it is possible to latch two or more outputs at the same time if the appropriate buttons are pressed at the same moment.

It is possible to include all options, i.e. one momentary and four latching ways if required. The momentary way can be used to indicate "message received".

Power Darlington transistors have been chosen at the receiver in case motors or solenoids are required. If you only wish to drive small buzzers or l.e.d.s, then the Darlingtons may be replaced by BC184L transistors.

The l.e.d. D1 on the transmitter is optional; it indicates that a switch is being pressed, and that the circuit is active (e.g. battery is OK). If the l.e.d. is omitted, then you can also omit R2 on the transmitter.

## CONSTRUCTION

We will begin construction with the coded transmitter. Ensure that you are clear about the options available (see above), particularly whether you are using the a.m. or f.m. modules.

The p.c.b. component and track layout details are shown in Fig.12. This board is available from the *EPE PCB Service*, code 228.

Begin assembly by fitting sockets for IC1 and IC2. (Do not fit the i.c.s (especially the delicate/expensive radio module) at this stage.) Whereas IC1 requires a normal d.i.l. socket, IC2 (as an a.m. module, position marked as IC2(A)) requires four single pin sockets. The best way to accommodate this is to buy a strip of s.i.l. sockets and cut two strips of 3-ways each. Next cut off the pin of the middle socket of each strip. The strips can now be soldered into the p.c.b. – one strip at each end of IC2.

This is much easier and stronger than soldering in single sockets. The f.m. version of IC2 (position marked as IC2(B)) requires one 2-way and one 3-way s.i.l. strip.

The alternative 2-pin a.m. transmitter has its position marked as IC2(C). It requires the addition of capacitor C3 and resistor R3 (*which are only required for this transmitter version*). The value for R3 should be chosen from Table 1 (earlier) to suit the power supply.

Solder in the resistors and capacitors taking care to fit C2 the correct way round and with its leads long enough to allow it to be bent over flat against the p.c.b.. This enables the p.c.b. to be housed in the rather thin case specified.

The optional l.e.d. occupies a central position on the p.c.b. so that it can be aligned with a hole drilled in the case. Note that the l.e.d. should be fitted on the copper side of the p.c.b., with its leads long enough to allow the l.e.d. to rest against the hole. Similarly, switches S1 to S4 must be mounted on the copper side of the p.c.b., assuming that the recommended case is employed.

## CODING SWITCHES

As discussed earlier, the set of eight switches within the d.i.l. switch modules allow the system to be encoded to prevent a signal from another transmitter from activating the receiver. The switches enable the code to be changed easily if necessary. It is essential to set the same code at both the transmitter and receiver.

Many people will have little cause to change the code, and so one or two wire links can be fitted in place of the d.i.l. switches to set a permanent code. It is essential to insert the same wire links in both the transmitter and receiver. If security is not an issue, it is not necessary to fit any wire links (or d.i.l. switches) – the associated pins on the coder/decoder chips can remain unconnected.

Solder in the d.i.l. switch if required, or any wire links to set the code as necessary.

Connect power leads as shown. Note that the f.m. version requires a 3V supply; the a.m. version can cope with a

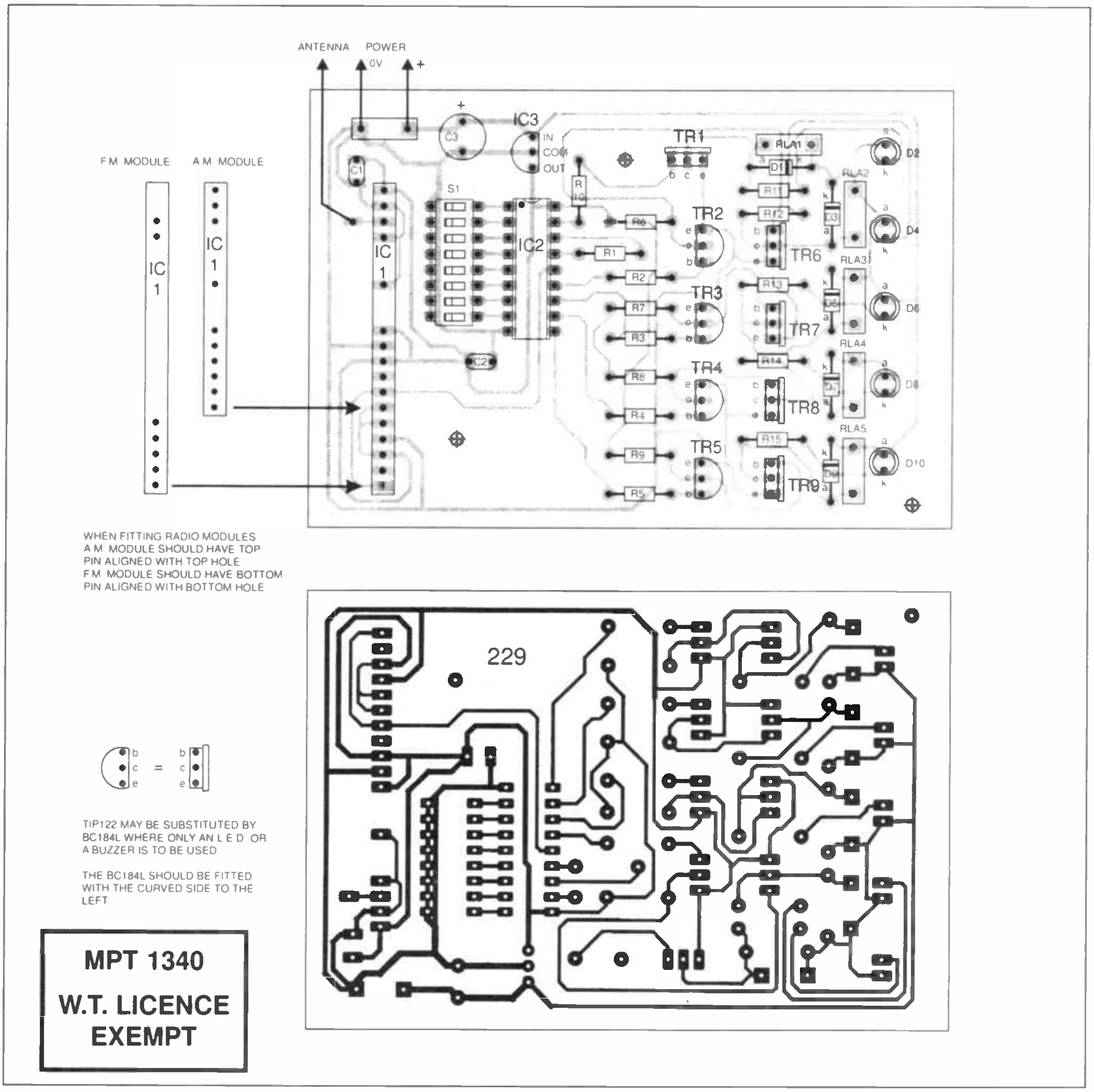



*Fig.13. Component layout and full size master foil track pattern for the Receiver p.c.b.*

wider voltage range, but 3V is also convenient. A battery holder housing two AAA cells fits neatly into the recommended case.

The antenna in the a.m. version must be connected to the pad as shown in Fig.12. If using the f.m. module, the antenna must be connected to the pad intended for pin 4 of IC2 (the top left hand corner of IC2 as in Fig.12). This arrangement allows either module to be employed without compromising the requirements of the antenna, i.e. a single conductor. The antenna can be an ordinary wire of total length 17cm.

Finally, insert IC1 and the radio module. The a.m. version fits parallel with the p.c.b.: note that the "overhang side" is towards the edge of the p.c.b. Treat both IC1 and IC2 as static sensitive devices, i.e. briefly earth yourself before handling them.

The alternative f.m. radio module fits upright, but it may be necessary to bend it parallel with the p.c.b. in order to fit the case. If so, use pointed-nose pliers to carefully bend the pins of the device.

## TRANSMITTER CASE

The transmitter is housed in a case which has one, two or four pushswitch buttons built in. These align with the switches mounted on the copper side of the transmitter p.c.b. Drill a hole on the front of the case (buttons side) as shown to allow the l.e.d. to show through.

The p.c.b. may be fixed with self-adhesive p.c.b. supports. It may be necessary to cut the base of two of the supports to allow them to fit inside the case. Three points have been marked on the p.c.b. to indicate positions for the supports.

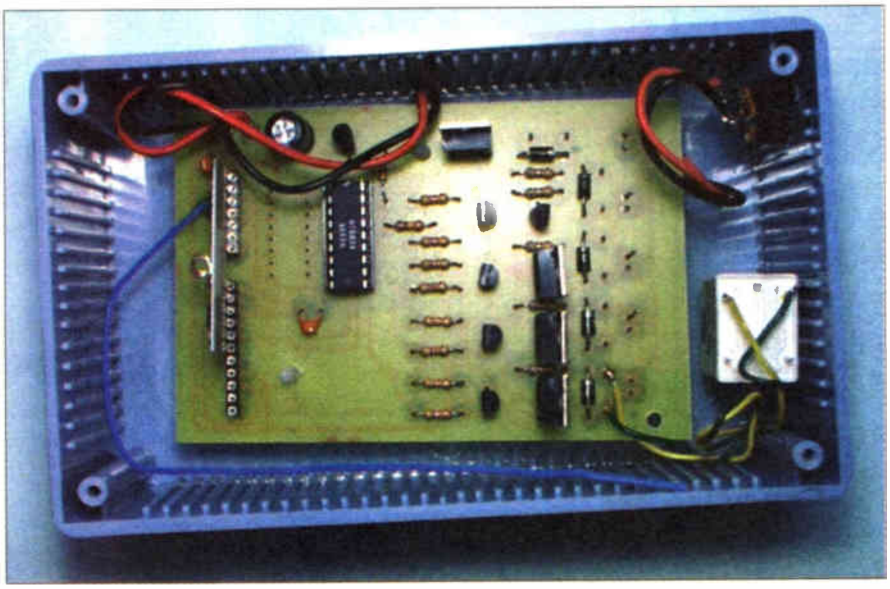
It is important that the buttons make contact with the switches on the p.c.b. and spacers cut from small pieces of plastic or rubber feet may be needed to lift the p.c.b. slightly. Double-sided self-adhesive pads are also very helpful at this stage.

Ensure that the switches are aligned properly when fitting the p.c.b., so that they click when each button is pressed. If the p.c.b. flexes too much, a pad of non-conductive material can be fixed to the back of the case to push against the p.c.b. above the positions of the switches.

## RECEIVER CONSTRUCTION

Details of the p.c.b. for the Receiver module are shown in Fig.13. This board is available from the *EPE PCB Service*, code 229.

The receiver p.c.b. is constructed in a similar way to the transmitter, again noting carefully which options are required. The a.m. and f.m. receiver modules are both "in-line" types, and care must be taken to fit the chosen one in the correct place.




The a.m. module requires three s.i.l. sockets, one each of 3-way, 1-way and 6-way. The f.m. module requires a 2-way and a 5-way s.i.l. socket. Alternatively, fit s.i.l. strips to occupy all the pads for both modules. Do not fit any i.c. or radio module at this stage.

Fit the d.i.l. socket for IC2, the optional d.i.l. switch or wire links, followed by resistors and capacitors, noting that C3 must be connected the correct way round. Leave out the l.e.d.s for the moment.

The power Darlington transistors can be replaced with BC184L transistors if you only wish to control small buzzers or l.e.d.s. The insert in Fig.13 shows how the flat side of the BC184L is equivalent to the metal tab of the TIP122.

The l.e.d.s may be joined to the p.c.b. via wires or, more conveniently, soldered on the copper side of the p.c.b. so that they align with a set of holes drilled in the case.

Fit leads for the power supply and solder on a rigid wire of length 17cm for the antenna.

It is wise at this stage to test the circuit without IC1 or IC2 fitted. With a 9V or 12V power supply applied, use a voltmeter to check that the positive (Vcc) and ground (0V) pads of both devices correctly receive 5V (see the circuit diagram in Fig.7 for the pin numbers). If this is not the case, check that the regulator IC3 has been fitted correctly.

Note that l.e.d.s D4, D6, D8 and D10 should light up when power is applied, assuming that IC2 is not fitted. If they do not, then check resistors R6 to R9 and transistors TR6 to TR9 to locate the fault before proceeding.

Finally, insert IC2 and the appropriate radio module. The a.m. module is fitted with its top end (pin 1) at the top of the row of pads, with the component side of the module facing the edge of the p.c.b.

The f.m. module is fitted with its bottom end (pin 7) at the bottom end of the row of pads. Note that the antenna pin of either module is correctly aligned by the pad labelled "ANTENNA". It should not be necessary to bend the module parallel with the p.c.b. since the case suggested is reasonably large. If bending is necessary take great care and use pointed-nose pliers to avoid straining the delicate material housing the module.

## TESTING

As with infra-red remote control, testing is a classic chicken and egg situation. Failure of the system to work could be due to the transmitter or receiver. Connect suitable power supplies and check that the l.e.d. (if fitted) on the transmitter lights when any switch is pressed. See if the receiver responds – l.e.d. D2 is very useful for detecting a signal.

If the system fails, an oscilloscope will show whether data is present at the data pin of the transmitter and, if so, a similar test will show if the same data is present at the receiver. Use a voltmeter to check the power pins on the radio modules and encoder/decoder i.c.s. Check the value of resistor R1 on both the transmitter (1MΩ) and the receiver (100kΩ).

More detailed tests can be made by attaching the negative lead of a voltmeter or oscilloscope to the 0V rail on either circuit, and measuring voltages or signals around the circuit as detailed earlier.

## RECEIVER CASE

The receiver may be mains powered via a suitable mains adaptor, in which case begin by drilling the necessary hole for its connection socket.

The l.e.d.s require holes drilled in the front of the case. If the l.e.d.s have been fitted to the copper side of the p.c.b. it is only necessary to drill appropriate holes which allow the l.e.d.s to show through when the p.c.b. is located into the case.

If the receiver is to be used to control mains devices via relays, the relays should be in an area away from the p.c.b. (see photo), or in another case. ***(Only constructors who are competent at mains wiring should connect up this circuit for mains control switching.)***

## USING THE SYSTEM

The range offered by the system (even with the a.m. version) is likely to be much greater than required, and a poor antenna (e.g. where the wire is bent to fit the case) is of little consequence.

However, if range is important then the antenna should be as straight as possible, and away from metal objects. Note that the use of a super high gain antenna is prohibited under MPT1340 regulations.

## LICENCE EXEMPTION

The transmitter modules referred to in this article have been approved by the Department of Trade and Industry for use in the UK under specification MPT1340 and require no radio operating licence. However, to comply with MPT1340, the following requirements must be observed:

1. All transmitters shall use integral antennas only. Receivers may use an external or integral antenna. An integral antenna is defined as one which is designed to be connected permanently to the transmitter or receiver without the use of an external feeder.

2. The equipment in which the module is used must carry an inspection mark located on the outside of the equipment which is clearly visible. It shall state "MPT1340 W.T. Exempt". The minimum dimensions of the mark shall be 10mm×15mm and the figure height shall be not less than 2mm. □

# PRACTICALLY SPEAKING

## Robert Penfold looks at the Techniques of Actually Doing It!

ELECTRONIC project construction is not just soldering irons, electronic components, and test meters, there is also a "nuts and bolts" side to things. Having successfully completed a circuit board you usually have a fair amount of work left to do before you are ready to show off your new masterpiece.

If you have a good selection of tools and are familiar with DIY jobs around the house you should not find things too difficult, but project construction and general DIY tasks are certainly different. It is certainly worth making the point to anyone experienced in putting up shelves or dealing with car servicing that electronic project construction requires a tender-handed approach.

You will often be dealing with plastic or aluminium cases that will not take kindly to the "bull in a china shop" approach. Some of the plastic cases are actually quite tough, but others are prone to cracking, and it is easy to buckle aluminium cases. Also, most cases have finishes that are easily damaged. When dealing with the "nuts and bolts" side of construction it is normally necessary to proceed carefully and use the minimum amount of force.

### Planning

Project articles normally give precise instructions for building the circuit boards and undertaking the wiring but tend to be a bit "sketchy" when it comes to the mechanical side of construction. This is simply because most constructors prefer to "do their own thing" with this aspect of construction, rather than producing a clone of the original project. You normally have great freedom to do things the way you want to, but this also creates a golden opportunity to make a complete mess of things!

When building anything it is important to carefully plan things rather than just pressing on hoping that you can muddle through successfully. With the muddling through approach you are likely to produce the perfect project, apart from the fact there is nowhere to put the battery, you cannot adjust the volume control when the headphones are plugged in, or something of this nature.

### Box Clever

There are numerous types of case available at present, but they break down into two general categories. These are simple boxes and instrument cases.

The cases of all-plastic construction are mostly simple plastic boxes consisting of a five-sided main moulding plus a removable lid or front panel. You can also obtain diecast aluminium and folded aluminium construction boxes, both of which take the same general form as the plastic variety.

Boxes are fine for projects that require a small to medium size enclosure, but they are often a bit awkward when applied to larger projects. For the bigger projects, and some smaller types, an instrument case is usually the more practical option. These vary considerably in design, but consist of something like a base section combined with front and rear panels, plus the lid and sides in another section.

Some cases of this type have removable front and rear panels which makes working on the panels very much easier. Instrument cases are mostly of all-metal construction, but there are a few plastic types, and plenty that have plastic outer casings plus metal front and rear panels.

### Take Note

It pays to read the notes on construction very carefully before selecting a case. While it is normally possible to use any type of case you like provided it is big enough, there are sometimes other considerations. This is mainly where it is necessary to use a metal case for some particular reason.

Metal cases are sometimes required because the project uses power devices and a metal case helps to conduct heat away from them. More usually a metal case is needed to provide screening. This can be needed to prevent a sensitive project from picking up electrical interference such as mains "hum", or to prevent a circuit from radiating interference.

If the article specifies a certain type of case, such as a diecast aluminium type for its good screening properties, you should definitely follow the advice. Otherwise it is a matter of choosing one that is within your budget and is large enough to accommodate the project.

Simple boxes are much cheaper than instrument cases, and are perfectly adequate for most small projects. They tend to be awkward to use with larger projects that have numerous controls, sockets, etc., and for these it is probably worthwhile paying the extra for an instrument case.

### Size Is Important

In theory it should be quite easy to work out whether or not a likely looking case will fit your latest project. Some measurements taken from the bits and pieces that will go into the case will give you a good idea of the minimum requirements, but even at this early stage you will have to give some thought to the general layout of the unit.

If you are lucky, the catalogue entry for the case will give internal dimensions and not just the external size. If not, deducting about eight millimetres from the external dimensions usually provides figures that are quite close to the internal ones.

The real problem is that modern cases often have various internal obstructions, which effectively reduce the internal dimensions. These include mounting pillars and guide-rails for printed circuit boards (p.c.b.s), threaded pillars for the lid's mounting screws, and various mouldings that have no obvious purpose at all.

Plastic cases are the worst offenders, and I have encountered one or two that have so many internal lumps that it is difficult to fit anything into them. Even with simple two-part metal cases you have to allow for the fact that the fixing screws for the cover will each penetrate several millimetres into the case. It is easy to come up with a plausible looking layout that results in one of the fixing screws going straight into the battery or a circuit board.

Unless a project really does need to be as small as possible it is best to err on the side of caution and choose a case that seems to be slightly too large. Making projects small just for the sake of it makes construction difficult and may make the finished project awkward to use. Anyway, a case that initially seems to be slightly too large will probably turn out to be just about right when you start installing the components.

Before starting any drilling it is certainly a good idea to place the circuit board, battery, and any other large components inside the case to make sure that everything fits, and that nothing prevents the lid from fitting into place properly. Make careful measurements to ensure that you do not have controls and the circuit board vying for the same space.

*A hand-drill is adequate for electronic project work, but a cordless power drill is probably the best option. Remember to keep it well charged!*

## Measured Approach

Before starting work on a case you have to finalise the overall layout for the unit and make any adjustments if necessary. With most projects there are few restrictions on the placement of the controls, etc. and it is just a matter of coming up with something that looks reasonably good and is ergonomic.

However, read the article carefully to see if there are any pitfalls to avoid. For example, with some projects it is important to keep input and output sockets well separated. Ignore this sort of advice and you can reasonably expect the finished unit to be erratic in operation, if it works at all.

Otherwise, it is just a matter of trying to keep things reasonably neat and avoiding the classic mistake of crowding the controls so close together that they are difficult to adjust. If necessary, relegate sockets to the rear of the unit to give more space for the controls or use smaller control knobs.

Things will be neater if the spacing between control knobs of the same size is kept constant, but it does not usually pay to be too mathematical when designing front panel layouts. The neatest layout is the one that looks the neatest in real life, and not the one that looks the best "on paper".

My favoured method is to place the control knobs onto the front panel, together with fixing nuts to represent things like toggle switches or panel l.e.d.s, so that you can see almost exactly what the finished project will look like. When everything looks right it is a matter of making some careful measurements so that a plan of the layout can be sketched out.

## Making Your Mark

Having finalised and checked the layout it is then a matter of transferring it to the case. You will mainly be dealing with plastic and aluminium cases, both of which are relatively soft materials. There are actually some steel cases available, but these are best avoided unless you have proper facilities and the know-how to deal with them.

The softness of plastic and aluminium means that you have to be careful not to scar the case for life when marking the centres of holes and cutouts. Indelible marks inside the case will not matter too much, but you have to be careful with the exposed sides of front and rear panels.

The softest of pencils (about 5B or 6B) will do the job quite well, as will some fibre-tipped pens. It is best not to use fibre-tipped pens having spirit-based inks on plastic cases as they can etch into them slightly.

The safest method is to cover the panel with paper held in place using double-sided tape or a water-based adhesive such as Pritt-Stick. It is then easy to make the marks with great precision, and they should be very clear. You can even use a computer drawing program to produce the design, and then fix the printout onto the panel.

Either way, the paper will give a degree of protection to the panel while you are working on it. The paper can be peeled away once the work has been completed, and any adhesive or bits of paper that remain are simply washed off. This method clearly involves a lot more work than marking straight onto the panels, but it is the one recommended for soft plastic cases which can otherwise be difficult to deal with.

With aluminium cases use a centre punch to mark the centres of all holes prior to drilling them. The indentation acts as a guide for the drill and makes accurate drilling much easier. An automatic punch is the best type to use, but a conventional punch and small hammer will do, provided you do not get carried away. Remember that aluminium panels buckle and distort quite easily.

