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EVERYDAY

MAY 1998

**PRACTICAL**

# ELECTRONICS

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**ELECTROMAGNETIC GUN PLANS** Projects a metal object a considerable distance- requires adult supervision. £5 ref F/EML2.

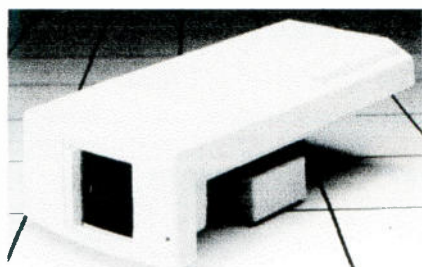
**ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND!** £5/set Ref F/EMA1.

**SOLAR POWERED WIND UP RADIOS BACK IN!** These FM/AM radio's have a solar panel and a hand operated charger! £17.95 ref SOLRAD

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**CIRCUIT PACKS** Packs of 35 circuit diagrams covering lasers, SW radios, geigers, bugs, char etc. Pack1, Pack2, Pack3 £4.99 each. **SMOKE ALARMS** Mains powered, made by the famous Gert company, easy fit next to light fittings, power point. £4.99 ref SMIKX **CONVERT YOUR TV INTO A VGA MONITOR FOR £26!** Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and software. Ideal for laptops or a cheap upgrade. Supplied in kit form for home assembly. SALE PRICE £25 REF SA34

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**SOLAR NIGAD CHARGERS** 4 x AA size £9.99 ref 6P476, 2 x C size £9.99 ref 6P477

**GIANT HOT AIR BALLOON KIT** Build a 4.5m circumference, fully functioning balloon, can be launched with home made burner etc. Reusable (until you loose it!) £12.50 ref HA1

**AIR RIFLES** .22 As used by the Chinese army for training purposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80.

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**HI POWER ZENON VARIABLE STROBES** Useful 12v PCB fitted with hi power strobe tube and control electronics and speed control potentiometer. Perfect for interesting projects etc. 70x55mm 12vdc operation. £6 ea ref FLS1, pack of 10 £49 ref FLS2

**RUSSIAN BORDER GUARD BINOCULARS** £1799 Probably the best binoculars in the world! ring for colour brochure.

**NEW LASER POINTERS** 4.5mw, 75 metre range, hand held unit runs on two AA batteries (supplied) 670nm. £29 ref DEC49

**HOW TO PRODUCE 36 BOTTLES OF WHISKY FROM A SACK OF POTATOES** Comprehensive 270 page book covers all aspects of spirit production from everyday materials. Includes construction details of simple stills etc. £12 ref MS3

**NEW HIGH POWER MINI BUG** With a range of up to 800 metres and a 3 days use from a PP3 this is our top selling bug! less than 1" square and a 10m voice pickup range. £28 Ref LOT102

**BUILD YOU OWN WINDFARM FROM SCRAP** New publication gives step by step guide to building wind generators and propellers. Armed with this publication and a good local scrap yard could make you self sufficient in electricity! £12 ref LOT81

**NEW LOW COST VEHICLE TRACKING TRANSMITTER KIT** £29 range 1.5-5 miles, 5,000 hours on AA batteries, transmits info on car direction, left and right turns, start and stop information

Works with any good FM radio. £29 ref LOT101a

**CCTV CAMERA MODULES** 46X70X29mm, 30 grams, 12v 100mA auto electronic shutter, 3.6mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

**IR LAMP KIT** Suitable for the above camera, enables the camera to be used in total darkness! £6 ref EF138

**UK SCANNING DIRECTORY** As supplied to Police, MOD, M15 and GCHQ! covers everything from secret government frequencies, eye in the sky, prisons, military aviation etc. £18.50 ref SCANB

**INFRA RED POWERBEAM** Handheld battery powered lamp, 4 inch reflector, gives out powerful pure infrared light! perfect for CCTV use, night sights etc. £29 ref PB1.

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& rear waveguides, 1.1"x2.7"x4.6" fits on sun visor or dash. £149 ref

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Could be adapted for laser listener, long range communications etc. Double beam units designed to fit in the gun barrel of a tank, each unit has two semi conductor lasers and motor drive units for alignment. 7 mile range, no circuit diagrams due to MOD, new price £50,000? us? £199. Each unit has two gallium Arsenide injection lasers, 1 x 9 watt, 1 x 3 watt, 900nm wavelength, 28vdc, 600hz pulse frequency. The units also contain an electronic receiver to detect reflected signals from targets. £199 for one. Ref LOT4.

**NEW LOW PRICED COMPUTER/WORKSHOP/HI-FI RCB UNITS** Complete protection from faulty equipment for everybody! Inline unit fits in standard IEC lead (extends it by 750mm), fitted in less than 10 seconds, reset/test button, 10A rating. £6.99 each ref LOT5. Or a pack of 10 at £49.90 ref LOT6. If you want a box of 100 you can have one for £250!

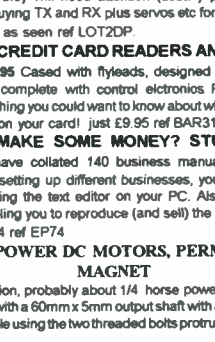
**DIGITAL PROPORTIONAL B GRADE RADIO CONTROLLED CARS** From World famous manufacturer these are returns so they will need attention (usually physical damage) cheap way of buying TX and RX plus servos etc for new projects etc. £20 each sold as seen ref LOT2DP.

**MAGNETIC CREDIT CARD READERS AND ENCODING MANUAL** £9.95 Cased with flyleads, designed to read standard credit cards! complete with control electronics PCB and manual covering everything you could want to know about what's hidden in that magnetic strip on your card! just £9.95 ref BAR31

**WANT TO MAKE SOME MONEY? STUCK FOR AN IDEA?** We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is the certificate enabling you to reproduce (and sell) the manuals as much as you like! £14 ref EP74

**HIGH POWER DC MOTORS, PERMANENT MAGNET**

12-24v operation, probably about 1/4 horse power, body measures 100m x 75mm with a 60mm x 5mm output shaft with a machined flat on it. Fixing is simple using the two threaded bolts protruding from the front



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

Cover Photo - Andrew Syred / Science Photo Library. Coloured scanning electron micrograph of circuit paths on a microprocessor chip at a magnification of over 2,000 times

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MAY 1998

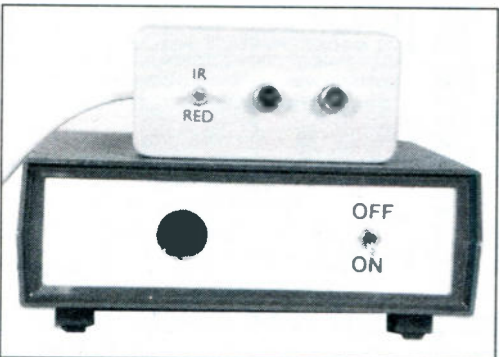
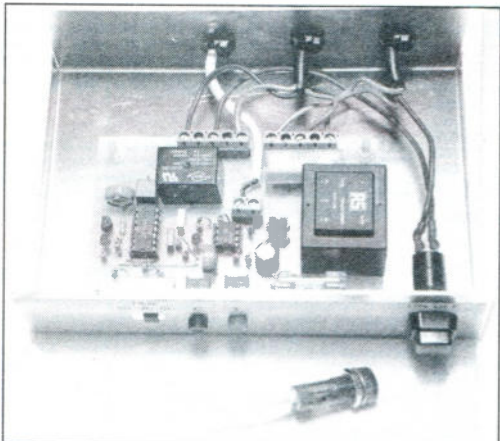
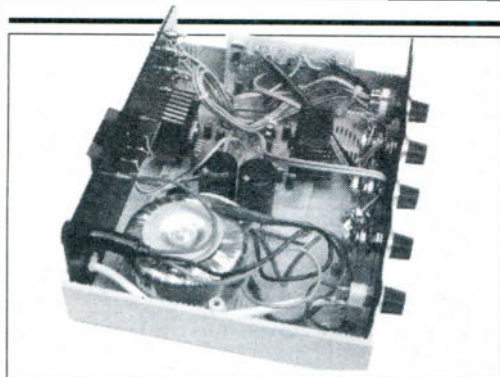
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The No. 1 Magazine for Electronics Technology  
and Computer Projects



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## FREE

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Our June '98 issue will be published on Friday, 1 May 1998. See page 323 for details.

Everyday Practical Electronics, May 1998

Surplus always wanted for cash!

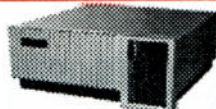
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Table listing various floppy disk drives and prices: 3 1/2" Panasonic JU363/4 720K or equivalent RFE £24.95 (B), 3 1/2" Mitsubishi MF355C-L 1.4 Meg. Laptops only £25.95 (B), etc.

HARD DISK DRIVES

Table listing various hard disk drives and prices: 2 1/2" TOSHIBA (19 mm H) MK2101MAN 2.16 Gb. New £199.00, 2 1/2" TOSH (12.5 mm H) MK1002MAV 1.1 Gb laptop. New £115.00, etc.

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TV SOUND & VIDEO TUNER CABLE COMPATIBLE

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Table listing TELEBOX models and prices: TELEBOX ST for composite video input type monitors £38.95, TELEBOX STL as ST but fitted with integral speaker £39.50, TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner £69.95

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LENT little used condition. Order as T18 & Swivel Base £4.75 Only £119 (E) Order as VEGA cable for IBM PC included. MITS-SVGA External cables for other types of computers CALL.

As New - Ex Demo

17" 0.28 SVGA Mitsubishi Diamond Pro monitors Full multisync etc. Full 90 day guarantee. £325.00 (E)

Just in - Microvitec 20" VGA (800 x 600 res.) colour monitors. Good SH condition - from £299 - CALL for info

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PHILIPS HCS31 Ultra compact 9" colour video monitor with standard composite 15.825 Khz video input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive a/cure black plastic case measuring W10" x H10" x 13 1/2" D. 240 V AC mains powered. Only £79.00 (D)

KME 10" 15M10009 high definition colour monitors with 0.28" dot pitch. Superb clarity and modern styling. Operates from any 15.825 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13 1/2" x 12" x 11". Good used condition. Only £125 (E)

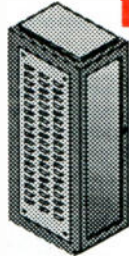
20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & optional sound input. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc. In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

SPECIAL INTEREST ITEMS

- Table listing various special interest items and prices: MITS. FA3445ETKL 14" Industrial spec SVGA monitors £245, IBM 6230 Type 1, Token ring base unit driver £760, Wayne Kart RAG20 Audio frequency response analyser £750, etc.