Neither type of centre punch is a safe option when dealing with plastic cases, which could be shattered by the punch. It is still necessary to make an indentation to stop the drill bit from wandering, and this is best done using a hand bradawl or similar tool, using a minimum amount of pressure.

You are now ready to start the drilling and cutting. Several ways of dealing with large cutouts were covered in the previous "*Techniques*" (March '99 issue) article and this subject is something we will not consider here.

Most panel mounting components require round mounting holes of up to about 10mm in diameter, and do not require the use of any unusual tools. Plastics and aluminium are quite soft, which means that you do not need a powerful electric drill. In fact, a powerful electric drill is a bit "over the top" for project construction and can be rather unmanageable at times.

Plastic cases can actually start to melt if the drill bit rotates too fast, producing some very rough results. A hand-drill is perfectly adequate and much more controllable. Recently I have changed over to a cordless power drill, and these seem to be ideal for project construction.

Due to the softness of the materials you will be working on it is not essential to use top quality drill bits. As an emergency fill-in measure I bought a set of inexpensive drills from the local "Woollies" store a while back, and several dozen projects later they are still perfectly usable.

## A Firm Hand

It is important to have the case or panel firmly fixed in place before you start drilling, and to have a piece of scrap timber, MDF, etc. under the work piece. You may be able to clamp everything into some form of vice, but it is usually a matter of using G-clamps to fix everything to the worktop.

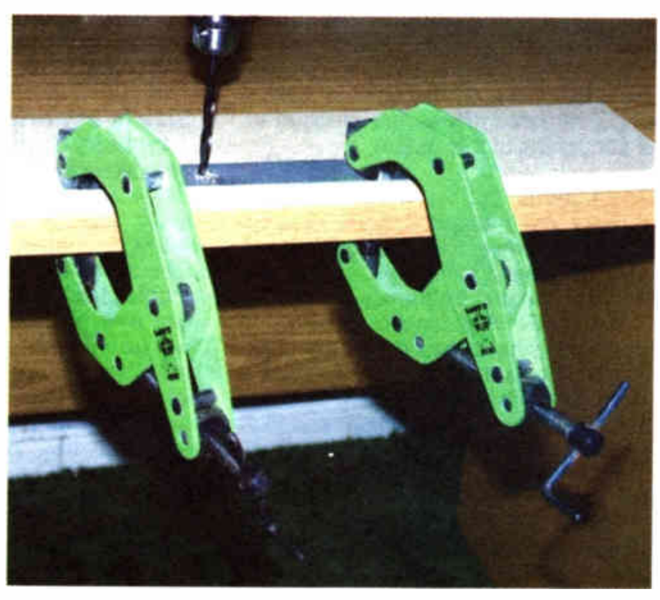
Some clamps are kinder to panels and cases than are others, but if necessary use pads of kitchen towel to prevent the clamps from scratching the work piece. The backing piece will stop the drill from crashing through the completed holes and will also help to give "clean" holes.

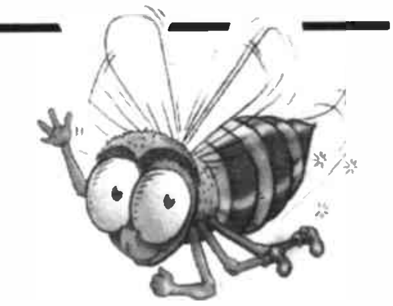
However, drilling hardly ever gives perfect results and a certain amount of de-burring will usually be required. There are tools specifically for this purpose, but a miniature round file ("needle" file) will do the job quite well.

With soft materials such as plastic and aluminium the small blade of a penknife is also very effective, but always proceed carefully when using a sharp tool. With the holes and cutouts completed it is time to fit everything into the case and complete the wiring.

*An automatic centre punch (top) is ideal for use with aluminium but should not be used with plastic. Instead use a sharp bradawl or stiletto (bottom) with no more than moderate pressure.*

*(Right) It is dangerous to work on a case or panel that is not firmly fixed in place. Clamp the workpiece and a backing board to the workbench.*





# PhizzyB COMPUTERS

## Part 7: Equipping the PhizzyBot with Optical Sensors

Clive "Max" Maxfield and Alvin Brown

HI THERE! Last month, as you no doubt recall, we created a rather cunning program to detect when the PhizzyBot collided with something and to respond in an appropriate manner. This program was designed to be user-friendly, such that it was relatively easy to specify, read, and modify the sequences of actions performed by the PhizzyBot, thereby facilitating our ability to experiment with different sequences. This month we get PhizzyBot involved in measured space travel, and add to its senses by giving it eyes – six of them.

THE ACTIONS and movements discussed last month were specified using constant declarations like **STOP**, **FORWARD**, **TURN_L** (turn left), and **SPIN_CW** (spin clockwise). However, the "units" associated with these actions were always those of time (measured in tenths of seconds).

### WAITS AND MEASURES

Associating actions with units of time made sense in the context of the way we developed our program. But when you come to think about it, a command like "*Go forward for three seconds*" isn't perhaps quite as useful as being able to present an instruction in the form: "*Go forward for fifteen centimetres*".

Similarly, the command "*Spin clockwise for two seconds*" doesn't convey the same intent as "*Spin clockwise for ninety degrees*". Well, perhaps it does convey the same intent (if you want to be pedantic), but it is certainly less people-friendly when it comes to working out exactly what's going to happen.

So what we need is a technique that will allow us to replace delay values with units like centimeters and degrees. In order to do this, we first need to ascertain the relationship between time and distance travelled. One way to do this would be to mark out a specific distance (say three metres) and time how long the PhizzyBot takes to travel this distance.

Alternatively, you could easily modify last month's program such that clicking Switch 1 will cause the PhizzyBot to travel forwards for some specified time (say ten seconds) and measure the distance travelled.

Whichever technique you choose to use, you should repeat the process a number of times and average the results to compensate for experimental errors. In the case of our PhizzyBot, it took approximately fifteen seconds to travel three metres. This equates to five seconds per metre, or 0·5 seconds to travel ten centimetres, or 0·1 seconds to travel two centimetres.

As 0·1 seconds is the smallest interval we can measure with our current program, this means that the smallest distance we can instruct the PhizzyBot to travel is two centimetres. (In order to achieve finer control, we could modify the program, or change the gearing on the motors to make them slower, or reduce the diameter of the PhizzyBot's wheels, or . . .)

But let's stick with what we've got. One thing we could do would be to create a whole host of constant declarations as follows:

```
_2cm:     .EQU 1
_4cm:     .EQU 2
_6cm:     .EQU 3
_8cm:     .EQU 4
          :
          etc.
```

Remember that label names cannot commence with a number, so we can't use 2cm, 4cm, 6cm, and so forth, but labels can start with an underscore as shown above. So this would allow us to specify action sequences in the form:

```
FORWARD,    _4cm
BACKWARD,   _8cm
            :
            etc.
```

(We've omitted the labels and **.BYTE** statements associated with these action sequences for clarity and space considerations.) One problem with this technique is that it requires us to create one heck of a lot of constant declarations to cover every time value from 1 to 255. One alternative would be to just create one constant declaration (say **_2cm .EQU 1**) and to then use expressions to modify this in the action sequences, for example:

```
FORWARD,    10 * _2cm
```

That's right, we can use expressions in these statements, as you doubtless recall from reading Appendix D from *The Official Bebop-uter Microprocessor Databook*.

In reality we might create a small number of constant declarations to cover any "standard" values like **_10cm**, **_20cm**, and so forth, and to then modify these with expressions as required.

### IN A SPIN

Now set the PhizzyBot to spinning clockwise, and time how long it takes to make ten complete revolutions. As before, repeat the process a number of times and average the results to compensate for experimental errors.

In our case, it took our PhizzyBot approximately 25 seconds to complete ten revolutions, which equates to 2·5 seconds per revolution (360 degrees). Remembering that the smallest interval we can measure with our current program is 1/10 of a second, this means that the smallest rotation we can instruct the PhizzyBot to perform is 14·4 degrees (which we can "round up" to 15 degrees for the sake of this discussion).

So once again we could create some constant declarations along the lines of:

```
_15deg:     .EQU 1
_30deg:     .EQU 2
_45deg:     .EQU 3
_60deg:     .EQU 4
            :
            etc.
```

In fact, in this case we really only have twelve labels to declare to cover 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, and 180 degree increments, because we can use these declarations as assignments to both clockwise and anticlockwise spin commands. (And we can always use expressions to modify these constants if we wish; for example, 4 * **_180deg** will instruct the PhizzyBot to perform two full revolutions.)

### NO HISTORY

There is an old saying that those who fail to learn the lessons of history are doomed to repeat them (this is particularly true in the case of history courses at high school)! One of the limitations of last month's program is that it had no sense of history, which means that the PhizzyBot has no knowledge of anything that's happened before the current time.

The end result is that the PhizzyBot could easily get itself stuck in a repetitive "loop", such as endlessly bouncing back and forth between two closely spaced objects. If the program were modified to maintain some record of what had gone before, then we might be able to circumvent this sort of thing.

As a simple example, if the program had some method of checking its last few moves, it could essentially say, "Hmmm, I seem to be cycling between the same two action sequences, perhaps I should try something else and see if that gets me out of this jolly awkward predicament".

Not that we're going to tell you how to do this, you understand – we've got too much new stuff to be getting on with. The only reason we're mentioning this here is that we thought that you might be desperately looking for something to do this coming weekend . . .

**Listing 1**

```
### Start of Constant Declarations
LSENSORS: .EQU $F011          # Light Sensors
MGRAPH:   .EQU $F030          # Motor bargraph display
TGRAPH:   .EQU $F031          # Timer bargraph display
MCONTROL: .EQU $F032          # Motor controller board
DELCONST: .EQU $0C            # Delay constant value
STOP:     .EQU %00000000      # Stop motors
FORWARD:  .EQU %00001010      # Go forward
SPIN_CW:  .EQU %00000110      # Spin clockwise
SPIN_ACW: .EQU %00001001      # Spin anticlockwise
_1sec:    .EQU 10             # Delay = 1 second
_10cm:    .EQU  5             # Delay = 10 centimeters
_30deg:   .EQU  2             # Delay = 30 degrees
_60deg:   .EQU  4             # Delay = 60 degrees
_90deg:   .EQU  6             # Delay = 90 degrees
_120deg:  .EQU  8             # Delay = 120 degrees
_150deg:  .EQU 10             # Delay = 150 degrees
_180deg:  .EQU 12             # Delay = 180 degrees
### End of Constant Declarations

### Start of main program initialization
          .ORG   $4000        # Start of program
           BLDSP $4FFF        # Load stack pointer
### End of main program initialization

### Start of Main Program Body
### End of Main Program Body

### Start of Subroutines
### End of Subroutines

### Start of Temp Locations and Data Values
GOFLAG:   .BYTE  $01             # Flag (0=stop, 1=go)
TVALUE:   .BYTE                  # Main timer temp value
TEMPX:    .2BYTE $0000           # Temp index register
### End of Temp Locations and Data Values
          .END
```

## COMING INTO THE LIGHT

But we digress . . . In Alan Winstanley's construction article in this issue, he describes how to use a set of six light-dependent resistors (l.d.r.s) as the basis for a rudimentary optical sensor for the PhizzyBot.

For our part, we are going to create a simple program that utilizes this optical sensor to make the PhizzyBot act the role of a "MothBot". That is, a Bot that's attracted to the light from a torch (or a flashlight as they would have it in the vernacular of the good old US-of-A, which is where we Phizzy authors happen to find ourselves at this moment in time).

## SKELETON PROGRAM

As for last month, the first thing we're going to do is to create a skeleton (framework) program, which we'll develop as we go along. Invoke your PhizzyB Simulator, activate the assembler, and enter the program shown in Listing 1.

Note that the values you assign to the **_10cm**, **_30deg**, **_60deg**, and so forth labels to control your PhizzyBot may be different to the ones shown here, because the gearing of your motors and the size of your wheels may differ from ours (bounce back to the In a Spin section earlier for more details).

Before you do anything else, save this skeleton program as **ffxp1.asm**. Now consider the Constant Declarations section at the beginning of the program. The **LSENSORS** label will be used to associate our new light sensor device with the input port at address $F011 (so make sure you connect the little rascal to this port).

Next we're going to use the PhizzyB's on-board 8-bit l.e.d. bargraph display to indicate the value we're driving to the motors. Thus, we equate the **MGRAPH** label to the address of this output port, which is $F030.

As for last month, we're also going to connect the 8-bit l.e.d. bargraph display we created in Part 2 (Dec '98) to the output port at address $F031, and then use this to reflect the current value in the timer. Thus, we equate the **TGRAPH** label to the address of this output port.

Also, we're going to connect our motor controller board from Part 5 (Mar '99) to the output port at address $F032. Hence the **MCONTROL** declaration.

The **DELCONST** label, which is used to persuade our timing subroutine to loop around for 1/10 of a second, is assigned a value of $0C (12 in decimal). (We determined the value of **DELCONST** by trial and error as discussed in Part 5).

The **STOP**, **FORWARD**, **SPIN_CW**, and **SPIN_ACW** labels are assigned values that can be used to control the PhizzyBot's motors so as to stop the Bot, drive it forward, spin it clockwise, or spin it anticlockwise, respectively. Ideally we would use the multi-label approach we introduced last month; assigning these values directly is a "quick and dirty" solution, but it serves our purposes here.

The remaining constant declarations (**_1sec**, **_10cm**, **_30deg**, **_60deg**, and so forth) have been discussed in excruciating detail above. The rest of the skeleton program consists of two initialization statements, the reserving of some temporary locations, and some comments, all of which have been discussed into the ground earlier in this series. So, without further ado, let's leap into the fray!

## TIMER SUBROUTINES

In a moment we're going to leap into the really interesting stuff, but before we do we need to add the timer routines shown in Listing 2 (add these between the "Start and End of subroutines" comments in the skeleton program).

These routines are exactly the same as last month, so we won't spend any time discussing them here. The only point to note is the test of the **GOFLAG** label at the beginning of the **TIMER** routine. We really aren't going to have any use for the **GOFLAG** label this month, but we will leave it (and the test) where it is, because we don't want to do anything to affect the delays in the **TIMER** routine. Note that we pre-assigned a value of $01 (the "go" value) to the **GOFLAG** location when we declared it at the bottom of Listing 1, so we won't have to concern ourselves with this flag anymore.

## SIMPLE TEST PROGRAM

Before you do anything else, make sure that the new light sensor device is plugged into the PhizzyB's input port at address $F011. Also ensure that this device is oriented on top of the PhizzyBot such that the l.d.r. driving bit IP0 of the input port is pointing towards the front of the Bot (Fig.1).

Now, add the following statements between the two comments saying Start and End of main program body in your skeleton program:

**Listing 2**

```
#== Start of "Main Timer" Routine
TIMER:      STA    [TVALUE]       # Store original count
TLOOPA:     JSR    [ONETENTH]     # Call 1/10 Sec loop
            LDA    [GOFLAG]       # Load flag
            JZ     [TRETURN]      # Jump if flag=0
            LDA    [TVALUE]       # Load count value
            DECA                  # Decrement it
            STA    [TVALUE]       # Store it
            STA    [TGRAPH]       # Store it to LEDs
            JNZ    [TLOOPA]       # Loop again if !=0
TRETURN:    RTS                   # Exit subroutine
#== End of "Main Timer" Routine

#== Start of "1/10 Second" Routine
ONETENTH:   LDA    DELCONST       # Load count value
OTLOOPA:    DECA                  # Decrement it
            JNZ    [OTLOOPA]      # Loop again if !=0
OTRETURN:   RTS                   # Exit subroutine
#== End of "1/10 Second" Routine
```

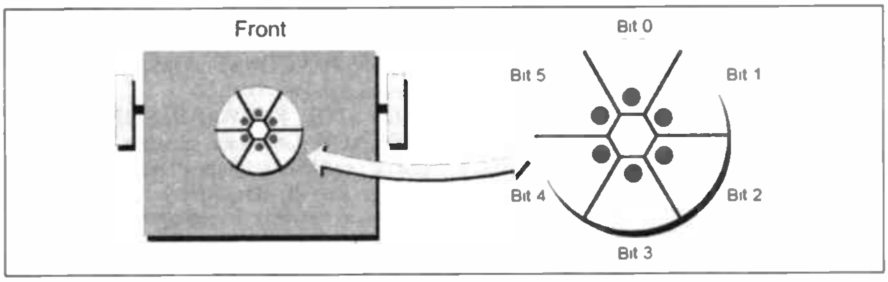



*Fig.1. Ensure that the l.d.r. driving port bit IPO is pointing towards the front.*

```
LOOP:     LDA [LSENSORS]
          AND %00111111
          STA [MGRAPH]
          JMP [LOOP]
```

All this program does is to loop around reading from the port connected to the light sensors and writing to the 8-bit l.e.d. bargraph display connected to output port $F030 (label **MGRAPH**) on the PhizzyB. However, it is worth taking special note of the AND instruction, which is used to "mask out" the top two (unused) input port bits and force them to zero values.

The way the sensor circuits work is that if an l.d.r. is not illuminated it will have a high resistance, so the tap (connection) point between the 22kΩ resistor and 10kΩ potentiometer will be pulled up towards a logic 1 (+5V) value. This will be inverted by IC1 to present a logic 0 to the input port.

Similarly, if an l.d.r. is illuminated, its resistance will fall and the tap point will be pulled down towards a logic 0. This, in turn, will be inverted by IC1 to present a logic 1 to the input port. The end result is that any of the l.d.r.s that are illuminated will be "seen" as logic 1 values by the PhizzyB.

In order to test this, assemble your program, download the resulting **ffexp1.ram** file to the PhizzyB, and set the program running. Assuming that you've calibrated the sensors as described in Alan's constructional article, then all of the l.e.d.s on the bargraph display should initially be off. Now shine a light at each of the l.d.r.s in turn, and ensure that the corresponding l.e.d. lights up.

(Note that even if you don't have a real PhizzyB and PhizzyBot, you can still perform all of the experiments described in this article on the PhizzyB Simulator by presenting the appropriate values to input port $F011 and observing the results.)

When you've satisfied yourself that everything is working as it should, reset the PhizzyB (and/or the PhizzyB Simulator) and proceed to the next section.

## BLINDED BY THE LIGHT

Although you may not have fully appreciated this, the way in which we implemented last month's "Collision Detection" program was based on the assumption that only one microswitch would be triggered at a time. However, in the case of our new light sensor device, it is more than possible for multiple l.d.r.s to be activated simultaneously (Fig.2).

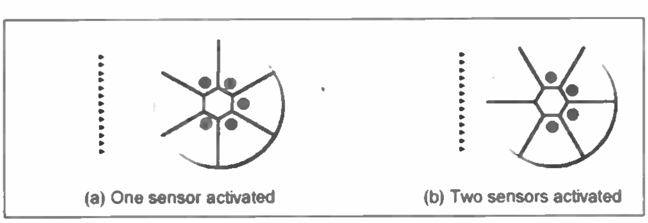



*Fig.2. Multiple l.d.r.s may be activated simultaneously.*

This article is based on the assumption that either one sensor will be activated as shown in Fig.2a, or two adjacent sensors as shown in Fig.2b. However, depending on how you construct your sensor housing (including the positioning of the sensors and the lengths of the internal dividing "spokes"), it might be possible for your torch (flashlight) beam to activate one, two, or even three adjacent sensors.

In fact, we also have to consider the fact that stray light beams from external sources may activate one or more sensors (e.g. the sun shining through a window). And it's not beyond the bounds of possibility that a prankster may be sabotaging your experiments by surreptitiously shining their own light source at the PhizzyBot from behind the sofa . . .

So although we're only going to focus on the cases involving one or two (adjacent) sensors, our program has to accommodate the fact that any combination of l.d.r.s may be illuminated. As we have six sensors, and each may be in one of two states (On or Off), we actually have $2^6 = 64$ different patterns of 0s and 1s to deal with. (This is one reason why we didn't use eight sensors, because we didn't want to have to contend with $2^8 = 256$ different patterns). But fear not, because this isn't going to be as tricky as you might suspect . . .

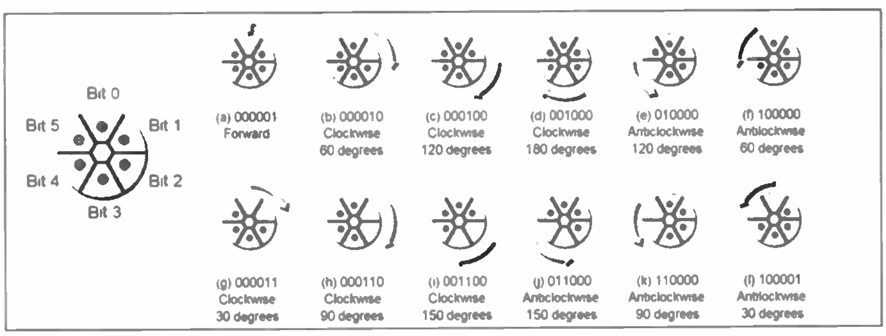



*Fig.3. All 12 of the one and two (adjacent) active sensor cases.*

## $2^6$ = 64 EEEKKK!

The first thing we need to do is to create 64 labels just before the "End of Temp Locations and Data Values" comment in Listing 1. Each of these labels will commence with the characters "LS" (standing for "light sensors") followed by a 6-bit binary code. Each label will also be followed by a .BYTE statement and associated values as shown in Listing 3 (we'll discover the purpose of these values in the not-so-distant future).

**Listing 3**

```
##543210 # Bit numbers
LS000000: .BYTE STOP, _1sec # Stop & wait
LS000001: .BYTE STOP, _1sec # Stop & wait
LS000010: .BYTE STOP, _1sec # Stop & wait
LS000011: .BYTE STOP, _1sec # Stop & wait
    :          :      :          :
LS111101: .BYTE STOP, _1sec # Stop & wait
LS111110: .BYTE STOP, _1sec # Stop & wait
LS111111: .BYTE STOP, _1sec # Stop & wait
### End of Temp Locations and Data Values
```

As we see from this listing, the binary codes associated with these labels follow a standard binary count sequence. This should be easy enough, but just in case you're a little unsure, here's a simple trick you can use to create these entries.

Start off by entering the first line for label LS000000 (including the .BYTE STOP, _1sec portion), then copy this line 64 times. In order to edit these 64 lines such that they reflect a binary count, commence by making the least-significant (bit 0) column alternate between 0 and 1, for example:

**LSxxxxx0:** etc
**LSxxxxx1:** etc
**LSxxxxx0:** etc
**LSxxxxx1:** etc
**LSxxxxx0:** etc
**LSxxxxx1:** etc
etc

Now make the bit-1 column alternate between two 0s and two 1s, for example:

**LSxxxx00:** etc
**LSxxxx01:** etc
**LSxxxx10:** etc
**LSxxxx11:** etc
**LSxxxx00:** etc
**LSxxxx01:** etc
etc

Continue with the bit-2 column alternating between four 0s and four 1s; the bit-3 column alternating between eight 0s and eight 1s; the bit-4 column alternating between sixteen 0s and sixteen 1s; and finally the bit-5 column starting with thirty-two 0s and ending with thirty-two 1s (phew!).

In reality our program only needs the first of these labels as we'll see. The other labels are intended for us so that we can see what we're doing.

## WHICH WAY TO TURN?

As we previously noted, we're only going to focus on the cases where one or two (adjacent) sensors are activated (Fig.3.)

As there are 360 degrees in a circle, each of our six sensors is responsible for a 60-degree

### Listing 4

```
LS000001: .BYTE FORWARD,    _10cm
LS000010: .BYTE SPIN_CW,    _60deg
LS000011: .BYTE SPIN_CW,    _30deg
LS000100: .BYTE SPIN_CW,   _120deg
LS000110: .BYTE SPIN_CW,    _90deg
LS001000: .BYTE SPIN_CW,   _180deg
LS001100: .BYTE SPIN_CW,   _150deg
LS010000: .BYTE SPIN_ACW,  _120deg
LS011000: .BYTE SPIN_ACW,  _150deg
LS100000: .BYTE SPIN_ACW,   _60deg
LS1J0001: .BYTE SPIN_ACW,   _30deg
LS110000: .BYTE SPIN_ACW,   _90deg
```

### Listing 5

```
LOOP: LDA  [LSENSORS]      # Load ACC from sensors
      AND  %00111111       # AND to mask unused bits
      SHL                  # Shift ACC left 1 bit
      STA  [TEMPX+1]       # Store to LS byte of X
      BLDX [TEMPX]
      LDA  [LS000000,X]    # Get action
      STA  [MGRAPH]        # Store to LEDs
      STA  [MCONTROL]      # Store to motor control
      INCX                 # Increment index reg
      LDA  [LS000000,X]    # Get delay
      JSR  [TIMER]         # Call timer subroutine
      JMP  [LOOP]          # Do it all again
```

arc. If only the forward (bit 0) sensor is active, we want the PhizzyBot to trundle forwards (Fig.3a). If only the bit 1 sensor is active (Fig.3b), we want the PhizzyBot to spin clockwise for 60 degrees, which should suffice to align the bit 0 sensor with the light source again. And so forth for the remaining one-sensor cases.

Similarly, if both the bit 0 and bit 1 sensors are active (Fig.3g), and if we assume that the light source is located exactly between them, then we want the PhizzyBot to spin clockwise for 30 degrees, which should serve to bring the bit 0 sensor in line with the light source once more. And so forth for the remaining two-sensor cases.

Fortunately, we've already got everything in place to easily accommodate these requirements. All we have to do is to modify the assignments to the twelve labels associated with these cases as shown in Listing 4.

## MAIN PROGRAM BODY

Delete our earlier test program statements from between the two comments saying "Start and End of main program body", and replace them with the code shown in Listing 5. Unlike last month, this program is going to be "easy-peasy!"

As we see, the main loop for this program is really small. First of all we read the value on the sensors and store it in the accumulator. Next we use an AND instruction to mask out the two MS bits, which aren't connected to any sensors (this masking operation ensures that these two bits don't confuse us with unexpected values).

We know that each of our **LSxxxxxx** labels has two bytes associated with it, so we shift the value in the accumulator left one bit, which is the same as multiplying it by two (this technique was discussed in the bonus article accompanying Part 3).

Now this is the cunning part, because we save this "Sensor × 2" product in the LS byte of our 2-byte **TEMPX** value, then we use a **BLDX** instruction to load this value into our index register. Next we use an indexed addressing mode instruction **LDA [LS000000,X]**. This loads the accumulator with the data byte it finds at the address calculated by adding the address of label **LS000000** with the contents of the index register.

As an example, let's assume that the pattern read from the sensors was 000110 (6 in decimal). Shifting this left results in 001100 (12 in decimal). Remember that each of our **LSxxxxxx** labels has two bytes associated with it, so adding a value of 001100 to the address of label **LS000000** will give us the address of label LS000110, which is what we wanted in the first place. (We know that this seems a bit convoluted at first, but once you've wrapped your brain around it, you will come to realize that this is actually rather elegant . . . or not as the case might be.)

We know that this first data byte is a "motor control action", so we store it to the l.e.d.s displaying the state of the motors and also to the output port driving the motor controller device.

We now increment the index register, load the next data byte (which is the "delay"), and jump to the **TIMER** subroutine to wait for this delay to time out. Finally we jump back to the beginning of the loop and do it all again.

If you return to the **LSxxxxxx** labels, you can now see that whenever no sensors are active (or if an unexpected combination is active), the program will simply stop the motors and wait for a second. After this short delay, it will recheck the sensors to see if anything has changed.

Thus, when left to "roam wild and free", the PhizzyBot should hunker down and wait for you to shine a light at it. As soon as it "sees" the light, it should spin around to orient itself towards the light and race towards it. If the light should be extinguished, the PhizzyBot will stop where it is and wait for the light to reappear.

Save this new program as **ffexp2.asm**, assemble it, download the resulting **ffexp2.ram** file to your PhizzyBot (or load it into your PhizzyB Simulator) and experiment away with gusto and abandon!

## MORE PRECISION

One thing that may have struck you is that the "visual resolution" of the PhizzyBot leaves something to be desired. This is because we only have six sensors, each of which handles a 60-degree field of view (Fig.4).

This means that our program as described above can't guarantee that the PhizzyBot will trundle directly towards a light source. Instead, the PhizzyBot may initially head off at a slight tangent until the light hits a second sensor, at which point the PhizzyBot will detect its error and attempt to correct it (Fig.5).

Suppose we wanted to make the PhizzyBot more accurate using just these six sensors – how could we do this? Well first of all we'd have to modify our **TIMER** subroutine to measure smaller units of time. For example, we know that 1/10 of a second equates to the PhizzyBot spinning approximately 15 degrees. Thus, if we could time delays in 1/100 of a second increments, then the PhizzyBot could be instructed to spin in increments of 1·5 degrees.

Of course our current subroutine has a maximum delay of 255 × 1/10 of a second, which equals 25·5 seconds. If we started counting in 1/100 of a second, our maximum delay would only be 2·55 seconds, which would be somewhat limiting. One way around this would be to use two bytes to specify the delay. Two bytes can represent 0 through 65,535 in decimal, which gives us a maximum delay of 65,535 × 0.01 seconds = approximately 655 seconds (almost 11 minutes), which should be more than enough for our purposes.

Assuming that we had the ability to time in 1/100 second intervals, then we could use this to improve the "visual resolution" of the PhizzyBot. When a light was first detected, we could spin the PhizzyBot until its bit 0 sensor was activated. Next we could spin the PhizzyBot clockwise in 1·5 degree increments until the bit 0 sensor went inactive and/or the bit 5 sensor became active. This gives us one "end" of the bit 0 sensor's field of view.

Next we could spin the PhizzyBot anticlockwise in 1·5 degree increments using the bit 0 and bit 1 sensors to detect the other end of the bit 0 sensor's field of view. Our program could count how many 1·5 degree

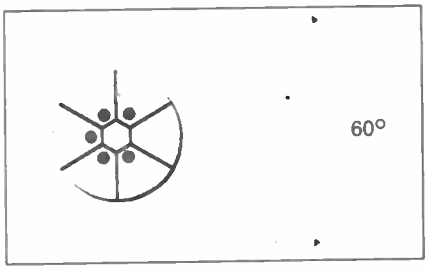



*Fig.4. Each sensor covers a 60-degree arc.*

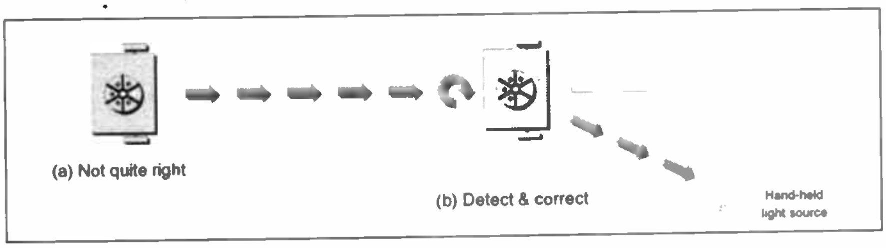



*Fig.5. The program may "hunt and seek" a little.*

increments it took to go from one end to the other. Now all we would have to do would be to spin the PhizzyBot clockwise for half of this number, which should leave it pointing almost directly at the light source.

### MOTHBOT VERSUS ROACHBOT

Our program has so far focused on making the PhizzyBot act the role of a MothBot that's attracted to the light. Another simple experiment you could perform would be to modify this program such that it now acts like a RoachBot that scurries away from the light and furtively tries to hide itself away in dark places.

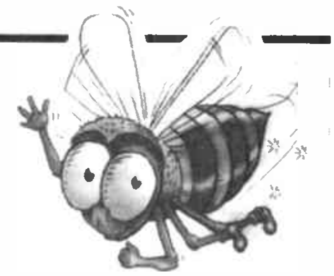
Now what we'd like you to do is to combine the program we've just discussed here with the program from last month (Part 6). Your mission (should you decide to accept it) is to create a program that allows the PhizzyBot to meander around the room bumping into things and responding appropriately. But as soon as it "sees" a light source, it should stop whatever it was doing and hurl itself towards the light at full pelt.

### NEXT MONTH

Sad to relate, next month is the final issue in this PhizzyB series (little tears are rolling down our cheeks as we pen these words and our lower lips are all aquiver). But turn that frown upside down into a smile, because in the final issue we'll be discussing all sorts of exciting experiments you can perform with your PhizzyB Simulator, PhizzyB, and PhizzyBot, plus we'll be inviting you to contribute your own input/output device suggestions to the *Ingenuity Unlimited* column.

So "keep on trucking" with your PhizzyBot, and we'll be with you again next month.

## Understanding Computers



# PhizzyB COMPUTERS

## Construction – PhizzyBot Eyes

Alan Winstanley

*Six eyes give PhizzyBot a whole new view of the world and open up a range of possibilities.*

LAST month we described a simple method of adding "feelers" to the PhizzyBot computer-controlled motorised platform. By using a series of microswitches around the periphery of the PhizzyBot, it can detect the presence of an obstacle and, under the control of a computer program, the PhizzyBot can avoid it by spinning, turning or reversing.

As usual, the control program was fully detailed in the Tutorial, and it could be developed and refined on a Windows-compatible PC using the PhizzyB Simulator software on CD-ROM: the PhizzyB is programmable via the PC's serial port and programs can be uploaded to the PhizzyB in a trice. Many of the demonstrations could also be followed on-screen without the use of the hardware PhizzyB, although you'll be missing a heck of a lot of good fun in the process!

### PRACTICALLY FINAL

This month sees the final practical project related to the unique PhizzyB Computers series. In the accompanying tutorial article, Max and Alvin describe further techniques related to controlling the direction and travel of the PhizzyBot buggy. We show how the computer program used by the PhizzyBot can be refined to offer a greater degree of control of the PhizzyBot's motorised movements.

One further tutorial will be presented next month to "wrap" the series and then it is hoped that readers will develop further applications, circuitry and programs for the powerful PhizzyB computer.

Apart from "doing your own thing", readers may rest assured that help will continue to be available to those picking up this series for the first time, even when the published series has drawn to a close. You can write to the authors c/o the Editorial address or by E-mail – see the details at the end of this article.

### MULTIPLE EYES

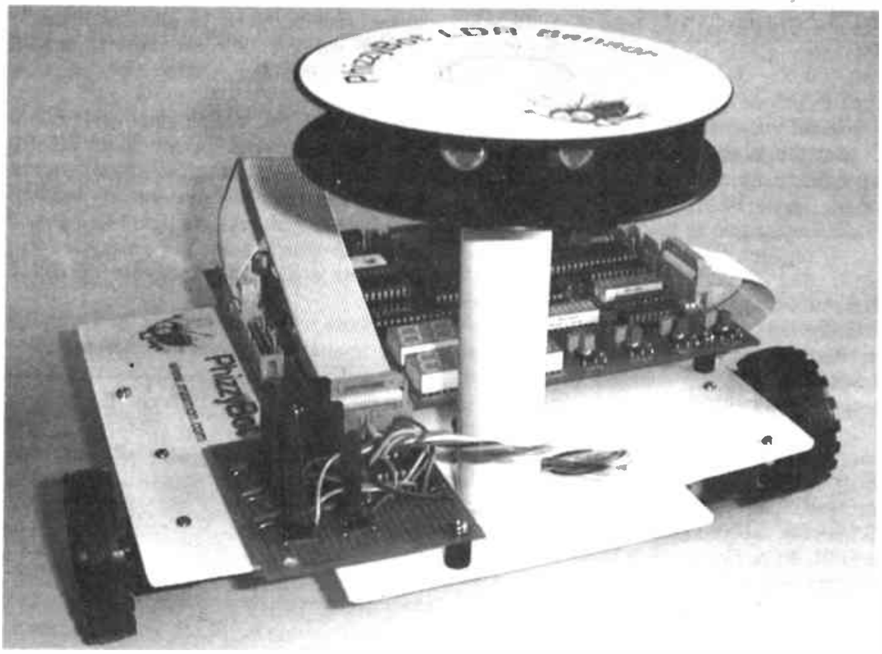
The constructional details which follow describe the addition of an array of light-dependent resistors (l.d.r.s) which are used to provide the PhizzyBot with "eyes". This addition can be used to demonstrate how the PhizzyBot, with the aid of a suitable computer program, can be made to react when it detects a source of light.

It also demonstrates the principles of how the PhizzyBot can in general be made to respond to externally-generated control signals – whether by being attracted to a stimulus or, indeed, by recoiling away from it! This opens up new possibilities for applying a PhizzyBot in a number of computerised control systems – perhaps as a white line follower, or a buggy armed with magnetic detectors (or Hall Effect switches) which follows an "invisible" metal stripe buried in the carpet underneath.

All it requires is a simple input device, such as the light-sensitive type described next, and an appropriate computer program to help the PhizzyB make sense of it all.

### ALL-ROUND VIEW

The light-dependent resistor array described in the main feature consists of



six photo-conductive cells coupled to a series of electronic switches. A common NORP12-type l.d.r. is used which has a resistance of several megohms in darkness, this falls to a few hundred ohms under bright conditions.

The tutorial article describes the very cunning way in which the six devices are arranged around a hexagon, and by separating each l.d.r. from its neighbour using a divider, a 360 degree field of view can be created. The hexagon arrangement is sandwiched between two discs to make the unit "directional".

It is designed such that either one or two l.d.r.s can be illuminated at any one time by a source of light, and this can be decoded by the computer program to enable the PhizzyB to "know" the direction from which the light is being emitted.

The assembly of the l.d.r. sensor falls into two parts: an interface board which connects to a PhizzyB input port, plus the construction of the hexagonal array itself. Now here's an opportunity to have some fun and practise one's model engineering skills once again!

The building of the optical sensor and circuit is straightforward and somewhat easier than some of the more ambitious I/O circuits presented in earlier parts of the series.

## SENSOR CIRCUIT

Circuit diagram details for of the l.d.r. sensor are shown in Fig.1. All six sensors use an identical circuit based on a Schmitt inverter. A Schmitt-triggered device is one which converts a slowly-moving signal to a rapid "snap action" on-off voltage, whilst an inverter merely outputs a logic state opposite to that of the input signal so a "low" voltage is inverted to a logic "high".

In the circuit diagram, an l.d.r. and a variable trimmer resistor (potentiometer) are used with a fixed "pull up" resistor to produce a potential divider. In the case of the first digital bit, based around LDR0 and IC1a, when light falls upon the l.d.r., its resistance will fall, which may take a short time because an l.d.r. has a relatively slow response.

In order to generate a clean on-off signal (i.e. a fast pulse edge) this is converted by the Schmitt inverter IC1a. The voltage at pin 1 of IC1 is sent by the l.d.r. towards 0V. A point will be reached where the inverter will suddenly detect a low input signal. Consequently, a logic 1 is sent from pin 2 to IP0 of the PhizzyB input port at pin 19.

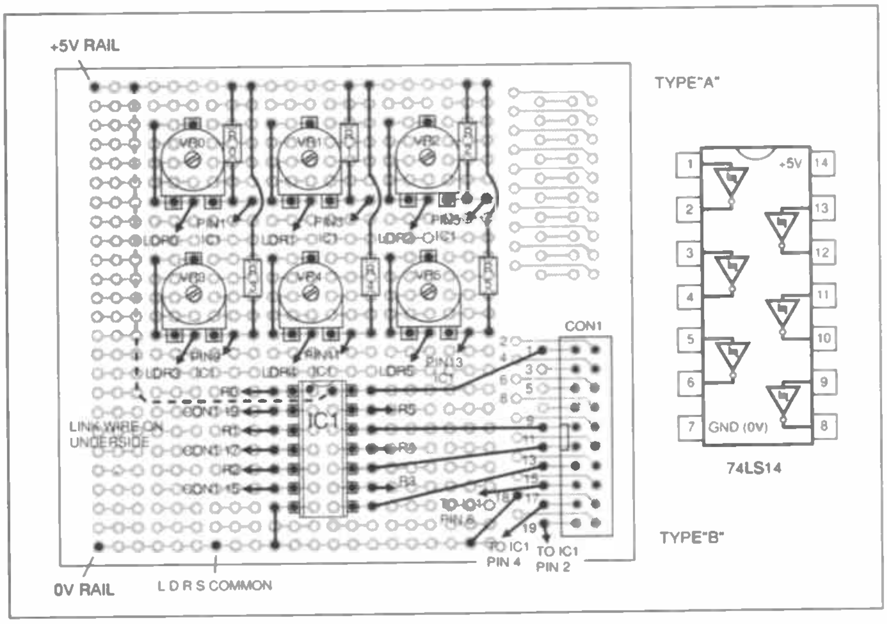



*Fig.2. The presets and hex inverter are mounted on the board, but the sensors are wired off-board.*

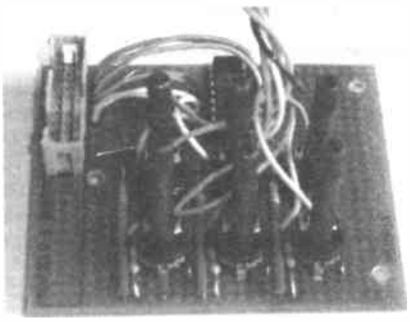
This arrangement is repeated for the five remaining l.d.r.s, each having its own trimmer resistor and outputting via a Schmitt inverter gate to the PhizzyB input port. The trimmer resistor (preset) is used to enable some adjustment of the triggering point for each l.d.r., also allowing the user to compensate for ambient light conditions.

## EYES OFF THE BOARD!

In Fig.2 is shown the layout of all the "eyesight" components, mounted on one half of a PhizzyB I/O board, with the exception of the six l.d.r.s which are mounted externally. Commence construction by soldering the trimmer resistors and i.c. socket into place to act as a reference, then complete all interwiring as shown. On the prototype, extension spindles were used for the trimmer resistors to make adjustment and setting up more convenient.

The component layout should be followed closely, noting that three resistors (R3 to R5) should be insulated with PVC sleeving or similar to prevent shorting to nearby flying leads. A single link wire is soldered on the underside of the board as indicated, and both tinned copper wire and general-purpose hook-up wire can be used for the jumper wires.

The wiring doesn't need to be very neat but it should be effective. It will prove very useful to use six different colours for the



jumper leads which connect to IC1 and CON1, in order to identify the six connections IP0-IP5. The same colours should be used in relation to the l.d.r. assembly, described next. Hence, use six colours to identify the wiring of each "channel".

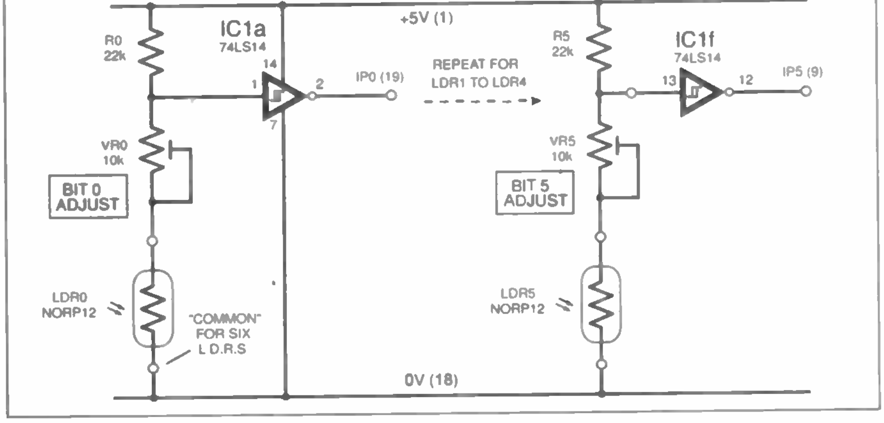



*Fig.1.Circuit diagram for the optical sensors.*

## COMPONENTS

**Resistors**
R0 to R5 — 22k (6 off)
All 0.25W 5% carbon film

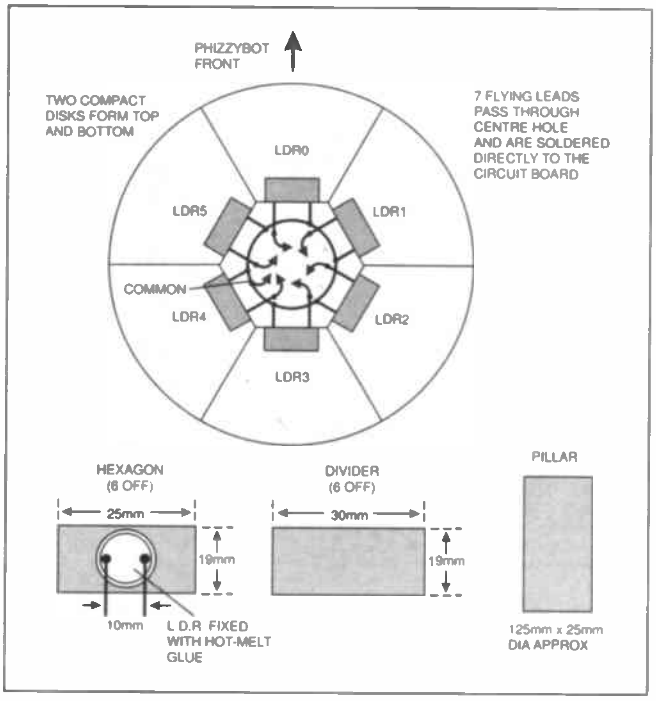
**Potentiometers**
VR0 to VR5 — 10k min. horiz. preset (6 off) with extension spindles (see text)

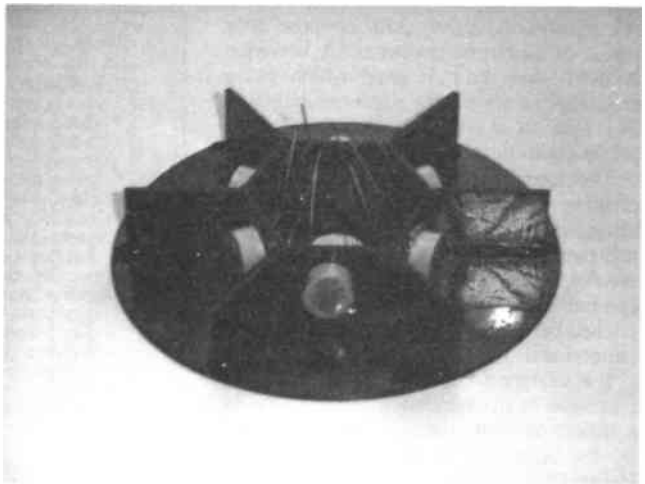
**Semiconductors**
LDR0 to LDR5 — NORP12 (or ORP12) light-dependent resistor (6 off)
IC1 — 74LS14 hex Schmitt trigger inverter

**Miscellaneous**
CON1 — 20-way IDC box header

One half PhizzyB I/O board; 14-pin d.i.l. socket; hook-up wire (assorted colours); materials for l.d.r. assembly, including two CDs (see text); 20-way IDC connector cable.