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Top quality 19" rack cabinets made in UK by Optima Enclosures Ltd. Units feature designer, smoked acrylic lockable front door, full height lockable half lowered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the most versatile we have ever sold. Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays.

Overall dimensions are: 77 1/4" H x 32 3/4" D x 22" W. Order as: OPT Rack 1 Complete with removable side panels. £345.00 (G) OPT Rack 2 Rack. Less side panels £245.00 (G) Over 1000 racks, shelves, accessories 19" 22" & 24" wide 3 to 46 U high. Available from stock !!

32U - High Quality - All steel RakCab

Made by Eurocraft Enclosures Ltd to the highest possible spec, rack features all steel construction with removable side, front and back doors. Front and back doors are hinged for easy access and all are lockable with five secure S lever barrel locks. The front door is constructed of double walled steel with a 'designer style' smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members to take the heaviest of 19" rack equipment. The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A mains distribution panel internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin switched utility socket. Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvers. The top panel may be removed for fitting of integral fans to the sub plate etc. Other features include: fitted castors and floor levelers, pre-punched utility panel at lower rear for cable / connector access etc. Supplied in excellent, slightly used condition with keys. Colour Royal blue. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23 3/4" W.) Sold at LESS than a third of makers price !!

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SIMM SPECIALS

Table listing SIMM prices: 1 MB x 9 SIMM 9 chip 120ns Only £8.50, 1 MB x 9 SIMM 3 chip 80 ns £10.50 or 70ns £11.95, etc.

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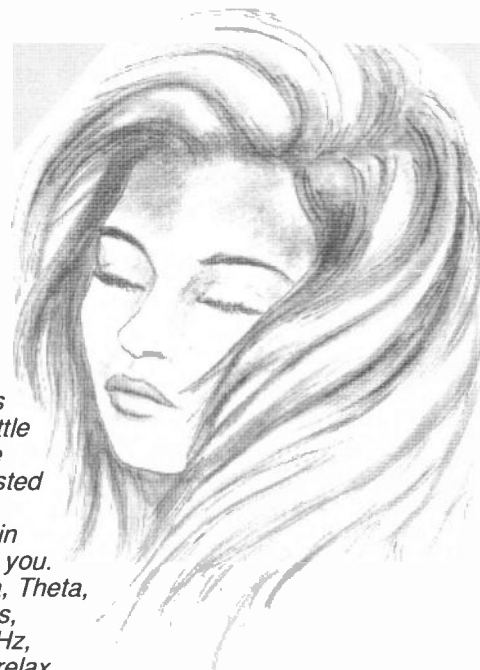
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# NEXT MONTH



## 8051-BASED EEPROM MICROCONTROLLERS

Over the last couple of years or so, we have seen ample evidence of how single chip microcontrollers, such as those in the PIC family, can greatly simplify electronic design.

PICs, though, are not the only family available, indeed there are many families from a variety of manufacturers. One such family is that based on Atmel's 8051 microcontroller and within it are two devices especially useful to the hobbyist designer. These are the AT89C2051 and AT89C1051 micros, which are EEPROM-based and have 2K and 1K bytes of program memory respectively.

In a two-part article next month, we examine the 8051 family, with especial emphasis on the 2051 and 1051, discuss its programming needs and then describe the construction of a circuit which allows you to program the latter devices from your PC-compatible computer. We conclude with the construction of an experimental board that you can use to get to know these interesting and extremely versatile microcontrollers.



## MOOD CHANGER

An experimental electromagnetic field generator that simulates and theoretically stimulates various brainwaves. This little gadget has achieved some interesting results when tested by the author.

If you have any interest in entrainment then this is for you. It can be adjusted for Delta, Theta, Alpha and Beta frequencies, i.e. between 0.5Hz and 25Hz, and might help you sleep, relax or get your brain in gear.

## SIMPLE SHORT WAVE RECEIVER

We have probably reached the stage where it is not possible for the home constructor to genuinely compete with sophisticated ready-made short wave receivers, but this is not to say that it is not possible for the enthusiast to enjoy building and using them.

The more traditional forms of receiver will not give the same level of performance as a ready-made set costing hundreds or even thousands of pounds, but simple sets are still capable of receiving numerous transmissions from all over the world. Whether you are looking for a low cost introduction to short wave listening, or have used expensive equipment and would like to try something more challenging and rewarding, a basic do-it-yourself receiver has a lot to offer.

This Simple Short Wave Receiver project covers a frequency range of about 5MHz to 15MHz, which includes the most popular short-wave broadcast bands. It is also possible to plug in alternative coil units which bring in coverage of the low frequency bands around 1.6MHz to 5MHz, and the high frequency bands from 15MHz to 30MHz.

## REACTION TIMER

Test your reaction time to a resolution of 0.1 milliseconds. Do you believe a drink or two won't affect you – this will prove you wrong! This simple, low cost PIC-based project will provide hours of fun and can also be used for serious research work into reaction times.

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## DID YOU MISS THESE?

### DEC '96

**PROJECTS** ● Vari-Colour Christmas Tree Lights ● PIC Digital/Analogue Tachometer ● Stereo Cassette Recorder ● EPE Elysian Theremin, Part 2.  
**FEATURES** ● Build Your Own Projects, Part 2 ● Interface ● Circuit Surgery ● Ingenuity Unlimited ● Net Work - Internet News.

### JAN '97

**PROJECTS** ● Earth Resistivity Meter, Part 1 ● Psycho Rat ● Theremin MIDI/CV Interface, Part 1 ● Mains-Failure Warning.  
**FEATURES** ● Ingenuity Unlimited ● Build Your Own Projects, Part 3 ● Circuit Surgery ● Interface ● Net Work - Internet News ● PCS32 Storage 'Scope Interface Review.

### FEB '97

**PROJECTS** ● Pacific Waves ● How To Use Intelligent L.C.D.s, Part 1 ● PsiCom Experimental Controller ● Earth Resistivity Meter, Part 2 ● Theremin MIDI/CV Interface, Part 2.  
**FEATURES** ● Ingenuity Unlimited ● Build Your Own Projects, Part 4 ● Circuit Surgery ● Interface ● Net Work - Internet News.

### MARCH '97

**PROJECTS** ● Simple Dual-Output TENS Unit ● Video Negative Viewer ● Tri-Colour NiCad Checker ● How To Use Intelligent L.C.D.s - 2 ● Oil Check Reminder.  
**FEATURES** ● Interface ● Ingenuity Unlimited ● Build Your Own Projects, Part 5 ● Digital TV - The Reality ● Circuit Surgery ● Net Work.

### APRIL '97

**PROJECTS** ● 418MHz Remote Control System ● Midi Matrix ● Puppy Puddle Probe ● PIC-Agoras Wheelie Meter - 1.  
**FEATURES** ● Interface ● Ingenuity Unlimited ● Digital TV and MPEG2 ● EDWin NC Software Review ● Circuit Surgery ● Net Work.

### MAY '97

**PROJECTS** ● 2 Metre F.M. Receiver ● EPE PIC-A-Tuner ● Alarm Operated Car Window Winder ● Quasi-Bell Door Alert ● PIC-Agoras - 2.  
**FEATURES** ● Ingenuity Unlimited ● Circuit Surgery ● Techniques - Actually Doing It ● Great Experimenters - 1 ● Type 7660 Voltage Converters ● Net Work.



### JUNE '97

**PROJECTS** ● PIC Digilogue Clock ● Child Minder Protection Zone ● Pyrotechnic Controller ● Narrow Range Thermometer.  
**FEATURES** ● Great Experimenters - 2 ● Circuit Surgery ● Interface ● Reactobot and Virtual Reality ● Ingenuity Unlimited ● Net Work.

### JULY '97

**PROJECTS** ● Micro PESt Scarer ● Karaoke Echo Unit ● Infra-Red Remote Repeater ● Computer Dual User Interface ● Micropower PIR Detector - 1.  
**FEATURES** ● Ingenuity Unlimited ● Techniques - Actually Doing It ● Circuit Surgery ● Great Experimenters - 3 ● Electronics Workbench V5.0 Review ● Net Work.

### AUG. '97

**PROJECTS** ● Variable Bench Power Supply ● PIC-olo Music Maker ● Universal Input Amplifier ● Micropower PIR Detector - 2.  
**FEATURES** ● Interface ● Ingenuity Unlimited ● Colossus Recreated ● Circuit Surgery ● Great Experimenters - 4 ● Net Work.

### SEPT '97

**PROJECTS** ● PIC-Noughts & Crosses Game ● Ironing Safety Device ● Active Receiving Antenna ● Soldering Iron Controller ● Micropower PIR Detector - 3.  
**FEATURES** ● Ingenuity Unlimited ● Raising the Pressure - RC4190 Switch-Mode I.C. ● Circuit Surgery ● Techniques - Actually Doing It ● Great Experimenters - 5 ● Net Work.



### OCT '97

**PROJECTS** ● PIC Water Descaler ● Remote Control Finder ● Multi-Station Quiz Monitor ● Rechargeable Handlamp.  
**FEATURES** ● Ingenuity Unlimited ● It's Probably Murphy's Law ● Interface ● Circuit Surgery ● Kanda PIC Explorer Review ● Network

### NOV '97

**PROJECTS** ● Portable 12V PSU/Charger ● Case Alarm ● Auto-Dim Bedlight ● EPE Time Machine.  
**FEATURES** ● Satellite Celebration ● Ingenuity Unlimited ● TEACH-IN '98 - An Introduction to Digital Electronics-1 ● Techniques - Actually Doing It ● Circuit Surgery ● Net Work ● Free Greenweld Catalogue.

### DEC '97

**PROJECTS** ● Safe and Sound - Security Bleeper ● Active Microphone ● Car Immobiliser ● Mini Organ.  
**FEATURES** ● TEACH-IN '98 - An Introduction to Digital Electronics-2 ● Circuit Surgery ● Interface ● B<sup>2</sup> Spice Review ● Ingenuity

Unlimited ● Alternative and Future Technologies-1 ● Net Work - The Internet ● Free Giant Data Chart - Formulae.