**Approx.cost guidance only £15**



*Above: The l.d.r.s on their hexagonal disc.*

*Left: Fig.3. Showing how the l.d.r.s are arranged, plus the extra bits that are needed*

## OPTICAL DISCS

Two discs are used to sandwich the hexagonal arrangement of six light-dependent resistors. Rather than attempting to produce the discs from, say, plastic card, it was found that a pair of unwanted compact discs (e.g. outdated catalogue CDs – at last, a practical use for them!) proved admirable for this purpose.

The hexagonal centre and the six dividing pieces can be cut from plastic available from model shops, and the approximate dimensions are shown in Fig.3. Note that two holes (10mm apart and approximately 1mm diameter) are required in each hexagon face to carry an l.d.r., so drill these next. File all edges so that they are reasonably square and level.

Use a felt tip pen to mark out the layout on the lower CD. The six centre pieces can then be glued to the shiny side (glue may not adhere to the printed side) of the CD to form the hexagon. Hot-melt glue is perfect for this, but any general-purpose plastic cement or super glue could be used (CDs being made of polycarbonate which glues readily).

When the glue has set, the surface of the resulting assembly should be spray-painted black (preferably matt) using cycle or car aerosol touch-up paint. The paint will help prevent unwanted reflections and stray light from "confusing" the PhizzyBot light sensor array, which might otherwise generate erroneous signals. The other CD which will fit on top should also be spray painted on both sides.

The six light-dependent resistors should then be glued to the faces of the hexagon by feeding their leads through the plastic, scraping off any paint prior to gluing.

## FLYING LEADS

Manipulate one wire of each l.d.r. to join them all together within the hexagon, and solder these together as one large joint, to create a common rail for all the l.d.r.s. A single flying lead (approximately 230mm) should then be soldered to this common rail and fed out through the centre hole in the disc. This will ultimately be wired to 0V on the circuit board.

Solder six more flying leads, one to each remaining l.d.r. leadout. It is very important that you are able to identify the l.d.r. used for Bit 0 because this must face forwards when fitted to the PhizzyBot. Perhaps mark the underside of the disc with a felt-tip pen or label, to indicate which l.d.r. is Bit 0.

Six 230mm flying leads should then be soldered to the remaining leads of each l.d.r., using a coloured wire to correspond with the wiring scheme used on the circuit board: this is necessary to identify each digital bit once the l.d.r. assembly is complete (refer also to the diagrams in the main tutorial article at this point).

Feed each wire out through the centre hole in the disc. The second disc can then be glued on top, using hot melt glue which hides a multitude of sins as far as accuracy and alignment is concerned! Obviously, once the l.d.r.s are sealed into position like this, the only way of identifying which l.d.r. signal is which, will be to refer to the colour-coded wires.

## HOT WIRED

The final aspect is to mount the completed l.d.r. array on a form of "pillar" which will raise it above the PhizzyBot platform. Some resourcefulness may be needed! The prototype used a plastic plunger from a small empty silicone sealant "syringe" which proved ideal at about 130mm high and 25mm diameter. On the prototype, the seven wires were fed through the middle and the tube was then glued to the underside of the discs using more hot-melt glue.

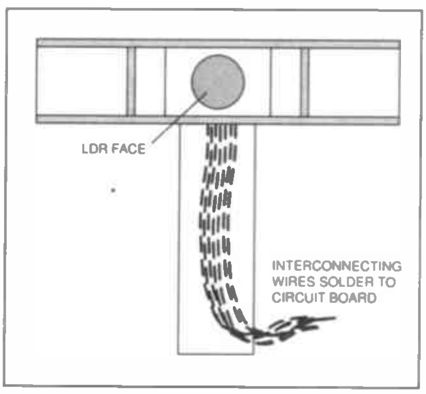



*Fig.4. Sideways view of the l.d.r. sandwich assembly.*

The seven flying leads can then be soldered directly to the circuit board, and the sequence of coloured wires should then be seen to follow all the way through from the l.d.r. directly to the PhizzyB input port connector. At this point, the final positioning of the circuit board and l.d.r. array should be determined, noting that a 20-way IDC lead is needed to connect CON1 to $F011, so locate the circuit board on the chassis so that the lead will reach: you can use one of the cables made in the earlier parts of the series.

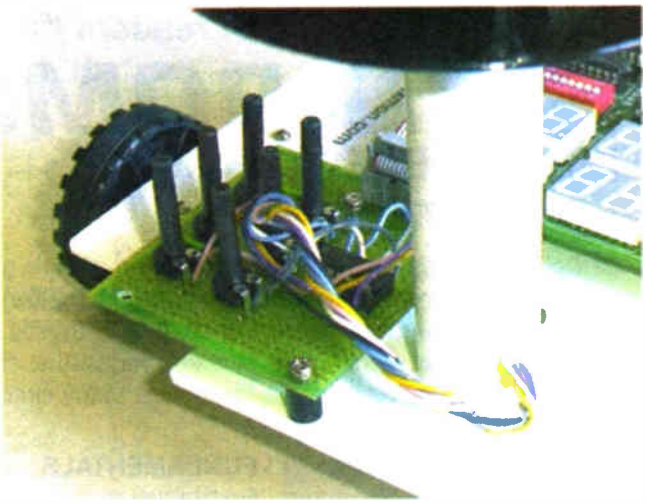
Lastly, the round pillar can be glued down onto the PhizzyBot chassis with hot-melt adhesive: remember that Bit 0 must point towards the front of the PhizzyBot. As a finishing touch, a decorative CD-ROM label was created and applied to the top disc. (Enterprising readers can fetch the Flying Bee logo from the Maxmon web site!) With the l.d.r.s now installed, the circuit board can be connected to $F011 and assembly is then complete.

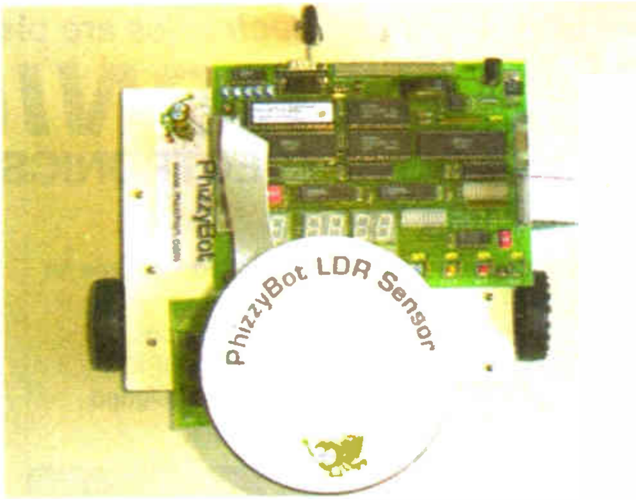
## SIGHT TEST

In order to test the photo-sensors, the on-board l.e.d. bargraph $F030 can be used along with the following test program to adjust the six trimmer resistors (VR0 to VR5) for ambient light and sensitivity. This is best carried out away from windows or any sources of direct light. Load the PhizzyBot with the following program:

```
LSENSORS:   .EQU $F011
LEDS:       .EQU $F030
            .ORG $4000
LOOP:       LDA [LSENSORS]
            AND %00111111
            STA [LEDS]
            JMP [LOOP]
            .END
```

This just loops around reading from the sensors plugged into input port $F011 and writes that value to the on-board bargraph. Shine a torch (flashlight) at the sensor array from across the room and "tweak" each






trimmer resistor until the sensor responds to it. The idea is to trim each variable resistor associated with each sensor to get an appropriate triggering point, such that the associated l.e.d. isn't always on or off, nor is it always on with "standard" ambient light, but it is only on when a torch is shone at the corresponding opto-resistor. Move the torch around the l.d.r. array and watch each light-emitting diode respond in sequence.

## GREAT PhizzyBILITY!

With construction and set-up finally complete, the control program can now be uploaded from the PhizzyB Simulator link software, the motors can be switched on and the PhizzyBot can be set loose.

It will be recalled that the motors use a 6V rechargeable power pack and the PhizzyBot itself can run in a completely independent mode by powering it from a 9V Ni-Cad rechargeable battery instead of a mains power supply; this permits the platform to roam around the floor and gradually move towards the source of light.

It may well prove necessary to adjust the computer program to compensate for different motor speeds and wheel diameters, so you must be prepared to experiment in order to improve the response of the PhizzyBot.

## FAR-SIGHTED

This concludes the practical constructional articles which have accompanied our exclusive *PhizzyB Computer Tutorial*. One objective of the series is to stimulate further thought, and we hope you will be moved sufficiently to develop other forms of simple input sensors so that the PhizzyBot platform can be adapted to respond to other sources of stimuli.

For example, two l.d.r.s or infra-red opto-switches could be fixed to the front of the PhizzyBot to produce a simple white-line following buggy. Thermistors (thermally-sensitive resistors) could be used in place of NORP12s so that a PhizzyBot could respond to sources of heat. Hall-effect devices generate an electrical signal in response to magnetic fields and this could form the basis of a metallic stripe follower.

The PhizzyB single-board computer can also be embedded into other systems, and the CD-ROM software will be of great assistance in developing routines in a virtual environment prior to uploading them onto a real hardware PhizzyB.

## NEXT MONTH

Next month, Max and Alvin conclude the series by suggesting other applications for the PhizzyB. Readers who wish to develop their programming skills further will find *The Official Beboputer Microprocessor Data Book* a "must" remembering that PhizzyB actually stands for Physical Beboputer and it provides a unique way of developing programs on-screen using the PhizzyB Computer Simulator software before uploading programs onto the real PhizzyB hardware.

The Data Book can be purchased on-line for a very modest cost. The Maxfield & Montrose web site (**www.maxmon.com**) contains ongoing information, updates and links.

Lastly, remember that Max loves to hear from you by E-mail and you can contact him via the Maxmon web site. Readers with queries concerning the constructional aspects can write to Alan Winstanley, c/o the Editorial address, or via E-mail to **alan@epemag.demon.co.uk.** We hope you have enjoyed constructing and using your Physical Beboputer.

*Everyday Practical Electronics* are pleased to be able to offer all readers these

# ELECTRONICS CD-ROMS

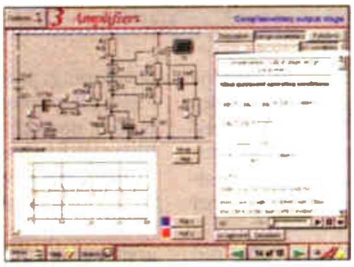
NEW

## ANALOGUE ELECTRONICS
### *by Mike Tooley*

*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.

**FUNCTIONS**

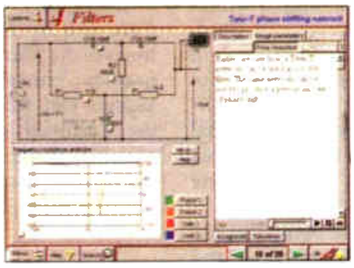
The component values on all circuits can be edited and the user can use the simulation engine to see how the value of each component affects circuit performance. You can, for instance, alter frequency and phase angle and plot outputs on a virtual oscilloscope or show load line graphs etc.



Complimentary output stage.

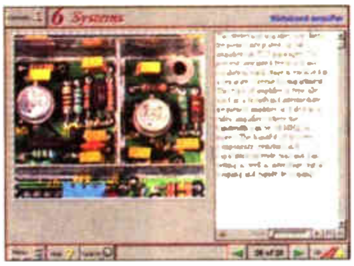
**COVERAGE**

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.



Twin-Tphase shifting network

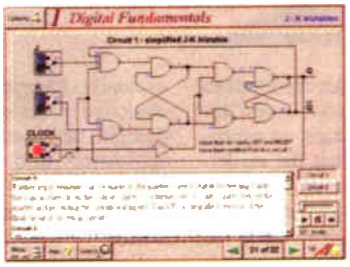
- **Includes SPICE circuit simulator with over 50 circuits**
- **Unique virtual laboratories**
- **Editable assignments**
- **Design parameters for circuits included**
- **Complete hi-fi amplifier case study**



Gallery – Wideband Amplifier

## DIGITAL ELECTRONICS
### *by Mike Tooley*

*Digital Electronics* builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (below), 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.



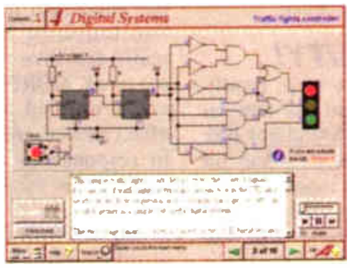
Virtual laboratory – Flip-Flops

**FUNDAMENTALS**

Fundamentals introduces the basics of digital electronics including binary and hexadecimal numbering systems, ASCII, basic logic gates and their operation, monostable action and circuits, and bistables – including JK and D-type flip-flops.

**COMBINATIONAL LOGIC**

Multiple gate circuits, equivalent logic functions and specialised logic functions such as majority vote, parity checker, scrambler, half and full adders. Includes fully interactive virtual laboratories for all circuits.



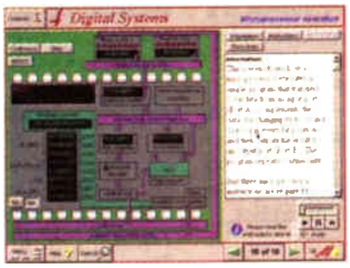
Virtual laboratory – Traffic Lights

**SEQUENTIAL LOGIC**

Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers.

**DIGITAL SYSTEMS**

A/D and D/A converters and their parameters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units.



Microprocessor

**GALLERY**

A catalogue of commonly used IC schematics taken from the 74xx and 40xx series. Also includes photographs of common digital integrated circuits and circuit technology.

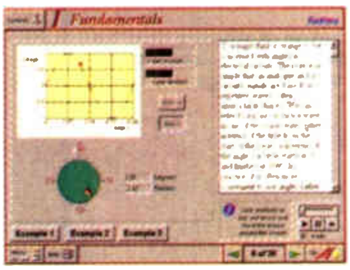
**Prices for each of the two CD-ROMs above are:**

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

TWO APPLICATIONS ON ONE CD-ROM

## ELECTRONIC CIRCUITS & COMPONENTS + THE PARTS GALLERY *by Mike Tooley*

*Electronic Circuits & Components* 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 as they proceed through the sections on the CD-ROM. Sections on the disk 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***



Virtual laboratory – sinusoids

*The Parts Gallery* – many students have a good understanding of electronic theory but still have difficulty in recognising the vast number of different types of electronic components and symbols.
*The Parts Gallery* helps overcome this problem: it will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.
Selections on the disk include: ***Components ,Components Quiz, Symbols, Symbols Quiz, Circuit Technology***

Hobbyist/Student ...................................£34 inc VAT
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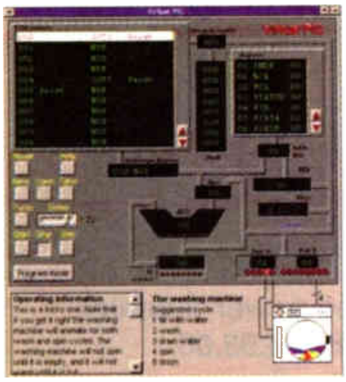
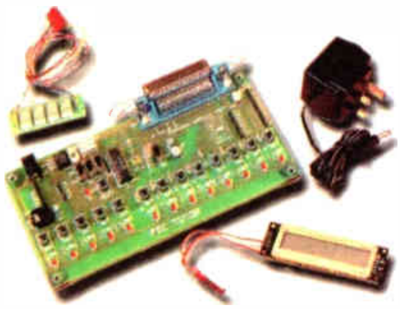
Circuit technology screen

## *Interested in programming PIC microcontrollers? Learn with* **PICtutor** *by John Becker*



The Virtual PIC



Deluxe PICtutor Hardware

Developed from John's *EPE* series, this highly acclaimed CD-ROM, together with the PICtutor experimental and development board, will teach you how to use PIC microcontrollers with special emphasis on the PIC16x84 devices. The board will also act as a development test bed and programmer for future projects as your programming skills develop. This interactive presentation uses the specially developed **Virtual PIC Simulator** to show exactly what is happening as you run, or step through, a program. In this way the CD provides the easiest and best ever introduction to the subject.
Nearly 40 Tutorials cover virtually every aspect of PIC programming in an easy to follow logical sequence.

**HARDWARE**
Whilst the CD-ROM can be used on its own, the physical demonstration provided by the **PICtutor Development Kit**, plus the ability to program and test your own PIC16x84s, really reinforces the lessons learned. The hardware will also be an invaluable development and programming tool for future work once you have mastered PIC software writing.
Two levels of PICtutor hardware are available – Standard and Deluxe. The Standard unit comes with a battery holder, a reduced number of switches and no displays. This version will allow users to complete 25 of the 39 Tutorials.
The Deluxe Development Kit is supplied with a plug-top power supply (the Export Version has a battery holder), all switches for both PIC ports plus l.c.d. and 4-digit 7-segment l.e.d. displays. It allows users to program and control all functions and both ports of the PIC and to follow the 39 Tutorials on the CD-ROM.
All hardware is supplied **fully built and tested** and includes a PIC16F84 electrically erasable programmable microcontroller.

### *PICtutor CD-ROM*
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**Institutional (Schools/HE/FE Industry) .......................£99 *plus* VAT**
**Institutional 10 user (Network Licence)...................£199 *plus* VAT**

### *HARDWARE*
**Standard PICtutor Development Kit .............................£47 inc. VAT**
**Deluxe PICtutor Development Kit ...............................£99 *plus* VAT**
**Deluxe Export Version ..................................................£96 *plus* VAT**
***(UK and EU customers add VAT at 17.5% to "plus VAT" prices)***

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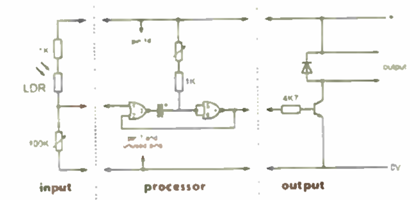
## MODULAR CIRCUIT DESIGN by Max Horsey and Philip Clayton

Developed from Max Horsey's *Teach-In* series *A Guide to Modular Circuit Design* (*EPE* Nov '95 to Aug '96). This highly acclaimed series presented a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects.
Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

**Single User Version £19.95 inc. VAT**
**Multiple User Version £34 *plus* VAT**

**designing your circuit**
simply select your modules from the wide choice available. read how they work and join them up to make your circuit




*"I found that I could design a circuit without my teacher's help. And it worked! Everything was to hand – which chips to use – and which pins did what"* Andrew Preston (GCSE student)

A Web Browser is required for Modular Circuit Design – one is provided on the *EPE CD-ROM No. 1* (see below) but most modern computers are supplied with one.

---

Minimum system requirements for these CD-ROMs: PC with 486/33MHz, VGA+256 colours, CD-ROM drive, 8MB RAM, 8MB hard disk space. Windows 3.1/95/98/NT, mouse, sound card (not required for *PICtutor* or *Modular Circuit Design*).

## CD-ROM ORDER FORM

**Please send me:**
- ☐ **Electronic Circuits & Components +The Parts Gallery**
- ☐ **Analogue Electronics**
- ☐ **Digital Electronics**
- ☐ **PICtutor**

- ☐ **Hobbyist/Student**
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- ☐ **PICtutor Development Kit – Standard**
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- ☐ **Modular Circuit Design – Single User**
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### ALL PRICES INCLUDE UK POSTAGE

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Demos (not Modular Circuit Design) available on the ***EPE CD-ROM No. 1*** (Free with the November '98 issue) – send £2 for this CD-ROM if you require the demos. For Modular Circuit Design demo send £6.95 for cut down version (£5 refunded if you buy full version). **Minimum order for** credit card payment is £5.

# READOUT

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

## WIN A DIGITAL MULTIMETER

The DMT-1010 is 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 DMT-1010 Digital Multimeter to the author of the best *Readout* letter.