### JAN '98

**PROJECTS** ● Disco Lights Flasher ● Simple M.W. Radio ● EPE Virtual Scope-1 ● Surface Thermometer.  
**FEATURES** ● TEACH-IN '98 - An Introduction to Digital Electronics-3 ● Circuit Surgery ● Ingenuity Unlimited ● Alternative and Future Technologies-2 ● Net Work - The Internet ● Free - Giant PIC Data Chart.



### FEB '98

**PROJECTS** ● Water Wizard ● Kissometer ● Waa-Waa Effects Pedal ● EPE Virtual Scope - 2.  
**FEATURES** ● TEACH-IN '98 - An Introduction to Digital Electronics - 4 ● Ingenuity Unlimited ● Techniques-Actually Doing It ● Circuit Surgery ● Net Work - The Internet ● Chip Special - HT7630 PIR Controller.

### MAR '98

**PROJECTS** ● Lighting-Up Reminder ● The Handy Thing ● Switch-Activated Burglar Alarm ● Audio System Remote Controller.  
**FEATURES** ● Teach-In '98 - An Introduction To Digital Electronics-5 ● Ingenuity Unlimited ● Interface ● Stripboard Magic Review ● Circuit Surgery ● Net Work ● EPE PIC Tutorial Supplement 1

### APRIL '98

**PROJECTS** ● Simple Metal Detector ● Single or Dual Tracking Power Supply ● Experimental Piezo-Cable Projects - Distributed Microphone - Vibration Alarm ● RC-Meter  
**FEATURES** ● Ingenuity Unlimited ● Patent Your Invention ● Teach-In '98 - An Introduction To Digital Electronics - 6 ● Circuit Surgery ● Net Work ● Techniques - Actually Doing It ● EPE PIC Tutorial Supplement 2

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**PINHOLE CAMERA MODULE WITH AUDIO!** Superb board camera with on board sound! extra small just 28mm square (including microphone) ideal for covert surveillance. Can be hidden inside anything... even a matchbox! Complete with 15 metre cable, psu and tv/rca connectors. £73.95 ref C66

**BBC SELECTORS WITH SMART CARD SLOT AND VIDEO CRYPT** Interesting new item in this week is this Selector. Originally made for the BBC to send encrypted video films to your VCR at night time. The project seems to have failed. Very complex units consisting of a smart card slot in the front plus several switches and an IR receiver. Fully cased and measuring 230 x 430 x 90mm, new and boxed. On the back of the unit is a smart socket plus a UHF input and output. A channel tuning control numbered 28 to 40 and an IR socket. Inside is a comprehensive tuner section, smart card reader mechanism and control electronics plus a power supply section. These units are sold as strippers but we imagine you could use one to convert a monitor into a TV or maybe use the videocrypt side of things for something else. Supplied complete with manual and mains lead. Clearance price just £9.95 ref BBC1X.

**INLINE RCB UNIT** This in line miniature earth leakage unit instantly shut off the mains supply in the event of any current flowing between live and earth thus preventing a potentially lethal shock. IEC plug one end, socket the other, fitted in seconds, reset button. The ultimate safety aid when working on electronic equipment, computers etc. As these units are fitted with an in-line IEC plug on one end and socket on the other than could even be used to extend standard IEC computer leads. Pack of 3 £9.99 ref L075A

**THE ULTIMATE ENCLOSURE** for your projects must be one of these! Well made ABS screw together beige case measuring 120 x 150 x 50mm. Already fitted with rubber feet and front mounted LED. Inside is a pcb fitted with other bits and pieces you may find useful. Sold either as a pack of five for £10 ref MD1, pack of 20 for £19.95 ref MD2 **17 WATT 12V SOLAR PANEL** A solar panel designed to give a nominal 12v. The solar cells are laminated within a high quality resin material which offers excellent protection against UV and moisture. Mounted on tempered glass in an aluminium frame. The panel is ideal for charging sealed lead acid batteries and a protection diode in the circuit prevents reversed current flow. Mounting is by four adjustable hooks and connection is by screw terminals. Max power 17 watts, 35 cells, 17vdc peak, 423x40x215mm, 1000mA max, 1.9kg. Solar panel £115 ref SOL4

**SOLAR POWERED AM/FM RADIO** A compact, AM/FM mono radio complete with earphone and a solar panel that recharges the built-in battery when placed in direct sunlight or under a strong lamp. It features a rotary Volume/On/Off control (which must be set to 'Off for recharging), AM/FM selector switch, rotary tuning control, metal belt clip and socket for external 3V DC supply. **Solar Radio £7.95 ref SR23** **MOTOR CYCLISTS RADAR DETECTOR** New in the Whistler 1560 Laser/Radar detector complete with a speaker for motorcycle helmets. Super wide band covering X, K and Ka plus lasers at 950nm +/- 10nm. 360 deg total perimeter protection, detects laser, radar and VGT-2 wherever they come from. £159.95 ref RD4

**MAGIC EAR** Unlike previous 'sound-magnifiers' we have offered, Magic Ear fits unobtrusively behind the ear itself. Magic Ear's micro technology is very advanced. Its built-in microphone is extremely sensitive and there's also a volume control to help you adjust to all conditions in use. Magic Ear is startlingly effective. It'll help you to follow every word of conversation even at a distance, and enjoy theatre, cinema or live music with stunning new sound. Comes fitted with 3 long life batteries, a free travel pouch, plus a choice of 3 different ear pieces designed to fit all shapes of ear. **Magic ear £16.99 ref MAGE3**

**RADIO METER** Perhaps the best of the scientific knick-knacks of the past and well overdue for revival! Fascinating, soothing and educational. In the vacuum inside the inverted bulb like container the vanes revolve, driven round by light particles alone! (each vane is black on one side white on the other) **Radiometer £9.99 ref SC120B**

**SATELLITE NAVIGATION £119** The GARMIN- GPS 38- is the one navigational tool for the great outdoors that offers big features in a small, lightweight package - all at a truly affordable price. Mark your favourite fishing spot, tree stand or camp site. Or retrace your steps back to the safety of your starting point using our all-new TracBack feature. The GPS 38 shows you exactly where you are, where you've been and where you're going. The GPS 38 features easy, one-thumb operation and weighs only 255g. There's a resettable trip odometer, graphic compass, and highway steering guidance. And it provides up to 20 hours of use on a set of 4 AA batteries. The GARMIN GPS 38. The affordable way to bring you back. £119 ref GPS1

**DIFFERENTIAL THERMOSTAT KIT** An electronic self assembly kit designed for use in solar heating systems, heat recovery systems etc. The principle of the kit is that it has two thermostats that are placed on the items to be measured (typically a solar panel and a water storage tank) the controller then operates a relay all the time one temperature is higher than the other. The temperature difference is adjustable. A typical use would be to operate a pump all the time a solar panel was at a higher temperature than the water storage tank. **Differential thermostat kit £29 ref L073.**

**10 WATT SOLAR PANEL** Amorphous silicon panel fitted in a anodized aluminium frame. Panel measures 3' by 1' with screw terminals for easy connection. One of these panels will run our solar water pump in full sunlight although we would recommend that for optimum performance two panels would be preferable. 3' x 1' solar panel £55 ref MAG45

**12V SOLAR POWERED WATER PUMP** Perfect for many 12v DC uses, ranging from solar fountains to hydroponics! Small and compact yet powerful. Will work direct from our 10 watt solar panel in bright sunlight. Max head: 17ft Max flow rate: .8 lpm Current: .1 5A (Ref AC8) £18.99

**BOOST CELL PHONE RECEPTION ON THE MOVE!** Compared to high-powered carphones, hand-portable mobile phones don't always work too well in moving vehicles. Sometimes the signal 'drops out' during a call, other times there's too much interference to get through at all. However, the affordable Cell Patch provides a major improvement, dramatically boosting signal reception without wires or batteries. The 9.5 x 9.5cm (3.3" x 3.3") microthin antenna adheres to your car window sunvisor, ideally within 61-122cm (2-4') of the handset, or can be carried in a pocket. Works with all types of portable cellular phone. Cell Patch £11.99 ref CEL1

**CAT SCARER** produces a blanket of high sonic and low ultrasonic sound, which is inaudible to humans, birds and fish - so it is ideal where you want to protect your bird table or fish pond against feline predators. It will deter cats from your garden and other protected areas. It will also deter foxes. Mains operated, 10 m of cable. Running cost will be approximately 1 p per day. Garden watcher £42.45 ref GW2

**VIDEO PROCESSOR UNITS? 76v 10AH BATT/24V BA**

**TX** Not too sure what the function of these units is but they certainly make good strippers! Measures 390x320x120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear. Inside 2x6v 10AH sealed lead acid batts, pcb's and a 8A? 24v toroidal transformer (mains in). sold as seen, may have one or two broken knobs etc due to poor storage. £9.95 ref VP2X

**SOLAR MOTORS** Another new line for us are these tiny motors which run quite happily on voltages from 3-12vdc. We have tried one on our 6v amorphous 6" panels and you can run them from the sun! 32mm dia 20mm thick. £1.50 each

**TELEPHONES** Just in this week is a huge delivery of telephones, all brand new and boxed. Two piece construction with the following features- illuminated keypad, nice clear easy to use keypad, tone or pulse (switchable), recall, redial and pause, high/low and off ringer switch and quality construction. Each telephone is finished in a smart off white colour and is supplied with a standard international lead (same as US or modern card sockets) if you wish to have a BT lead supplied to convert the phones these are also available at £1.55 each ref BTLX Phones £4.99 each ref PH2

**INFRARED CAR PHONE KIT £7.99** Interesting box of goodies! This kit was designed to convert car phones to enable hands free dialling, the kit contains the following items. 1) A keypad designed to mount in the centre of the steering wheel, it requires a 9v PP3 battery and transmits the numbers using three on board high power infra red LEDs. 140 x 120mm. 2) An infra red receiver module containing a IR photo diode, IR filter and control electronics. 80 x 30 x 15mm (cased). 3) Control box (nice case) 100 x 170 x 35mm which we understand is the interface between the infra red and the car phone, it is also supposed to adjust the volume of your car stereo at the same time made for Phillips car phones (but we don't know the model) Complete kit is £7.99 ref CP1