## ★ LETTER OF THE MONTH ★

### RE-FUELING FOR THOUGHT

Dear EPE,

I write with regard to the *Fuel for Thought* letter in *Readout* April '99. Two years ago I retired from the Motor Industry Research Association (MIRA – **http://www.mira.co.uk**) where I was employed as a Technician Engineer. The letter(s) brought back some memories of technicians' "panic" solutions when a fuel gauge was found to be faulty at the last minute before testing:

- Use a dip stick – normally a long screwdriver
- Drop an old golf ball in the tank – it will rumble around when the fuel is low
- Tie a fishing line to a golf ball and hang 3/4 way down into tank – it will hit the tank when the level goes down by 3/4
- Fill the tank to the brim, zero trip meter and drive 10 to 12 miles. Fill tank to brim again and note the amount of fuel used. Zero trip meter again. Calculate mileage for 3/4 of a tank, from then on watch the mileage! (This is quite accurate as long as the driver is not changed!)
- "T" a polythene tube into the fuel line (before any fuel pump!) and use it as a sight glass. The tube needs a restriction, like a smaller diameter tube, near the "T" piece to dampen fuel movement (the end of the tube needs blanking when driving as carburation will take place with vehicle movement and can be *very* dangerous).

My proposed solution:

**Principle:** measure the "head pressure" of the fuel in the tank

**Method:** Use a low pressure piezo transducer (Maplin, RS, old engine management system), "T'd" into the tank or fuel line. Low-pass-filter the transducer output and use three comparators/l.e.d.s (3/4, 1/2, 1/4 full). I assume that when the tank is full and when it is empty will be known to the driver!

I believe that I am correct in saying that petrol is only 80 per cent the weight of water, so the pressures we are talking of are not high. At a depth of 300mm the pressure in water is approximately 0·3psi. This will not work if the fuel tank is pressurised, but is likely to be OK on a motor cycle.

On another subject – I hope you do not mind me criticising the "Next Month" paragraph on page 279 of the April '99 issue and written by the American authors, but do they realise that Europe, and most of the world, works in metric and a lot of youngsters have great problems in understanding the difference between old-fashioned *1 niche* and *25·umm??* Maybe they could use a metric protractor too (ha, ha)?

I must say there is a lot of reading in *EPE*, normally I get through mags in less than 30 minutes . . . Thanks and best regards.

**Ivor Mantell,**
**via the Net**

*Are there no limits to readers' levels of ingenuity? A remarkable set of suggestions Ivor! Thanks.*

*As to Metrics – in fact Max and Alvin are both English, but like a lot us who are a bit long in the tooth(!), they still work in inches. In fact it's me "wot tyakes 'a blyame (ayin'tit arl a blyading shyame?)" – we normally change Imperial measurements to metric, or quote both. On this occasion I didn't, and no-one else spotted my misdemeanour!*

*And yes, folks, Ivor does say* "1 niche and 25·umm"! *But rather than "protract" the issue, I'll just comment that metric angles would probably send us all off at a tangent (or would they make us* "radiant"*?)!*

### PEEEEPEHEEMETI

Dear EPE,

I think that you should not be concerned (*Readout* April '99) that a change of name would lose you existing readers. It is the content which matters and, with notification in preceding issues, regular readers would readily recognise the change.

Lee Elvin was right in his concurrent letter that it is new readers whom you need to attract, especially potential readers who are coming of age. You acknowledged that electronics hobbyist activity has declined since the 1980s and presumably your takeover of *ETI* implies that it is continuing to do so. And of recreational activities it is not only hobby electronics which is suffering from the draw of the goggle box and the computer game, and the consequences of depreciating educational standards.

Electronic engineering at its academic and professional level is an esoteric discipline and one requiring competence in advanced mathematics, both well beyond the ken of all but a tiny proportion of the populace. The great virtue of "*PEEEEPEHEEMETI*" is that it can inspire those who have an incipient interest in the applications of electronics to convert their interest to practical purpose.

Lee Elvin was also right in saying that a simple name for your magazine is needed. Whilst his *Electronics* might be too all-encompassing, a more specific name would be appropriate. *Practical Electronics* would be fine; but your integration of numerous past titles declares a need for a new and easily-recognisable name to accord with the magazine's role.

*Wireless World* was a respected journal of many decade's vintage long before the 1970s/80s splurge of amateur electronics magazines. It has had no trouble in changing to *Electronics World* – which title I suggested to its then publishers in a letter of 2 August '82.

**Jack Easthaugh,**
**Chesham, Bucks**

*Your further comments on the subject are appreciated. Nonetheless, we feel very strongly that people become loyal to a "brand image" and could well respond negatively if that image changes. In this context, I heavily regard our Title as being a brand image, one which people expect to see and have learned to trust. If images have to be changed, my personal opinion is that the change should be made subtly over time – and this would rule out any significant name change.*

*You quote one example of such a change and I cannot comment on what it has actually done for the magazine, only its publishers can answer that, but I could not support any change that might put us at risk of losing an existing market. Certainly we need to attract new readers (and we do so), but we need to have full regard to the expectations of readers who have been with us for far longer – some have been with us since we first began (as EE) in 1971.*

*Having said that, I would also stress that we do listen and respond to what people say about us. We welcome letters such as yours which offer considered opinions. We like hearing from you all!*

### POWERING PhizzyB AND SENDING 98

Dear EPE,

With respect to the hardware *PhizzyB*, is there any reason for using a regulated 9V power supply? Will an unregulated 12V supply which I have to hand be OK given the use of the LM340-T5 voltage regulator?

Also, I thought you would like to know that I have upgraded a 1-year old Dell computer from Win 95 to 98 and now somewhat regret it. In particular, the &H378 TASM Send program I use for programming PICs now does not work from a DOS window. I have to re-boot the computer into DOS mode to get it to work.

**Thomas Walton (age 11),**
**via the Net**

*No, 12V would be too high (says Alan Winstanley, who is our* PhizzyB *expert on the UK side of the planet). The on-board regulator is 5V and it would tend to dissipate too much heat because there is no room for a heatsink. This won't damage the device because it will thermally shut itself down, but it won't run very well when, for example, all the 7-segment displays are in use, when current consumption is highest.*

*Of the seven computers I use from time-to-time, three are Dells and I speak highly of them and their manufacturer to anyone who cares to listen. As I understand the comments about Win 98 that we receive here, it's having upgraded to 98 that is causing problems for many people. It seems to be a problem caused by other software already being on the system and which may have changed an unknown variety of system parameters, rather than due to any specific computer.*

*Those who are purchasing new machines with 98 already installed are, we understand, not likely to experience the same difficulties. (I'm not an expert on computer systems* per se, *so I would welcome* Readout *input on this from those who are.)*

*Knowing from several sources (including Alan Winstanley) that Dell are very helpful, we suggest that you contact them for advice. We suspect that trying to contact Microsoft directly might result in lengthy waits before you can get into their telephone queuing system (though an E-mail might do the trick).*

## NO NEW THING

Dear EPE,

Bart Trepak's *Mechanical Radio* of April '99 prompts me to quote the Bible, "There is no new thing under the sun". During the 1939/45 War, aircraft whose duties carried them over the sea carried inflatable dinghies whose kit included a "Gibson Girl". This was a buoyant yellow container with a handle on the top and a waist so that it fitted neatly between the legs of a seated person; the shape inspired it's name.

Turning the handle operated a generator through a gear chain giving 12 volts for the heaters and 400 volts for the anodes of a valved radio transmitter. As the handle was turned it moved a set of cams which switched the transmitter to provide a Morse distress signal. After the War the generators were available on the surplus market; I still have one.

In the 1950s, electronic flash was available for amateurs at low cost but using expensive 90V or 180V dry batteries to charge electrolytic capacitors which stored energy, about 25 joules, for the flash tube. I found that the high voltage output from the Gibson Girl generator charged the capacitor with a few turns of the handle. A diode was necessary to prevent discharge causing the generator to motor, and a neon to indicate operating voltage had been reached.

The high cost of the Bayliss radio is to a large extent due to the use of an excellent Tensator spring motor. These give constant power as they unwind and were widely used in 8mm cine cameras in the 1960s. However, the price of electric motors dropped and hand power was replaced with battery power in these cameras.

Hand-powered torches can be obtained from Bull Electrical. Regular squeezing of the handle keeps a flywheel and coupled generator spinning, so lighting a bulb; the output should power a small radio.

**Guy Selby-Lowndes,**
**Plaistow, Billingshurst**

*Fascinating! And could it be that the Gibson whose Girl it was, was Guy Gibson who (if memory serves me right) was in charge on the Dam Busters raids?*

*You have also reminded me of the mechanical shaver my father used in the late '40s/early '50s. It had a handle that caused the generation of rotational power when squeezed, and used a flywheel for energy storage between squeezes.*

## MORE ON BASIC

Dear EPE,

I have noticed in the past few months that people have been going on about what format the software for some *EPE* programs should be written in. I think that a switch to Visual Basic would be quite easy for yourself and the readers!

Visual Basic allows Windows programs to be written easily and is very easy to pick up and would allow readers to modify the programs to suit their own needs. Books can be found online and there are plenty of source codes and tutorials available on the Web.

I am currently a sandwich student on Placement and have been teaching myself Visual Basic and Visual C++ in preparation for getting a job when I graduate. My degree might be in Electrical & Electronic Engineering but I find the computing side really enjoyable, including the learning curve that comes with learning new programming languages. I hope you think about switching to Visual Basic.

**Robin Smith,**
**via the Net**

*Yes indeed, and once you know one language it becomes that much easier to learn others (this is one of the many great things about PhizzyB – teaches you programming techniques that can be used almost anywhere, even when the languages/dialects differ, the concepts remain the same.*

## POWERED START

Dear EPE,

Those who are well established in the field of electronics find your constructional projects quite interesting and worth building. This is not the kind of feedback received from newcomers to this wonderful world. Why not include projects that aid students in understanding the basics of electronics?

A mains operated power supply unit would be an excellent project for the student still trying to grasp the functions and implications of rectifier diodes, filter capacitors, etc.

**Karl V. Grant, via the Net**

*Slightly tricky one this, Karl. Whilst many of us started off having an interest in electronics by learning that fuses can be blown, as a magazine we have to be very aware that we do not encourage readers to blow themselves through the misuse of mains electrical power.*

*You will have noticed that when publishing mains-powered projects we always give warnings about not attempting their construction unless the constructors are suitably qualified/experienced. We go on to recommend that readers should consult a qualified electrician if they are in any doubt about their capabilities. It would be difficult, therefore, to publish a mains power supply specifically for beginners.*

*We do publish power supplies from time to time but they are not intended for construction by beginners, even though we have no doubt that some readers do not head our warning – that is entirely at their own risk.*

*On subjects where mains safety is not an issue, we frequently publish designs which are ideal for beginners. Notable in this respect are the* Teach In *series that we run every couple of years – each series taking a different viewpoint of elementary material. We are also about to publish a series of "Starter" projects aimed at beginners.*

Constructional Project

# PIC TOOLKIT Mk2


## JOHN BECKER


Part One

*How to improve your PIC programming options in a Flash, and it's a real pleasure to use!*

MICROCHIP'S new PIC16F87x series of Flash EEPROM microcontrollers offer greater program capacity and more facilities than the familiar PIC16x84 series. The latter, though, will still find a plethora of uses in less-demanding circuits where the greater sophistication of the '87s is not required. There are roles for both families.

Consequently, the *PIC16x84 Toolkit* of July '98 has been upgraded to make it compatible with both the '84 and the '87. The printed circuit board has been redesigned to accept the 18-pin '84s and the 28/40-pin '87s. The power supply control has been redesigned to remove the need for a regulated 12V/14V PSU – the Mk2 will run from any d.c. supply of between 5V and 20V (at around 10mA). The PC interface I/O lines have been buffered for greater stability.

Additionally, the controlling software has been considerably enhanced in a number of ways, offering more functions than the Mk1 version.

Whilst Toolkit can be used entirely as a stand-alone design, it can also be interfaced with the *PIC Tutorial* (Mar-May '98) and the *PICtutor* (CD-ROM) development boards, as discussed later.

The Mk2 Toolkit has the same basic options as the Mk1:

- Configure PIC
- Program PIC with TASM .OBJ
- Program PIC with MPASM .HEX
- Translate MPASM .HEX to TASM .OBJ
- Translate TASM .OBJ to MPASM .HEX
- Disassemble PIC to TASM .OBJ
- Disassemble PIC to MPASM .HEX
- Translate TASM .ASM to MPASM .ASM
- Translate MPASM .ASM to TASM .ASM

It also has the following additional options:

- Assemble TASM .ASM to .OBJ – totally replacing the need for a TASM shareware Assembler and its associated Send programs
- Directory paths display/change – eliminating any need to make changes to the Basic program (as required by Mk1)
- Directory display/select – displays file directories of choice, and allows automatic loading of selected file for use in any main program option
- Setup function allows PC ports to be tested and selected, and the PC's ability/inability to read (for PIC verify/disassemble) from its selected port established
- Load/read data to/from the PIC's internal EEPROM data memory
- Direct access to and return from DOS EDIT for editing any text files (.ASM source code files, for example).

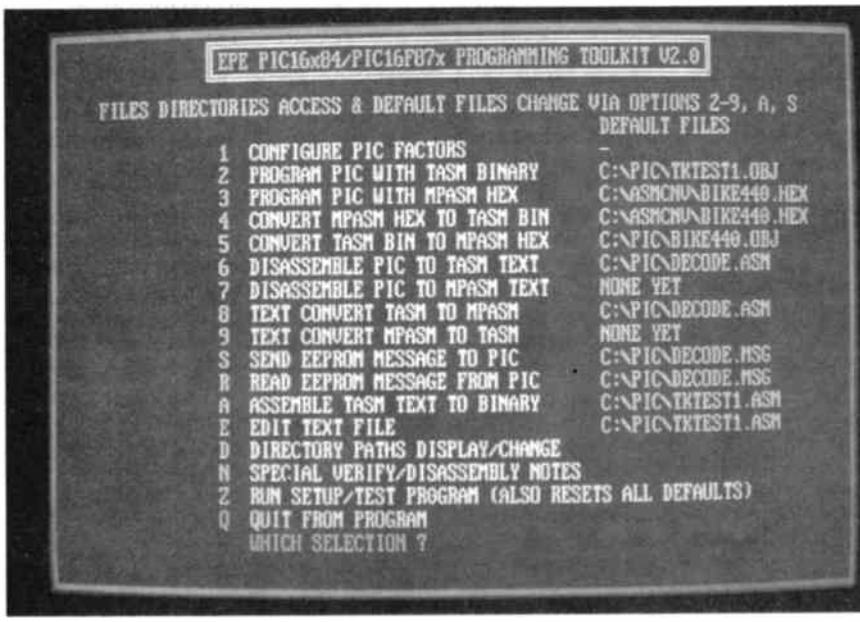
This software is far more sophisticated than the Mk1 and is supplied as a suite of four chained programs which call each other as required without the user's intervention. It can be run in QBasic, QuickBASIC, or as a stand-alone (.EXE) program without any need for a Basic controller.

By design, the software can also control Toolkit Mk1 without modification.

The full suite of programs may be run under DOS mode or Windows 3.1 or Windows 95. It is likely to run under Windows 98 though this has not been tested. The author has run it on several desk-top computers with a range of processor types, including '386, '486 and Pentium. Additionally, the software has been accessed and run via the *PICtutor* CD-ROM package. All-in-all it is *very* comprehensive in its facilities.

About 350K bytes of hard disk space are required.

It seems likely that other PICS which use 14-bit instructions (as do the '84s and '87s) could also be programmed using Toolkit, although this has not been tested and readers should check the PIC data sheets for themselves. Such devices might include: 16C54, 16C56, 16C58, 16C62, 16C71, 16C72, 16C74. (Note that some PICs use 12-bit and 16-bit instructions and are not suitable for Toolkit's programming software.)



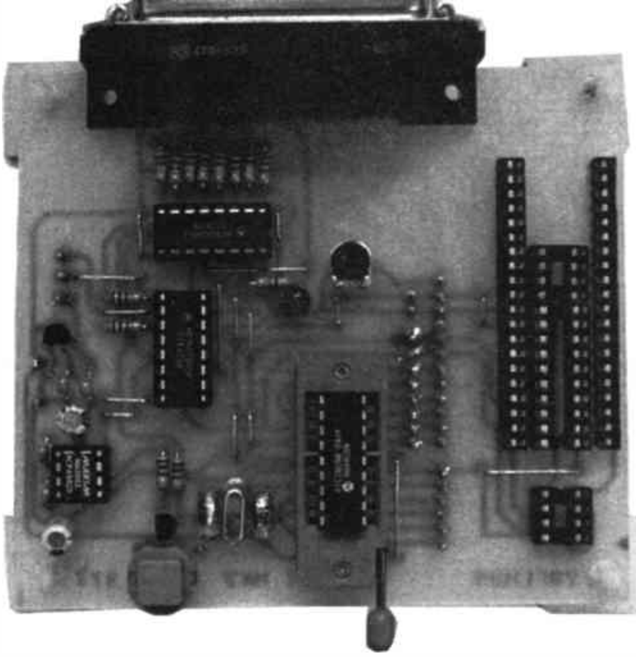

*The main menu for the Toolkit Mk2.*

### WHY A TOOLKIT?

In answer to the occasional question from readers, "Why do I need *PIC Toolkit* if I've already got *PIC Tutorial/Tutor?*" – because it makes life even easier!

The assembly and PIC loading programs (TASM and Send) used with *PICtutor* and *PIC Tutorial* (from hereon jointly referred to as *PIC Tutor* unless stated otherwise) were those which we originally published with Derren Crome's *Simple PIC16C84 Programmer* of Feb '96.

As such, the hardware had to be switched to apply +12V to the PIC's MCLR pin in programming mode, and to apply 0V to the same pin in order to reset



the PIC. In normal running mode +5V is applied to that pin. Additionally, it had been found disadvantageous to have the computer's DA0/DA1 lines connected to the PIC at the same time that the PIC's RB6/RB7 pins were also connected to any development circuit.

Consequently, in *PIC Tutor*, two additional changeover switches were included to prevent this joint interconnection. This meant that four switches had to be manually operated before and after programming a PIC. No great problem in itself, but becoming a bit tedious when frequent programming was called for.

One main purpose of Toolkit is to have the computer perform all the switching needed via control lines and a multiplexing chip, completely removing the need for manual switching. The original Send program did not include facilities to do this, and the programming software for Toolkit was written to perform this operation and to replace Send.

Secondly, there are several PIC assembly programs available on the general market, two of which are TASM and MPASM. TASM is a shareware general-purpose assembler to which PIC16x84 assembly facilities had been added on behalf of *EPE*, but which requires a registration fee to be paid to its designers if used beyond an evaluation period. MPASM is the assembly software available from Microchip (the PIC's manufacturers) and intended for use with their MPLAB hardware. Both TASM and MPASM are variously used by contributors to *EPE* and they are not mutually compatible.

For a start, although the two assemblers have much in common, the "grammar" used by each is not quite the same, different literal-value representations in particular being used, plus other subtle differences in command statements.

Secondly, TASM assembles the source code into a simple sequential binary code format, whilst MPASM assembles it into a complex hexadecimal format complete with checksum validation codes interspersed between the required program codes. Although TASM can be told to generate a similar hex code output, the order of the individual MSBs and LSBs (Most and Least Significant Bytes) is reversed.

The upshot is that neither TASM (and Send) nor MPASM can make use of the other's files. This eventually became a problem to readers who already had one of the assemblers and wanted to make use of the other's program files. As a result, Toolkit's software was written to provide automatic translation between the two formats to suit readers' needs.

Additionally, Toolkit was given the facility to read back program data already in a PIC16x84, allowing verification that the PIC had correctly received the data, and allowing program code within a PIC16x84 to be disassembled to a source code text file.

In other words, Toolkit Mk1 was introduced to add more (and easier) facilities which would be of benefit to PIC-users who were using TASM or MPASM, with or without *PIC Tutor*.

As you will have seen from the functions listed in the introduction, Toolkit Mk2 offers even more facilities than Mk1 already offers. TASM and MPASM inter-translation is retained and source code can be written in either format. The emphasis of this article, though, is placed on TASM grammar, even though TASM itself is no longer used as the assembler program. The author finds the TASM

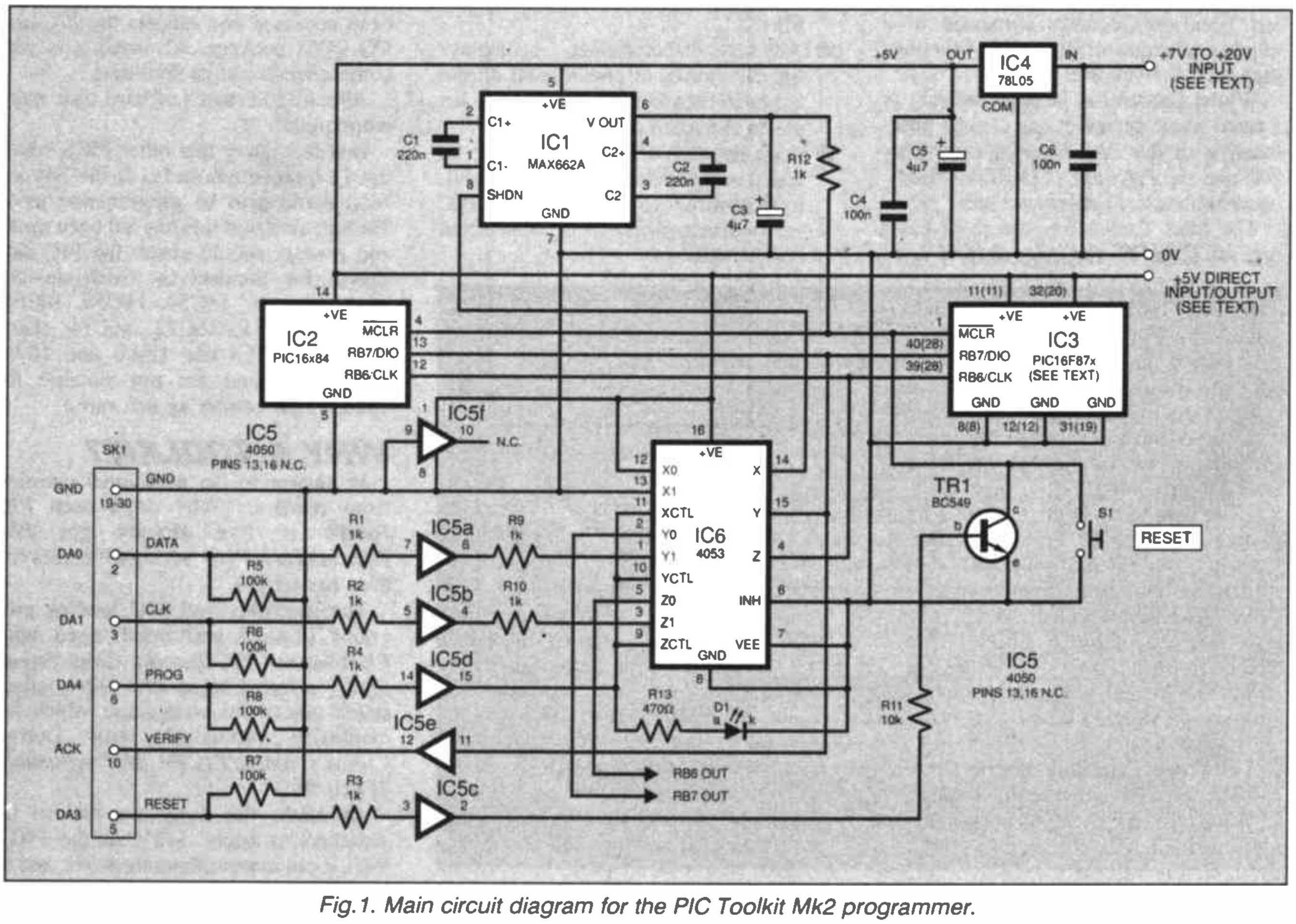



Fig.1. Main circuit diagram for the PIC Toolkit Mk2 programmer.

format somewhat easier to use and prefers to write his code in that format.