**Hi power 12v xenon strobe variable rate flasher modules and tubes** £6! Useful 12v PCB fitted with control electronics and a powerful Xenon tube! Just apply 12v DC to the input and the tube will flash. On the board is a small potentiometer which can be used to vary the flash rate! PCB measures just 70x 55mm and could be incorporated into many interesting projects! £6 ref FLS1 Pack of 10 is £49 ref FLS2 **WANT TO MAKE SOME MONEY?** Stuck for an idea? We have collated 140 business manuals that give you information on setting up different businesses, you peruse these at your leisure using the text editor on your PC. Also included is a certificate enabling you to reproduce the manuals as much as you like! £14 ref EP74

**TALKING WATCH** Yes, it actually tells you the time at the push of a button. Also features a voice alarm that wakes you up and tells you what the time is! Lithium cell included. £8.99 ref EP26A

**POWERBEAM INFRA RED LAMP** All this lamp gives out is infra red light, and loads of it! perfect for supplementing night sight and surveillance equipment. Most mono CCTV video cameras are infra red sensitive so used in conjunction with this lamp would greatly enhance their operating performance. Water resistant case and rubber covered switch make this unit perfect for all weathers. Krypton bulb. 4 D cells required. **Powerbeam lamp £29 ref PB1**

**GIANT SCREEN VIEWTUM** Turn your TV picture into a supersize screen! This high precision Fresnel lens converts even the smallest screen up to a massive 26', giving a crystal clear picture at a traction of the cost of a big TV. Easily fitted in minutes! Also ideal for PC monitors etc! £26.95 ref SVGA2

**NOGALIGHT NIGHT VISION £129** Open up a new world of adventures and experiences. Wildlife enthusiasts and adventurers in the wilderness, amateur astronomers, hunters, wargames, private eyes on surveillance, all find Nightispy indispensable for their use. Nightispy's unique features include a special tube protection device, to eliminate over exposure, and infrared illuminator used in total darkness, such as in cave exploration and operations in dark rooms. The Nightispy is light and hand held, or can be mounted on a standard tripod. It uses two standard AA batteries and can be operated by left or right hand users, with or without optical glasses. **Optical Magnification: X 1.7 Field of View: 10 Degrees Focusing Range: 25cm to infinity objective Focal Length: 50 mm F/11, 1.6 Diopter Range. +/- 3 Mechanical Length: 182 mm Width: 65mm Height 100 mm Weight 700 gr. Electrical: Power Source: 3 VDC, 2AA batteries Battery Life: 40 hours infra-red illuminator built-in Imaging Device: Night Vision Image Intensifier Tube. £129 ref NOGA**

**STEREO MICROSCOPES BACK IN STOCK** Russian, 200x complete with lenses, lights, filters etc etc very comprehensive microscope that would normally be around the £700 mark, our price is just £299 (full money back guarantee) full details in catalogue **SECOND GENERATION NIGHT SIGHTS FROM £748** **RETRON** Russian night sight, 1.8x, infra red lamp, 10m-inf, standard MA2 lens, 1.1kg. £349 ref RET1 **MAINS MOTORS 180 RPM** 90x70mm, 50x5mm 50x5mm output shaft, start cap included. £22 ref MGM1

**PC POWER SUPPLIES, CUSTOMER RETURNS, ALL FAN COOLED, OUR CHOICE, BARGAIN AT 8 PSU'S FOR £9.99 REF XX17**

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**JUMBO LED PACK** 15 10mm bicolor leds, plus 5 giant (55mm) seven segment displays all on a pcb £8 ref JUM1. Pack of 30 55mm seven seg displays on pcbs is £19 ref LED4, pack of 50 £31 ref LED50 **12VDC 40MM FANS MADE BY PANAFLO**, NEW. £4. REF FAN12

**ELECTRONIC SPEED CONTROLLER KIT** For the above motor is £19 ref MAG17. Save £5 if you buy them both together, 1 motor plus speed controller rrp is £41, offer price £36 ref M0T5A

**RUSSIAN 900X MAGNIFICATION ZOOM MICROSCOPE** metal construction, built in light, mirror etc. Russian shrimp farm, group viewing screen, lots of accessories. £29 ref ANALT7

**AA NICAD PACK** Pack of 4 tagged AA nicads £2.99 ref BAR34 **RUSSIAN NIGHTSIGHTS Model TZS4** with infra red illuminator, views up to 75 metres in full darkness in infrared mode, 150m range, 45mm lens, 13 deg angle of view, focussing range 1.5m to infinity, 2AA batteries required, 950g weight, £199 ref BAR61. 1 year warranty

**LIQUID CRYSTAL DISPLAYS Bargain prices**, 20 character 2 line, 83x19mm £3.99 ref SMC2024A, 16 character 4 line, 62x25mm £5.99 ref SMC1640A

**TAL-1, 110MM NEWTONIAN REFLECTOR TELESCOPE** Russian. Superb astronomical 'scope, everything you need for some serious star gazing! up to 169x magnification. Send or fax for further information 20kg, 885x800x1650mm ref TAL-1. £249

**YOUR HOME COULD BE SELF SUFFICIENT IN ELECTRICITY** Comprehensive plans with loads of info on designing systems, panels, control electronics etc £7 ref PV1