The use of the various functions offered by Toolkit Mk2 will be discussed as we progress, but first let's describe its basic hardware.

## BASIC BOARD FUNCTIONS

In keeping with the original Mk1, and for use with the PIC16x84 when *in situ*, the printed circuit board includes a crystal oscillator and terminal pin connections so that it can be used as an elementary test bed. The pins are arranged so that an alphanumeric liquid crystal display (l.c.d.) can be plugged straight in. A contrast control preset is included on the p.c.b. (not shown in the circuit diagram).

The l.c.d. pins on the Toolkit Mk2 board are in the same order as those used on the *PIC Tutor* boards (original and CD-ROM versions). Consequently, the l.c.d. modules (and l.c.d. software) already used with those boards can be used with Toolkit Mk2.

It was felt, though, that the complexity of the '87s precluded the use of the Mk2 board as a test bed for them. Consequently, no terminal pin connections for the '87s are included on the board. There are, though, two programming techniques available.

One is that the '87s can be programmed on the Mk2 board and then transferred to the board that is being assembled for a specific project and for which the software is already provided.

Alternatively, to facilitate prototype development, the three principal lines required for programming the PICs (RB6, RB7 and MCLR) have output pins from which connecting wires can be taken to any prototype board, so that any of the '84 or '87 PICs can be programmed *in situ* where they are being used. The devices don't actually have to be plugged into the Mk2 board.

## CIRCUIT DESCRIPTION

The main circuit diagram details for the PIC Toolkit Mk2 programmer are shown in Fig.1. IC2 and IC3 represent the power and programming connections for the PIC16x84 and PIC16F87x families respectively. Apart from the power supply connections, only three wires are needed between a PIC and the computer used to program it.

The data to be loaded into the PIC is supplied to its RB7 pin. A clocking signal goes to pin RB6 and the programming/running/reset voltage is applied to pin MCLR (master clear). Note that there are two sets of pin numbers shown for IC3. Those within brackets are for the PIC16F873 and '876 (28-pin devices): those outside brackets are for the PIC16F874 and '877 (40-pin devices). Their pinouts are shown in Fig.2.

There are two devices that separate the PICs from the computer connections, IC5 and IC6. The computer is coupled to the circuit via socket SK1, using an

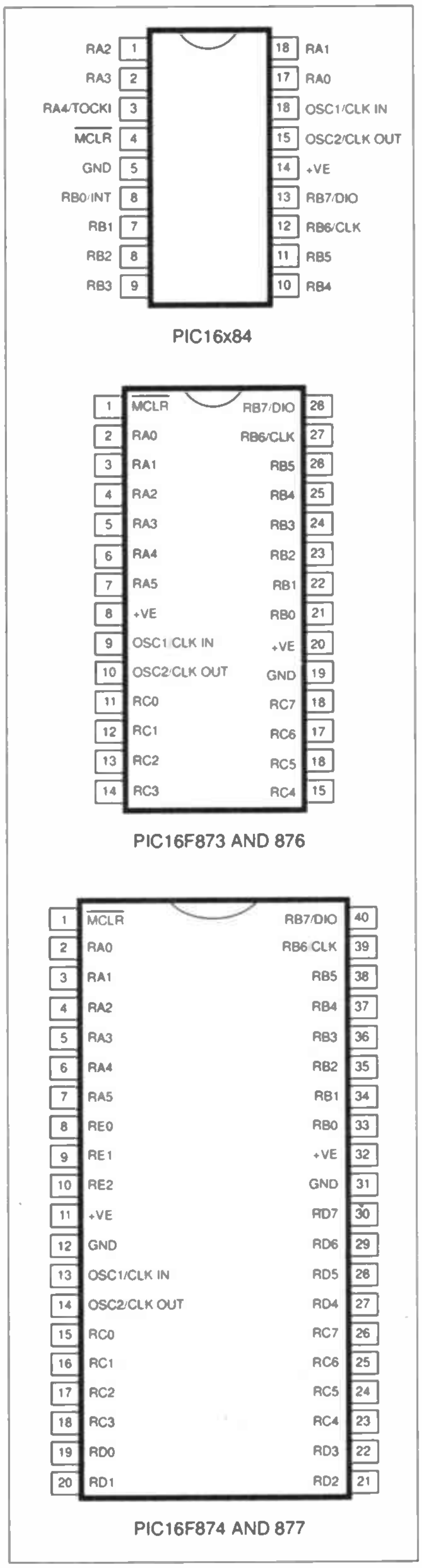



*Fig.2. Pinouts for the PIC16x84 and PIC16F87x families. The widths are not to scale.*

ordinary (Centronics) printer cable connected to the computer's parallel printer port. The computer lines being input to Toolkit are buffered by resistors R1 to R4 and non-inverting buffer gates IC5a to IC5d, whilst IC5e buffers Toolkit's single output back to the computer (IC5f is not used).

The resistors provide protection to the computer's output lines when Toolkit is unpowered. It was not felt desirable to resistively protect Toolkit's output connection to the computer since the latter might have pull-up/down biasing which could be affected by any intermediate resistor.

Resistors R5 to R8 bias IC5's inputs to 0V when Toolkit is not connected to a computer.

Tri-state bidirectional multiplexer IC6 routes the PIC's RB6/RB7 and MCLR control according to whether the PIC is being written to/from or is actively controlling a prototype development circuit (replacing switches S1, S3 and S4 in *PIC Tutor*).

Programming/read mode is set by taking computer line DA4 high (logic 1). This sets IC6 to its secondary routing configuration in which inputs X1, Y1 and Z1 are routed to outputs X, Y and Z respectively. This allows data lines DA0 and DA1 (data and clock signals) to reach PIC pins RB7 and RB6.

With DA4 high, IC6 disconnects RB7 and RB6 from any development circuit that is connected to its Y0/Z0 pins via paths RB7 OUT and RB6 OUT. When DA4 is low, these paths are re-instated and the DA0 and DA1 lines are isolated from the PIC.

## VOLTAGE CONVERTER

We now come to a significant difference between Toolkit Mk2 and its predecessors (*Toolkit Mk1, PIC Tutor, Simple PIC16C84 Programmer*). The latter all require an external +12V (to +14V) d.c. supply to be used during programming mode. In itself this is no great problem, but there is a more versatile option.

The PIC only requires +12V on its MCLR pin while it is being programmed or data read back from it. During normal running, +5V is applied to this pin. This dual requirement necessitates switching between the two voltages. In Toolkit Mk1 this was achieved by using line DA4 to switch a configuration of two transistors on or off (the other mentioned circuits used switches).

For Mk2, a more elegant solution is used – a device specifically designed to provide either +5V or +12V depending on the status of a controlling pin. The device is shown in Fig.1 as IC1 and is a readily-available Maxim product, MAX662A. It is described as a +12V 30mA Flash Memory Programming Supply device.

Its SHDN pin is internally biased to be normally held high, in which situation output pin VOUT is held at +5V. When SHDN is taken low, IC1 uses an internal oscillator to generate +12V from the +5V supply line. Charge-pump capacitors C1 and C2 set the oscillator's frequency and output current availability.

Although the maximum rated output current is stated as 30mA, in practice the author has noted that a saw-tooth ripple occurs on the output, rising in peak-to-peak value with increasing current being drawn.

With this mind, in some instances it might be preferable to omit the l.e.d. from the *PIC Tutor* board if Toolkit is connected to it (to reduce the current required from the MAX662A in its 12V mode), although the author has not experienced any problems through leaving that l.e.d. in place.

The great advantage of using a step-up voltage converter is that Toolkit can be supplied from a d.c. power source other than a regulated +12V d.c. supply, as discussed later.

## CONTROLLING MCLR

With computer line DA4 normally low, IC1 outputs +5V to the PIC's MCLR pin. The route to IC1's SHDN pin is via IC6 path X0/X, which couples the pin to the +5V power line (even though the pin has internal positive biasing, it was no problem to provide the +5V connection).

When line DA4 is taken high, the SHDN pin is taken low via IC6 path X1/X and IC1 outputs the required +12V. The status of DA4 is shown on l.e.d. D1, which is controlled by IC5d. When DA4 is high, D1 is turned on via ballast resistor R13.

A third control voltage level is needed for the MCLR pin. It needs to be taken low (0V) when the PIC has to be reset. Regrettably, the MAX662A is not capable of having its output set to 0V via a control pin. Consequently, the reset level is taken low by the same technique used in Toolkit Mk1.

Resistor R12 is placed in series with IC1's output and MCLR. To MCLR is connected transistor TR1, which is controlled by line DA3 via buffer IC5c, plus resistors R3 and R11. With DA3 low, TR1 is turned off and MCLR will be at either +12V or +5V, depending on DA4's status.

When DA3 is taken high, TR1 is turned on and MCLR is taken low, R12 preventing conflict with the output from IC1.

You will see that switch S1 has also been included across TR1. This has nothing at all to do with programming PICs. It is merely there to allow the PIC to be reset when it is in running mode as part of an attached prototype development board – a convenience the author finds useful from time to time.

## POWER SUPPLY

A wide range of power supply voltages can be used with Toolkit Mk2. With regulator IC4 in circuit, the supply can be between about 7V and the maximum limits that this device can handle – typically up to about 20V.

The maximum voltage, though, also depends on the current being drawn though IC4. The maximum current IC4 (a 78L05) can supply is 100mA, but the wattage dissipated must also be taken into account – if it gets too hot it will shut down.

With Toolkit used independently (not attached to *PIC Tutor* or other circuits) and with a PIC16F84 inserted, the prototype currents drawn were:

4·5mA in run mode
8mA in program mode with Reset off
47mA in program mode with Reset on

The high current demand is believed to be due to IC1 trying to keep up its obligation to supply 12V. Normally, having Reset on in program mode is under computer control and only lasts for a fraction of a second.

An ideal conveniently available supply would be 9V with, for example, just an l.c.d. connected to the board.

The other power source option is to use a directly-input regulated supply of 5V, omitting IC4 entirely. This is particular viable if Toolkit is used with a *PIC Tutor* board, since the 5V supply can be tapped directly from it, and take advantage of the 1A capability of its 5V regulator.

Do not feed any other voltage into the direct +5V input – the use of a 6V battery supply, for example, is *strictly not allowed* (unless fed in via a 1N4001 rectifier to reduce it by 0·7V). Regard all i.c.s as having an absolute minimum/maximum positive voltage range of 4·5V to 5·5V.

## CRYSTAL OPTION

As said earlier, Toolkit Mk2 can be used as a simple "test bed" when used with a PIC16x84. The circuit diagram for these options is given in Fig.3.

Here a crystal oscillator is shown, comprised of crystal X1 and two capacitors, C7 and C8. The crystal frequency is stated as 3·2768MHz, as this is a convenient frequency from which to derive real-time clock timings in seconds, minutes and hours. Other crystal frequencies may be used, though, up to 10MHz (provided the 10MHz version of the '84 is used and correctly configured).

The connections in the outline box to the right of the PIC are terminal pins on the p.c.b. for use as connections to other circuits, including the l.c.d. module previously referred to. (In fact, on the p.c.b., two terminal pins for each of RB0 to RB7 are provided, allowing the direct plug-in of the l.c.d. while still leaving access to terminal pins for other use. Details of typical l.c.d. pin connections are shown in various earlier *EPE* projects, including *PIC Tutorial* Part 3 (May '98).

## PIC PINOUTS

It is not the intention of this article to discuss the detailed operation of the '84 and '87 PICs. *PIC Tutor* covers the former in extensive detail. Microchip's data sheet should be obtained for the intimate details of the '87 family.

Nonetheless, it is appropriate to show the pinouts of both families, as we do in Fig.2.

Be aware that only the simple pin

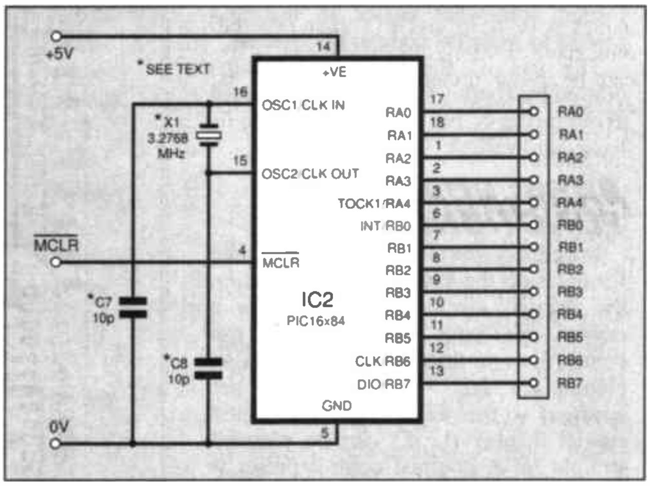



Fig.3. Oscillator option for the PIC16x84.

## COMPONENTS

**Resistors** — See SHOP TALK page

| | | |
|---|---|---|
| R1 to R4, R9, R10, R12 | 1k (7 off) | |
| R5 to R8 | 100k (4 off) | |
| R11 | 10k | |
| R13 | 470Ω | |

All 0·25W 5% carbon film or better.

**Potentiometer**

| | |
|---|---|
| VR1 | 10k preset, min. round (see text) |

**Capacitors**

| | |
|---|---|
| C1, C2 | 220n min. ceramic disc (2 off) |
| C3, C5 | 4μ7 axial elect. 16V (2 off) |
| C4, C6 | 100n min. ceramic disc (2 off) |
| C7, C8 | 10p polystyrene or ceramic (2 off) (see text) |

**Semiconductors**

| | |
|---|---|
| D1 | red l.e.d. |
| TR1 | BC549 *npn* transistor |
| IC1 | MAX662A +12V 30mA Flash memory programming supply |
| IC2 | PIC16x84 microcontroller (see text) |
| IC3 | PIC16F87x microcontroller (see text) |
| IC4 | 78L05 +5V 100mA regulator (see text) |
| IC5 | 4050 non-inverting hex buffer |
| IC6 | 4053 triple 2-channel analogue multiplexer |

**Miscellaneous**

| | |
|---|---|
| S1 | s.p. pushswitch, p.c.b. mounting |
| SK1 | 36-way Centronics female parallel printer connector, p.c.b. mounting |
| X1 | 3·2768MHz crystal (see text) |

Printed circuit board, available from the *EPE PCB Service*, code 227; 8-pin d.i.l. socket (2 off); 16-pin d.i.l. socket (2 off); d.i.l. or s.i.l. sockets for IC2 and IC3 (see text); p.c.b. supports (4 off); connecting wire; solder, etc.

**Approx. Cost Guidance Only £19** *(excl. microcontrollers)* names have been given – many of the pins have multiple functions that they can be programmed to perform. It is *essential* to read the appropriate sheet to understand them (see the Resources section later).

## CONSTRUCTION

Right then, so that's the basic outline finished with. We can now get into building the little rascal – as PhizzyB friend "Max" Maxfield might say!

Full details of the printed circuit board component and track layouts are shown in Fig.4. This board is available from the *EPE PCB Service*, code 227.

Note that IC4 *must* be omitted if Toolkit is to be powered from a regulated 5V source, such as from *PIC Tutor*. (In which case capacitor C6 can be omitted too.)

Additionally, resistors R9 and R10 must be replaced by link wires if Toolkit is to be connected to *PIC Tutor*. Failure to do so will result in incorrect voltage levels being applied to the DA6 and DA7 pins of the PIC on the *PIC Tutor* board.

Assemble the Toolkit Mk2 board in order of link wires first (note that one is under the IC6 socket position), and then the rest of the components in ascending order of size. Especially note the correct orientation of the semiconductors, electrolytic capacitors and switch S1. Do not insert any of the dual-in-line i.c.s into their sockets until after preliminary testing has been carried out (you'll be told when).

A special note on the use of sockets for IC2 and IC3 (the PIC sockets): ideally a ZIF (zero insertion force) socket should be used for IC2, although it can be an ordinary socket if funds don't run to ZIFs.

Now, on ZIFs, an 18-pin version is available and can be used for IC2. However, it is more expensive (for some odd reason) than a universal 24-pin ZIF. Consequently, provision has been made on the board for either version to be used (hence the two outlines shown for IC2).

It's up to you whether you solder the ZIF in place, or use an ordinary socket and then plug the ZIF into it when needed (the 18-pin ZIF is a bit difficult in this respect since its pins have been found to be thicker than those on the 24-pin).

It's worth noting, however, that if Toolkit is to be connected permanently to a *PIC Tutor* board, the socket for Toolkit's IC2 is likely to be seldom used and an ordinary d.i.l. socket will probably prove satisfactory (or even unnecessary), have a think about it.

ZIF sockets for IC3 are much more expensive still and it seemed inappropriate to even think about using them. Thus the board has been designed for ordinary d.i.l. 28-pin and 40-pin sockets to be nested in the same location.

The 28-pin socket is made up from a 20-pin and an 8-pin (narrow, 0.3-inch) d.i.l. socket. The 40-pin (broad, 0.6-inch) is made from two 20-pin s.i.l. (single-in-line) strips. A 40-pin d.i.l.

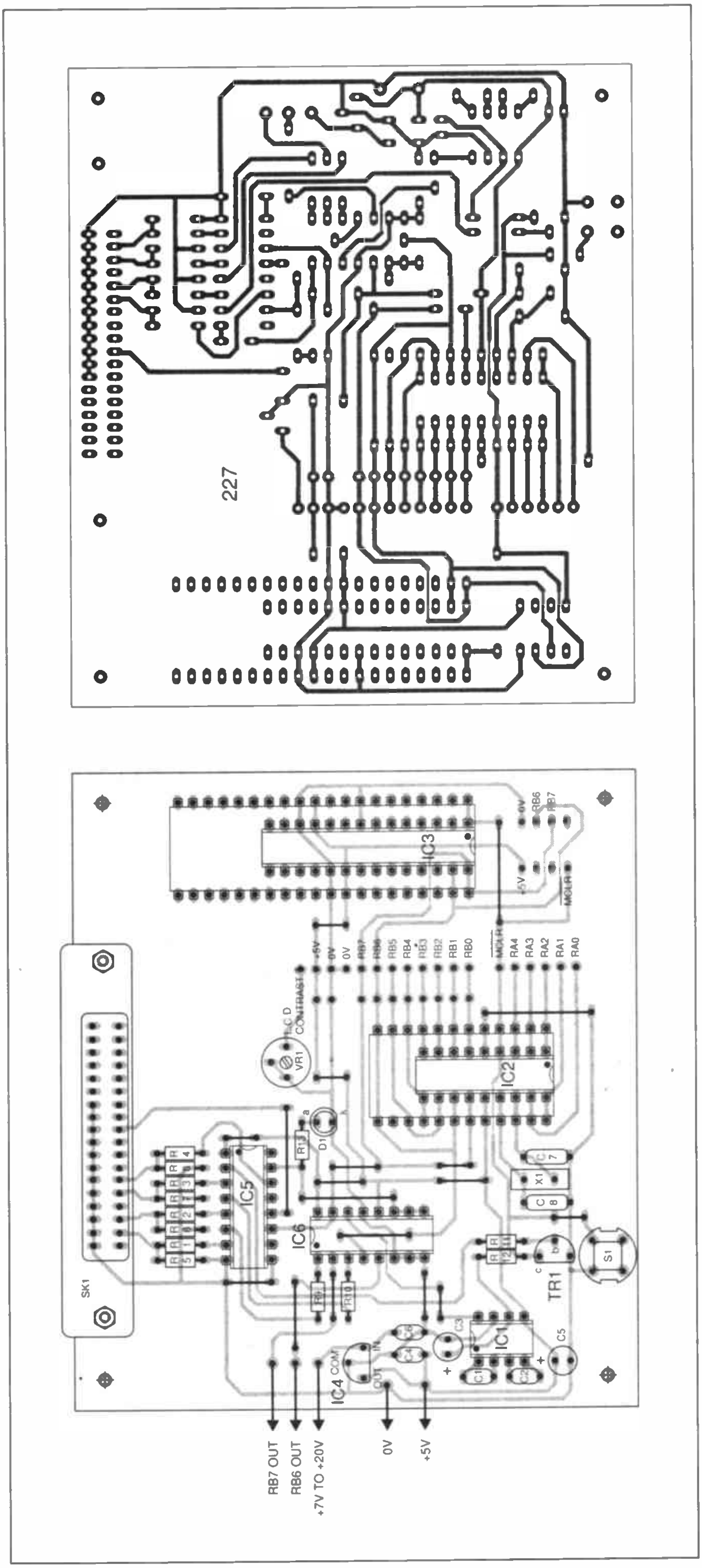



*Fig.4. Component and full size track master pattern layouts for PIC Toolkit Mk2.*

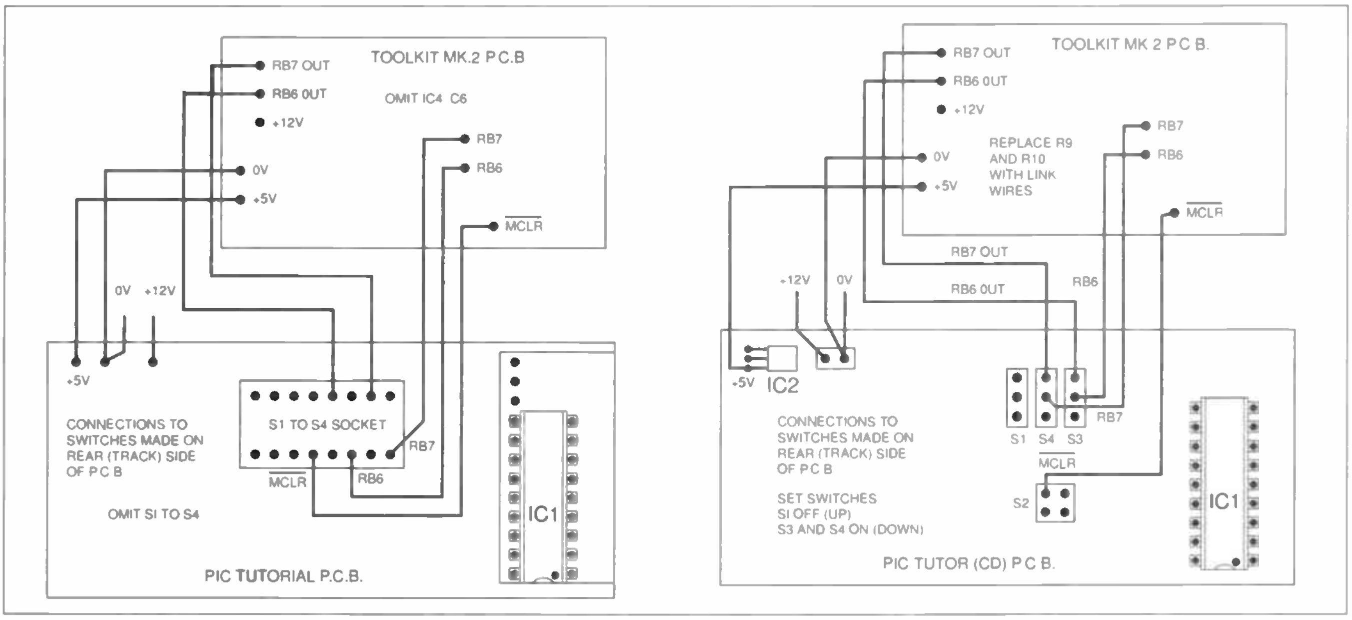



*Fig.5. Optional connections between Toolkit Mk2 and the* PIC Tutorial *and* PICtutor *boards.*

socket could be used if its cross struts are removed.

Since only a few of the IC3 position pads are actually used, you might consider using s.i.l. strip sections soldered only into those p.c.b. holes. It seems that this would actually make insertion and removal of an IC3 PIC a bit easier (this was only thought of after the prototype had been built. It has not been put to the test!).

At the bottom right of the p.c.b. is shown an additional 8-pin socket. It is from this socket that power and programming connections could be made to a prototype development board. Solder its connecting wires into another 8-pin d.i.l. socket and plug it into Toolkit's 8-pinner. Alternatively, you could just solder the connecting wires to the correct terminal pins on the board.

## PIC TUTOR CONNECTIONS

This brings us to using Toolkit with either of the two versions of the *PICtutor* board.

Details of the connections to the *PIC Tutorial* board published in March '98 are shown in Fig.5. This board uses a 4-switch module for S1 to S4 and this should be removed. Then solder the Toolkit connections to the *trackside* of the *PIC Tutorial* board (noting that Fig.5 shows them from the component side).

Connections to the board for the CD-ROM based *PICtutor* are also shown in Fig.5. With this board, different switch types and positioning were used. The switches for this board should be left in position. Note that switch S1 must remain permanently Off (up), while S3 and S4 must be set permanently On (down). The connections are again made to the trackside of the board.

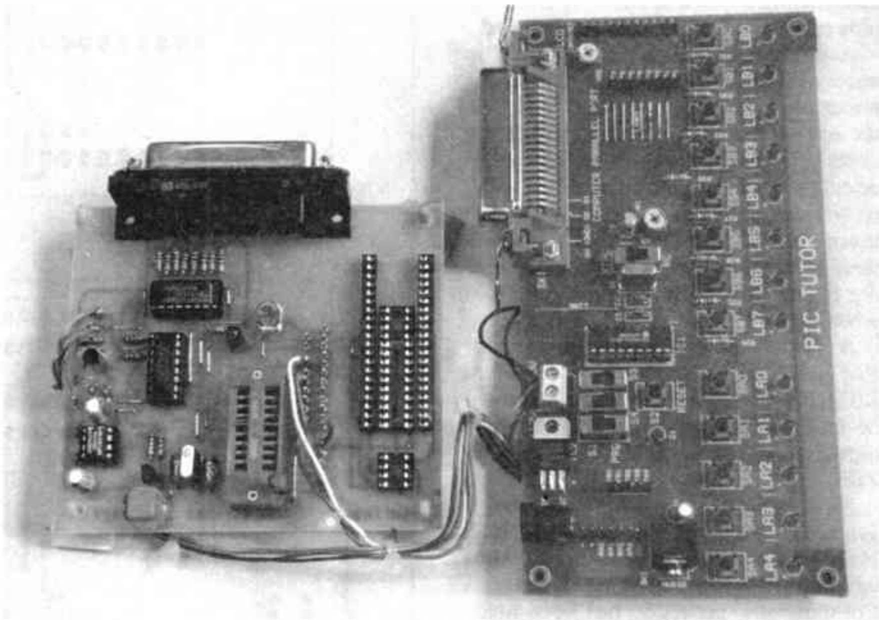
**Beware that you make these connections to the commercially manufactured and assembled *Tutorial* boards entirely at your own risk – their guarantees are invalidated by such action.**

The 0V connection to this board (CD-ROM *PICtutor*) may be connected to the 0V terminal of the on-board power input connector. The +5V connection should be soldered to the +5V (Out) pin of *PICtutor's* regulator IC2, preferably on the track side.

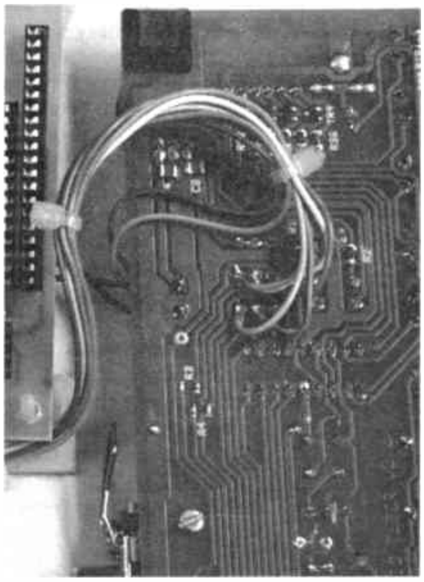
As an alternative, you could retain Toolkit's IC4 and C6 and take the +12V connection from (CD-ROM) *PICtutor's* power input connector to the +12V pin on Toolkit. Do not connect this +12V supply to any other Toolkit pin!

For workbench convenience, it is preferable to keep the interconnecting wires short-ish (see photograph), although the author has often had programming connection leads of as long as a metre without experiencing problems.

Note that the program sending aspect of the Toolkit Mk2 software can be used directly with either of the *Tutor* p.c.b.s., without them being connected to the Toolkit p.c.b., just plugging the computer connector into the *Tutor* board as normal.




*Toolkit Mk2 connected to the* PICtutor *board.*



*Trackside detail of the* PIctutor *board connections to Tookit.*

However, there is no screen advice given about when the *Tutor* board switches S1 to S4 should be used. You must remember to use them in the order discussed in the *Tutor* text when you are asked if you want to Process this Program.

Carry out the switching procedure and then press <Enter>. When advised that the sending is complete, again use the switches to terminate programming.

Verification and disassembly are never available when the *PIC Tutor* boards are used on their own without the Toolkit p.c.b. connected, irrespective of your computer's ability to actually read from its printer port.

## COMPUTER LEAD

It is strongly recommended that a proper ready-made printer connecting cable (normal – Centronics) with integral connectors is used to couple Toolkit to the computer.

It is, though, permissible to make your own simpler connecting lead, referring to Fig.6 for the pins involved.

Here now, we must reiterate the correction we previously published to Fig.7 of *Toolkit Mk1* which showed the use of printer port pin 11 instead of the correct pin 10 (as now shown in Toolkit Mk2's Fig.6). The error was compounded by both the text and the drawing referring to the computer's Busy line being used to read data from the PIC. In fact, the term *Acknowledge* should have been used instead of *Busy* and, as some readers pointed out, Busy is on pin 11, and Ack is on pin 10.

We now categorically re-state that both versions of *PIC Toolkit* use Acknowledge on pin 10 and the software for both is written to read pin 10 via its respective port register. Contrary to the assertion of a few readers, **there are no errors on the Mk1 p.c.b.**

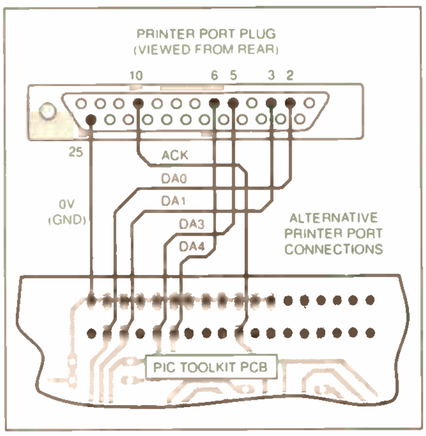
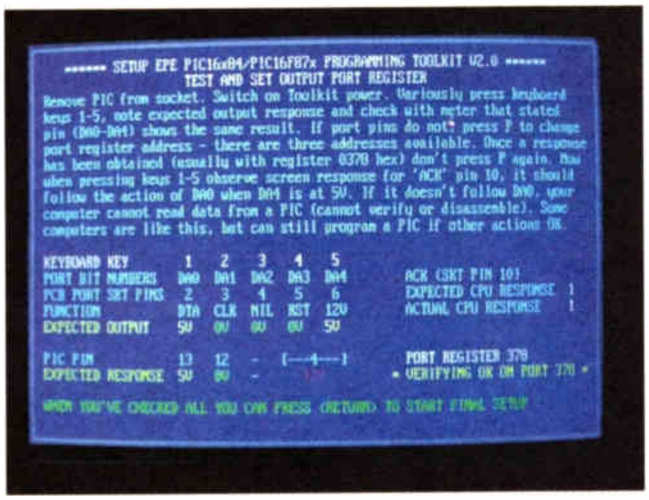



*Fig.6. Alternative connections between Toolkit Mk2 and the computer.*

## SOFTWARE LOADING

Software for Toolkit Mk2 is available on 3.5-inch disk and from the *EPE* web site (see later). Although originally written in QuickBASIC, it has been compiled as an independent suite of programs (.EXE) that run without the need to have QuickBASIC on your computer.

(The author's original **.BAS** source code files – in text fashion – are also on the same disk for the benefit of those who wish to examine them through a text editor (e.g. EDIT) or QuickBASIC/QBasic. Unless you really know about writing such **.BAS** programs, do not try to amend or run them. If you do run them, you will need to do so from the same directory in which your Basic resides and amend the **TK.BAT** file creation in **TKSET06.BAS** accordingly.




*The setup screen. It is interactive and allows you to fully check the connections between the computer and Toolkit, and ascertain if the port allows data to be read back.*

The stand-alone (.EXE) files are installed into directory **C:\PIC** which, if it does not exist already, is created automatically by the installation routine. All operations within Toolkit depend on this directory as being the "home" directory and no other can be used.

The recommended installation is intended to be done with the disk in Drive A, and the operating system in DOS mode. If you are already in Windows, exit from it back to the MS-DOS prompt (via Program Manager for Win 3.1 or the Shutdown facility for Win 95). The DOS prompt is likely to look like **C:\>** or **C:\WINDOWS>**. From this prompt type **A:** to enter Drive A.

Now type **TKINSTAL**. This auto-installation routine creates the **C:\PIC** directory (if necessary) and copies the relevant files into it. Once that has been done, the installation routine calls the main program (**TKMAIN02**).

At this point (and for reasons unknown) the instruction "Hit any key to return to SYSTEM" might appear. Do as it says and hit any key.

On entry, **TKMAIN02** checks whether file **C:\PIC\TKFACTS.TXT** exists. If the answer is false, the software assumes that it has not been run on this computer before, and calls up (Chains to) the Setup program **TKSET06**.

Many functions are performed by this program. For starters, an opening screen welcomes you and describes what takes place next. The first of these actions occurs via the next screen and asks you to press various keyboard keys and check what voltage readings (using a multimeter) are obtained on various parts of the Toolkit board (and *PIC Tutor* board if connected). Toolkit must, of course, be connected to the computer and to a suitable power supply. Any PIC in Toolkit or *PIC Tutor* should be removed before the power is switched on.

## PORT TESTING

Now, it's possible that your computer may not have its printer port register set to 0378 hex (as many consider to be the norm), it may be set to 0278 or 03BC hex. Initially, the Toolkit software is set to output via the 0378 register. You will only get the correct responses from the DA0 to DA4 pins if this is the register address set into the computer.

If you get no response, press P (for port) to change the register being examined by the software to 0278, and try again. If still no response, again press P to change to 03BC. A third press of P will return you to 0378.

If none of the register values produce the correct voltage reading on your meter, thoroughly recheck the connections between the computer and Toolkit.

Once you have found the register that produces a response, do not press P again.

During this process, the software assesses whether, with DA4 high, the logic on DA0 is readable via the ACK line. If at least five matches occur in sequence, it is assumed that the ACK pin can be read. The computer now beeps at you and an asterisked statement informs that Verifying is OK on that port.

If this statement refuses to appear, even though your voltage readings show that you are on the correct register, then your computer cannot read the data on pin 10. Regretfully, this means that it can neither verify nor disassemble from a PIC. It will be able to *program* the PIC, though, if you've found the correct responses through the meter readings.

When the beep occurs, or when you find that it's not going to, press <Enter> to continue the setting up.

Incidentally, it is permissible to run Setup *with* a PIC in the socket. You must ensure, though, that one of the earliest keys you press is that which resets the PIC. Failure to do so could result in incorrect responses from the output line back to the computer, and its ability to read back not recognised by Toolkit's software.

## FILES SETUP

Stage two of setting up involves the creation of many files which are called periodically by the various routines.

Amongst them are some test files (**.ASM** and **.MSG**).

All these files are created within the **C:\PIC** directory and are prefixed by the letters "TK", e.g. **TKTEST1.ASM**.

This stage of setting up is very quick, the author's various computers taking between about two and four seconds. When the screen tells you it's complete, pressing any key returns you to program **TKMAIN02**, which now displays the main menu of options available.

Each option is prefixed by a number or letter, and pressing that key selects that option. Alongside many of the options is a list of default file names. You will see, for example, alongside "A Assemble TASM Text To Binary", the default is **C:\PIC\TKTEST1.ASM**, others have the statement NONE YET. The latter will be updated in due course, depending on what other actions are subsequently taken.

If the port test has revealed that the computer cannot read data from Toolkit, three options will be "greyed" and the word Unavailable will be shown in the default column. It means what it says – you cannot access these functions, nor will the software try to verify code that has been sent to the PIC.

In writing this software, much emphasis has been placed on its ease of use, and where possible default choices are offered which merely require the pressing of a single key (frequently just the <Enter> key). Also, default file names are kept updated to suit circumstances, but remain unchanged where appropriate. This means, for example, that you can repeatedly return to a particular routine and still have immediate use of the same file name that you used last time you entered that routine.

## PROGRAM ASSEMBLY

Let's show you an example of using defaults. You have seen that **C:\PIC\TKTEST1.ASM** is the Assembly default name. This means that this file is ready to be assembled from a **.ASM** file to a **.OBJ** file suitable for sending to the PIC. (Note that it is only **.ASM** files using TASM grammar that can be assembled by this routine. MPASM files need translating through another menu option to make them suitable.)

First, switch off Toolkit, insert a PIC16C84 or PIC16F84 into the correct socket on Toolkit (or that on *PIC Tutor* if it's being used – but *never* have more than one PIC anywhere in the Toolkit/*Tutor* system), and switch on. We shall now assume that this PIC has never been used before and that you will not find any response from any of the PIC's data pins on a meter (or on the *Tutor* l.e.d.s).

From the main menu, press A to enter the Assembly program (a separate chained program named **TKPROG02**). The screen will confirm that you are in the Assembly routine and that you have several choices: pressing M <Enter> will return you to the main menu and D <Enter> will call up the directory. Any file selected from the directory will then become the default file (more on this later, and on the other statements now shown on screen).

You will also see that **C:\PIC\TKTEST1.ASM** is shown as the default file now available and that pressing <Enter> on its own will cause it to be assembled. You also have the choice of entering your own file name, pressing <Enter> to complete it (should you enter a name that does not exist, you will be told so and offered the chance to enter another name).

For now, just press <Enter> on its own. The routine then opens the file you have called, loads and assembles it. While it's doing so, progress statements appear on the screen plus the current time at which they occur (this is only for interest). You will see that it has taken about two seconds for this file.

Also shown is the byte count (actually the number of 14-bit commands) of the assembled code (14) and the number of lines in the original source code (28). An error count is shown too – the program has been checking your code while assembling it, seeing if there's anything that it doesn't recognise and if so incrementing the error count on each occasion. An error file (**.ERR**) is also written to with the details. On this occasion the count is 0.

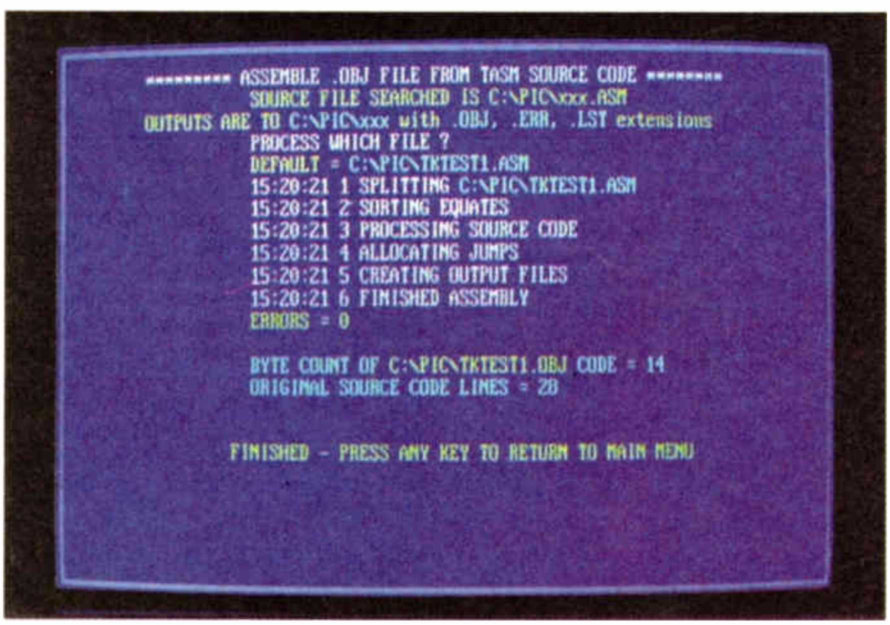
If errors are found, you can exit to DOS EDIT to correct them. More on the use of the EDIT facility in Part 2.

Now, though, since the code has been assembled successfully, it is ready to be sent to the PIC. Following the screen instruction, press any key to return to the main menu.

Back in the main menu you will see that option 2, Program PIC with TASM Binary, now has a default file name beside it whereas before it just said NONE YET. The file name is basically the same as that just used, but now with a **.OBJ** ending instead of the **.ASM**, i.e. **C:\PIC\TKTEST1.OBJ**. The original Assemble default name is still shown as previously.

The **.OBJ** file is now ready to be sent to the PIC. But on this occasion, because we are assuming the PIC itself has never been used before, we must configure it to suit the application in which it is to be used.

During assembly, three other files are created as well, with extensions of **.ERR** (containing assembly error information if applicable), **.REF** (used only during assembly and of no user value), and **.LST** (showing the original **.ASM** text, hex values of the assembled codes, the PIC addresses at which they will be placed plus a text line count). At the end of the file, any error information is repeated, plus the values/names for all "equates" and labels.



*A typical screen display following assembly of a source code file to an object file.*

## NEXT MONTH

In Part 2 we reveal the rest of the sophisticated PIC programming options provide by Toolkit Mk2. The author's finding it to be a Dream Machine to work with!

(In the meantime – to exit the software, press Q from main menu. To restart from DOS type TK from the PIC directory.)

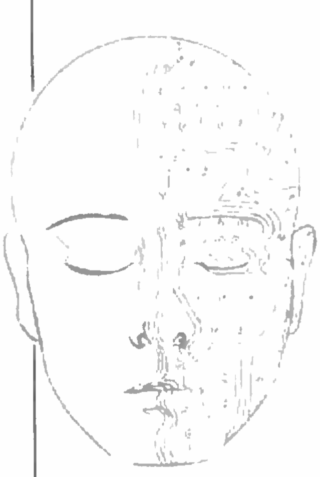
## RESOURCES

Software for PIC Toolkit Mk2 is available on 3.5-inch disk from the Editorial office and as a free download from the *EPE* web site – see *Shop Talk* column in this issue.

Data sheets for PIC devices are available from Microchip's web site at **http://www.microchip.com**.

Back Issues of *Toolkit Mk1* (July '98), the *PIC16F87x Review* (Apr '99) and reprints (back issues now all sold) of the *PIC Tutorial* articles of Mar-May '98 are available from the *EPE* Editorial office (see Back Issues page 385).

For details of the *PICtutor* CD-ROM see our *CD-ROMs for Electronics* page 364.



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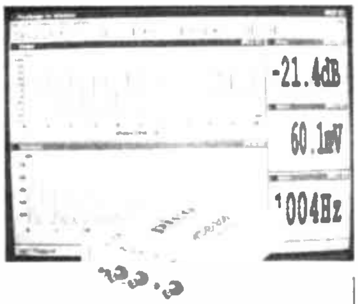




## Photo Slave Flash Unit – Flash Pictures

THE USE of a second "slave" flash as the main light enables the use of creative lighting effects in flash photography. By placing a second flash at, say, 45 degrees to the subject, shadows are formed to show its texture and form, and dramatic effects such as backlighting, strong side light etc. are also possible.

The flash on the camera fills in or softens the shadows made by the secondary flash. Using the circuit described in Fig.1, the camera flash also triggers the slave flash.

Firing of the camera flash is detected by a photo diode or phototransistor TR1. Capacitor C1 blocks the effect of A.C.-generated ambient light and allows only the pulse caused by firing the camera flash to reach the amplifier formed by transistor TR2 and resistors R3 and R4.

The amplified pulse is fed to the monostable formed by IC1, R5, C2 and C3. The fixed-length pulse produced by this is passed through resistor R6 and triggers thyristor CSR1. This shorts the two switch terminals of the secondary flash which fires.

The circuit works reliably in ambient light conditions ranging from full sunlight to a darkened room, and also responds to bounced flash. In practice that it is not necessary to point the sensor at the primary flash, giving greater scope for positioning the slave to give the best lighting effect.

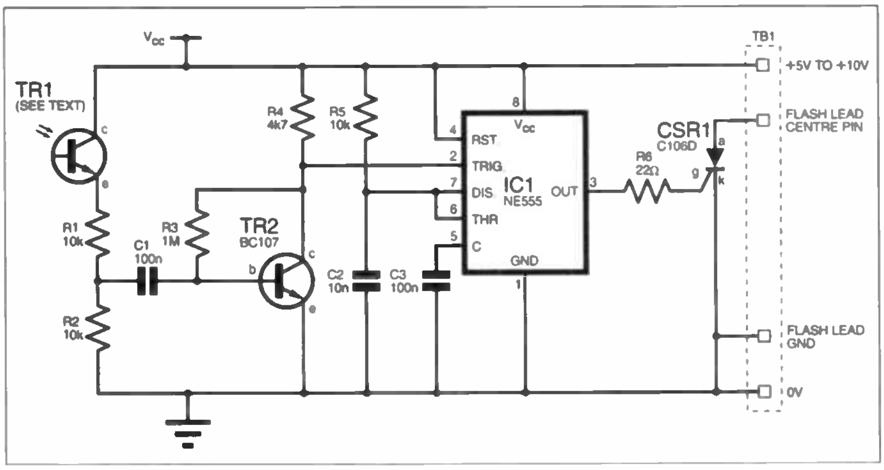


*Fig.1. Photo Slave Flash Unit circuit diagram.*

Component choice is not critical. TR1 has been tested using a variety of surplus photo diodes and phototransistors with consistent results. TR2 could be any general purpose *npn* silicon transistor. The circuit could either be powered from a 6V to 9V battery or from the flash gun's battery.

For further ideas, if TR1 were replaced by a microphone and amplifier the secondary flash could be triggered by sound. This would allow dramatic photographs of such things as breaking glass. A security camera could be developed to photograph burglars if the output from an intruder alarm replaced the photo sensor.

***Peter Taylor,***
***Mickleover, Derby.***

## Siren Sounder – Take Heed

A SIMPLE alarm circuit which is fun to build and will find many uses, perhaps as a warning device or as a novelty, is shown in Fig.2. The alarm is built around two 555 timers, which act as oscillators to produce a distinct two-tone effect. Note that only one resistor and capacitor is used on each oscillator.

Oscillator IC1 runs at a lower frequency than IC2. The low frequency signal generated by IC1 modulates the frequency of IC2 which changes the audio tone.

The output from IC2 at pin 3 is fed to the base of *pnp* transistor TR1, which amplifies the sound and drives the speaker, LS1. Resistor R4 limits the collector current.

The frequency and timing of each oscillator is dependent on R1 and C1 for IC1, and R3 and C2 for IC2 and these components could be changed to alter the note.

***P. Graham,***
***Yate, Bristol.***

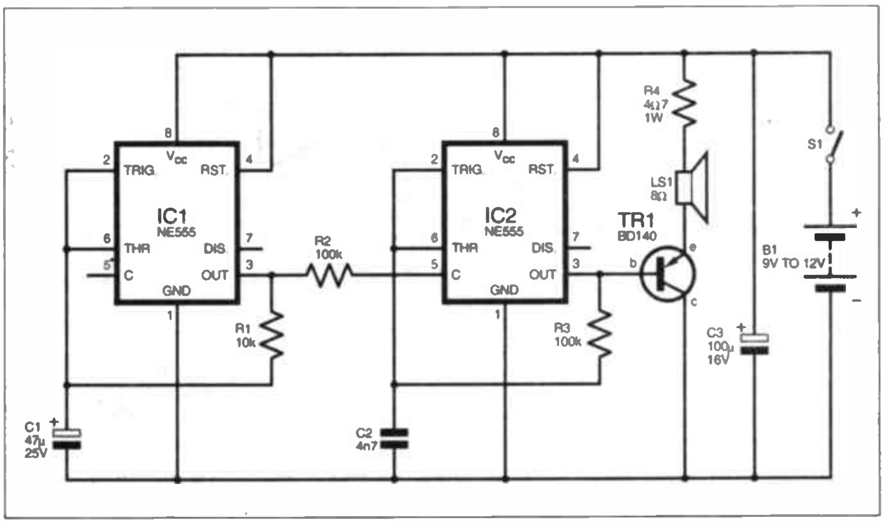


*Fig.2. Circuit diagram for a simple Siren Sounder.*

## Space Case Alarm – It's a Miracle.

SCHOOL pupils often use a strong plastic "space case" to house their ruler, pencils, etc. My young son wanted me to rig his space case with an alarm, so that it would go off when any other pupil opened the case without his permission. In the circuit diagram of Fig.3, IC1 is an inexpensive CMOS LSI melody generator, which comes in different versions (Christmas Jingles, Happy Birthday, etc.).

When a battery is connected, IC1 plays a melody once, then stops. While the sound is not very loud, it is certainly enough to attract the attention of a teacher! Switch S2 is a miniature slide switch which enables the pupil to set the alarm and is mounted inconspicuously in the side of the case, or even inside. Microswitch S1 triggers the alarm when the case is opened.

The battery is a small 3V lithium manganese cell which would probably give a year of use or more. Leads may be soldered directly to the battery but this must be done very rapidly, taking care to avoid excess heating. Use anti-static precautions when handling IC1 with care.

As simple as the design is, "dad" is delighted to report that other pupils were offering to pay my son's dad to construct a similar alarm for them, too!

*Rev. Thos. Scarborough, Fresnaye, Cape Town, RSA.*

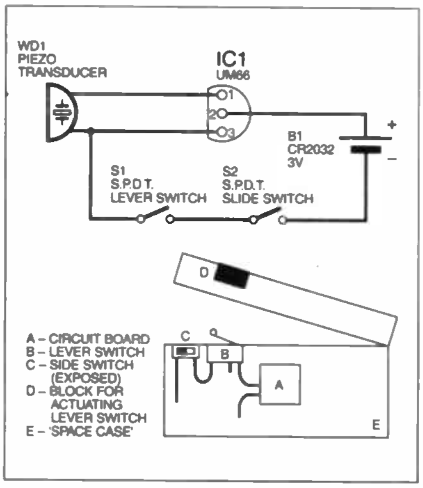


*Fig.3. Space Case Alarm.*

## PICO PRIZE WINNERS

It's time to decide the winners of superb PICO Technology PC-based oscilloscopes, once again generously donated by PICO (www.picotech.com) for three lucky entrants whom in our judgment submitted the best ideas published in the past six months. As always, every entry was judged on a number of criteria including the extent of "lateral thinking" or novelty, technical merit, resourcefulness, appropriateness, and overall completeness.

After careful consideration, *EPE* Editor Mike Kenward and *Ingenuity Unlimited* host Alan Winstanley finally selected the following winners:

**WINNER – receives an impressive PICO ADC200-50 PC Digital Storage Oscilloscope, *worth over £450!***

**Naseer Ahmad** – Using Solenoid Valves in Place of Motorised Valves (January 1999). An ingenious design based around a switched mode chip adapted for use in this control application.

**RUNNERS-UP** – both are lucky recipients of **PICO ADC-40 Single-Channel PC-Based Oscilloscopes.**

**Duncan Boyd** – Audio Limiter (April 1999). We felt this was a novel application for a limiting circuit which used a transconductance amplifier for the front end.

**J. D. Gray** – AF Sweep Signal Generator (February 1999). This design was thoroughly worked and presented.

**INGENUITY UNLIMITED**

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IU is *your* forum where you can offer other readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!

## Electronic Rotary Switch – A Good Substitute

IN THE circuit of Fig.4, a novel approach has been adopted for replacing mechanical rotary switches used in many types of circuit. A momentary push-to-make switch together with some electronics offers an option of making an electronic rotary switch to replace a mechanical one.

At power-on, a reset signal is applied by IC3a/b to reset IC1 and IC2. The output will be selected sequentially from Q0 to Q9 of IC2 and the selection will be advanced every time S1 is closed.

The R-S latch IC1 is used for switch debouncing and is set high every time S1 is pressed and reset after a delay generated by resistor R1 and capacitor C1. Hence it provides a debounced pulse, as a clock input to IC2.

The circuit acts similarly to a multi-way switch action for which a 4017 counter/divider has been used. The selection will be valid until the next switching action occurs.

When any Q output of IC2 is selected, it will be at a high state (logic 1). This can be used to activate a control pin of IC4 and turn a corresponding bilateral switch on. A 4016 Quad Bilateral Switch is used for this purpose.

At the bilateral switch output, the user's circuit can be interfaced as required, so that this circuit will offer a multi-way selection to the circuit. This could be useful in case of the selection of analogue signals which the 4016 can also handle. Digital circuits may be connected directly to the output of IC2.

A maximum of nine steps' selection is offered by the 4017. On every tenth switching, it will reset itself through IC3b and the cycle will repeat from Q0 onwards.

To provide fewer selections you can select Q outputs of your choice to reset the circuit. For instance, if you need only four selections, then connect Q4 (pin 10) to the OR gate IC3b pin 6 and now on every fifth selection the circuit will reset and start from Q0.

*B. D. Mehta, Ahmedabad, India.*

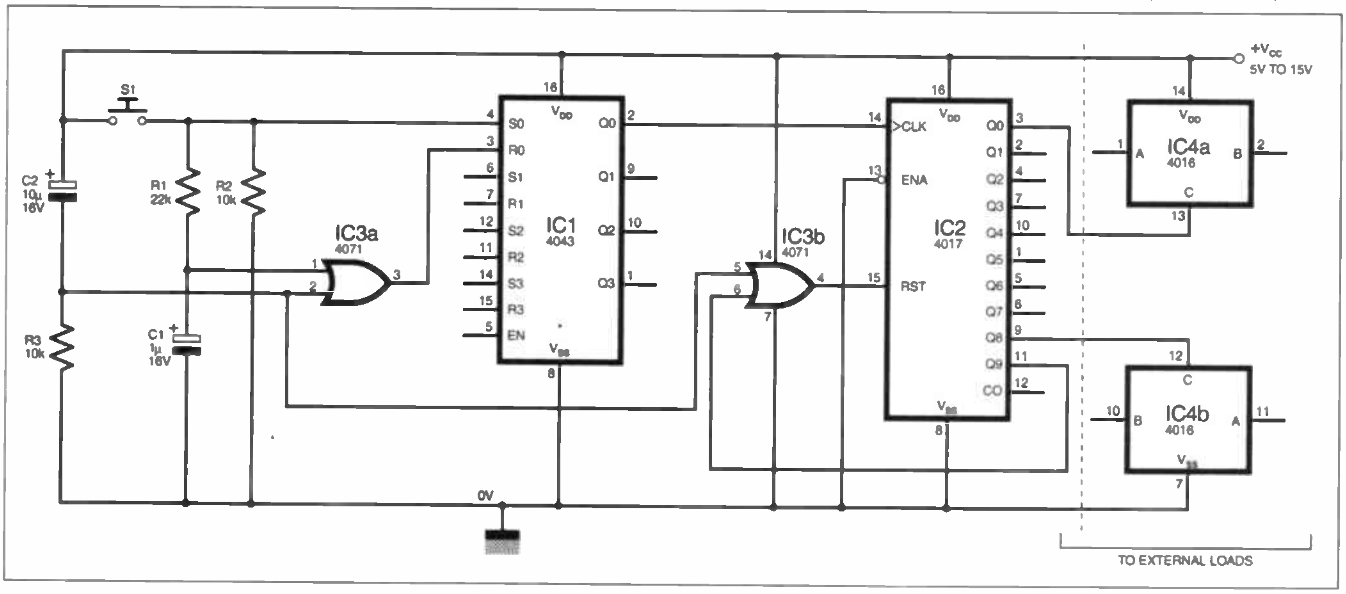


*Fig.4. Circuit diagram for an electronic rotary switch.*

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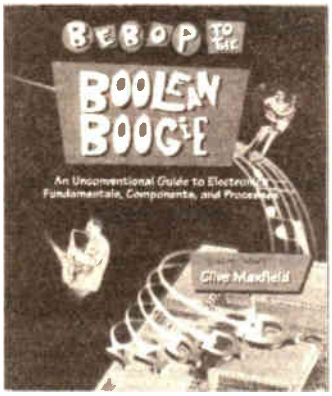


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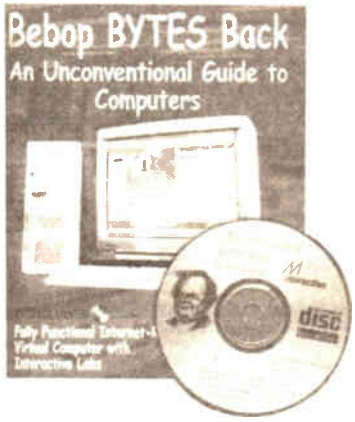


This follow-on to *Bebop to the Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers.

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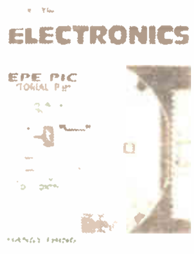


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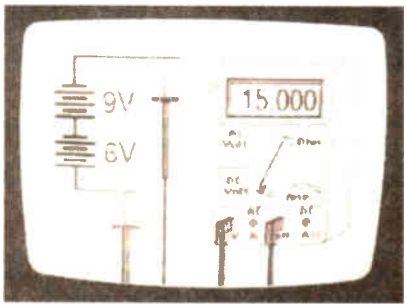


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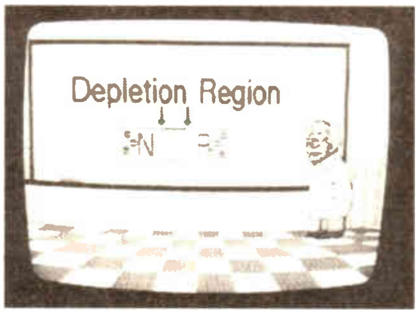


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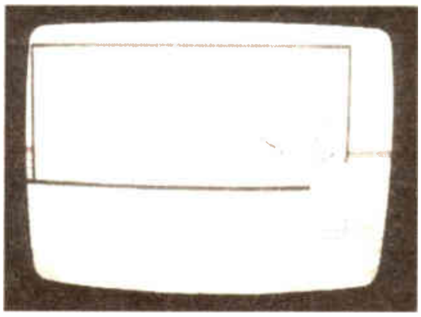

**Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes are imported by us and originate from VCR Educational Products Co, an American supplier.** (All videos are to the UK PAL standard on VHS tapes)

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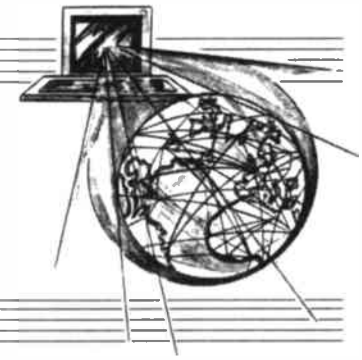

# NET WORK

## ALAN WINSTANLEY

*NET WORK* is our monthly column written for readers having access to the Internet. Don't forget that we maintain our own web site at **http://www.epemag.wimborne.co.uk**, and by using our Secure Server at **https://secure.tcp.co.uk/epemag**, readers can subscribe or renew their subscription on-line using Visa or Mastercard. The *EPE* Back Issues secure order form is a popular and convenient way of ordering reprints, issues and printed circuit boards.

New on the *EPE* web site is a web version of the history of both *Everyday Electronics* and its former sister magazine *Practical Electronics*, founded back in 1964. In his on-line article, Editor Mike Kenward describes how the magazines progressed from their early roots to merge into the leading UK hobby and educational magazine.

A separate illustrated section includes some fascinating screen shots of old issues and advertisements, also it shows some original cover shots of *Everyday Electronics*, and describes how the advent of affordable home computers in the mid 1980s was to have a profound impact in the future direction of the magazine. We hope you enjoy the feature.

### THE WORMS HAVE TURNED

Regular Internet users may have heard of the "Happy99" Windows "worm" which has been circulating the Internet. This month's *Net Work* looks at some of the risks faced by its users when fetching files from remote sites using E-mail, FTP or the web.

A worm first appeared on American networks on 2 November, 1988, when a student in Cornell University created what he thought was a harmless code which would replicate and grow on any susceptible Unix host computer. The worm would then seek to spread to other computers by exploiting the inherent weaknesses that existed at that time in government and research communications networks.

When the worm was unleashed the result was that American network systems – both military and academic – were eventually brought crashing to a halt, devastated by the way the worm propagated itself through the entire system, growing and choking up every computer in its path until the entire system locked up. Initial attempts to restore systems following this new form of attack were not entirely successful, because a "disinfected" system could soon be attacked again by other networks which were still under siege from what was later to be known as *The Internet Worm*.

### UNDER ATTACK

Many users are very casual about the risks involved in transmitting or receiving files by Internet. There are three forms of malicious code attack which computer users ought to be aware of, since the risks of becoming "infected" are now greater than ever given that file transmission via the Internet is commonplace.

A **worm** propagates itself from one host computer to another. The idea is simply that it copies itself at every opportunity. A worm is simply *there* but normally doesn't try to attack your system per se.

Trying to eliminate a worm may be difficult but usually a cure is found. **Happy99.exe** is a good example, discussed shortly. It can be propagated by being encoded into an E-mail, or can be transmitted via a Usenet post.

As reflected in its name, a **Trojan Horse** is a program which looks inviting and alluring: its perpetrators are trying to fool you into opening it and running it. Note that a Trojan Horse is not the same as a computer virus attack. The device may pretend to be a game or innocent-looking program, but behind the scenes it is busying itself by damaging the host computer setup.

How do you really know for definite that the file you just fetched from the Internet is really what it purports to be? Recently a Trojan Horse entitled **Picture.exe** was released which, amazingly, could sniff out and send AOL usernames and passwords from the host system to a particular remote E-mail address.

A computer **virus** can be intended to inflict deliberate damage on its host system. Virii can latch themselves on to genuine-looking program files, like bacteria infecting healthy tissue: the main program might continue to work but the virus can grow invisibly within the system and be transmitted to others – e.g. by residing on the hard disk or by infecting floppy disks – without the users' knowledge.

As to what happens after a virus attack, well it depends. There are thousands of viruses in circulation and when a host system contracts one of them, any number of effects can be observed, from the computer gradually slowing down because its memory is being filled, to files becoming corrupted, a system behaving bizarrely on a particular day (e.g. Friday the 13th) or – worst case scenario – a complete trashing of a hard disk. (You do back up important data every day, don't you?)

### DON'T PANIC

Probably the most common virus I come across is ***Form***, which tends to be introduced on dubious-looking floppy disks. Some variants wake up on the eighteenth of every month and display a "Don't Panic" message. Other attempted virus attacks include an innocent one (I assume) contained in a reader's floppy disk that arrived in the post. Fortunately my anti-virus software detected the presence of *Tan Pro 524* immediately.

Occasionally, a figment called the **Good Times** virus springs up, appearing in the form of a "damaging" E-mail message. This can cause novices great concern. The subject line of the E-mail threatens that the virus will harm the host system if it is opened and read.

*Good Times* is a hoax. If anything, it's the actual propagation of the E-mail message by worried users which is the "virus". Let me emphasise one thing: *you can't damage your system or introduce a virus merely by reading an E-mail message. You can, however, introduce a worm or a damaging virus by "running" an attached executable code.*

The worm **Happy99** (Happy New Year, right?) may appear as an attachment called **happy99.exe** in E-mail messages and it is very tempting to run the Windows executable file just to see what happens. This has actually struck uncomfortably close to home, since an E-mail message from an "official" software support technician to my brother did indeed have the **Happy99** worm attachment. The software vendor had been attacked by the worm and an employee must have run it, thereby propagating the worm onto its customers' systems. Worried Windows users can check for its presence by looking for a file called **ska.exe** or **wsock32.ska**. (The Symantec web site offers a cure.)

### UPDATE

The best defence in this warfare is to keep updated with an anti-virus package such as Symantec's *Norton Anti Virus*, which was one of the first to carry details of **Happy99**. Subscribe to updates if you value your data: Norton permits a series of monthly updates which can be obtained by a "Smart Update" direct modem transfer (no Internet connection being used necessarily, you notice). You can also submit suspicious program files to Norton for examination.

There are several good anti-viral (AV) resources on the web. The first is **www.symantec.com/avcenter**, the leading Symantec site with lots of data, including information on **Happy99**. Other respected vendors of AV protection include **www.mcafee.com, www.drsolomon.com, www.av.ibm.com** (an IBM-Symantec joint venture) and **www.datafellows.com**. Macintosh users could try **www.macvirus.com**. If your work depends on the Internet or dealing with files from external sources, you should sign up to an anti-virus update system today.

As usual the URLs mentioned above (and more besides) are already enabled on the *EPE* web site – go straight to my *Net Work* page and click. Suggestions for good electronics-related web resources are always welcome – please E-mail yours to **alan@epemag.demon.co.uk**.

# PCBs FROM PAST ISSUES OF ETI

(prior to the merger of EPE and ETI in March 99). See opposite page for ordering details.

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***EPE*** FTP site: **ftp://ftp.epemag.wimborne.co.uk**
Access the FTP site by typing the above into your web browser, or by setting up an FTP session using appropriate FTP software, then go into quoted sub-directories:

PIC-project source code files: **/pub/PICS**

PIC projects each have their own folder; navigate to the correct folder and open it, then fetch all the files contained within. *Do not try to download the folder itself!*

*EPE* text files: **/pub/docs**
*Basic Soldering Guide:* **solder.txt**
*EPE TENS Unit* user advice: **tens.doc** and **tens.txt**
*Ingenuity Unlimited* submission guidance: **ing_unit.txt**
New readers and subscribers info: **epe_info.txt**
Newsgroups or Usenet users advice: **usenet.txt**
Ni-Cad discussion: **nicadfaq.zip** and **nicad2.zip**
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Note that any file which ends in **.zip** needs unzipping before use. Unzip utilities can be downloaded from :
**http://www.winzip.com** or
**http://www.pkware.com**

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