**PHOTOMULTIPLIER TUBES** Boxed and unused straight from the ministry of defence. Made by EMI with a MOD part no of 10CV/ 5114 and packed almost 30 years ago. I do you have a use? do you want to count light particles? They would look nice on the mantle piece! Offered to you at £15 each (we think the MOD paid more than this is 1958! £15 each ref PM3)

**CLOCK CAMERA WITH AUDIO** Discretely monitor living rooms, reception, office, tills and any other area. Fully working clock houses an invisible spy camera complete with audio. Complete setup includes clock, camera, microphone, clock battery, 15 metres of cable, power supply, adapter for either smart or phono. Everything you need, no soldering required. Full instructions included. Easily installed in just a few minutes. Plugs straight into VCR or TV (smart or phono) Clock camera with audio £89.95 ref CC5

**AUTO RECORD KIT** This automatic system will instruct your VCR to start recording when movement is detected via the PIR. Recording will stop 30 seconds after your visitor has left which saves hours of tapes as the video only records what you want to see. Complete system with PIR, will work with all remote control video recorders. £89 ref CVC2

**TELEPHONE VOICE CHANGER** Changes your voice to a new or unfamiliar one. Simply place over the telephone mouth piece and speak into the changer. Fully adjustable for different voices. Supplied complete with batteries, ready to go. Unit measures 90 x 60 x 20mm Telephone voice changer £14.95 ref CC3

**EXTERNAL CAMERA** Introducing the Bulldog model 4 vandal resistant camera in heavy steel case for interior or exterior use. Top quality case housing a 420 line camera module. Each camera is supplied with a 15m cable terminating in Scart and phono plugs. Multi angle bracket for easy installation in any situation. A 12vdc psu is also included. Easily installed in a few minutes, plugs straight into VCR or TV (phono or scart). **Bargain price £89.95 ref CC1**

**GIANT INSULATORS** Just in this week are some giant ceramic insulators, each one measures 130mm high and about 170mm diameter. Finished in a high gloss brown and black glaze. In the base of each insulator is a threaded hole approx 1" diameter, rather like a mop/broom head thread. If you are into shortwave radio, crystal sets or high voltage experiments then these are for you. (We've got one as a door stop) Not too sure what their original purpose was, all we know is they were made for export about 25 years ago, never exported and been in store since then. **Price is £8 each ref INSX**

**NATO RADIATION MONITORS** Interesting new line! These are small modules that strap on your wrist (strap supplied) and monitor radiation. We have strapped one apart and they contain a small piece of 'crystal' this could be something like Naphthalene or any other rare radiation sensitive crystal. When radiation strikes the crystal, it scintillates and a small amount of light is produced in the crystal in reaction to the radiation exposure. That light is then picked up by a micro pv cell measuring about 2mm square! Also in the unit is a sheet of foil, a circular metal plate (insulation between the two) and a small pair of additional parallel metal plates. NATO part no is 8695-99-225-2314 any information gratefully received! Alternatively if you wish to buy one they are just £3 each ref NATOX

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Smallest room transmitter kit in the world! Incredible 10mm x 20mm including mic. 3V-12V operation. 500m range..... £16.45

**MTX Micro-miniature Room Transmitter**  
Best-selling micro-miniature Room Transmitter. Just 17mm x 17mm including mic. 3V-12V operation. 1000m range..... £13.45

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High performance transmitter with a buffered output stage for greater stability and range. Measures 22mm x 22mm, including mic. 6V-12V operation, 1500m range. £15.45

**VT500 High-power Room Transmitter**  
Powerful 250mW output providing excellent range and performance. Size 20mm x 40mm. 9V-12V operation. 3000m range..... £16.45

**VXT Voice-Activated Transmitter**  
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**HVX400 Mains Powered Room Transmitter**  
Connects directly to 240V A.C. supply for long-term monitoring. Size 30mm x 35mm. 500m range..... £19.45

**SCRX Subcarrier Scrambled Room Transmitter**  
Scrambled output from this transmitter cannot be monitored without the SCDM decoder connected to the receiver. Size 20mm x 67mm. 9V operation. 1000m range..... £22.95

**SCLX Subcarrier Telephone Transmitter**  
Connects to telephone line anywhere, requires no batteries. Output scrambled so requires SCDM connected to receiver. Size 32mm x 37mm. 1000m range..... £23.95

**SCDM Subcarrier Decoder Unit for SCRX**  
Connects to receiver earphone socket and provides decoded audio output to headphones. Size 32mm x 70mm. 9V-12V operation..... £22.95

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Transmits a continuous stream of audio pulses with variable tone and rate. Ideal for signalling or tracking purposes. High power output giving range up to 3000m. Size 25mm x 63mm. 9V operation..... £22.95

**CD400 Pocket Bug Detector/Locator**  
LED and piezo bleeper pulse slowly, rate of pulse and pitch of tone increase as you approach signal. Gain control allows pinpointing of source. Size 45mm x 54mm. 9V operation..... £30.95

**CD600 Professional Bug Detector/Locator**  
Multicolour readout of signal strength with variable rate bleeper and variable sensitivity used to detect and locate hidden transmitters. Switch to AUDIO CONFORM mode to distinguish between localised bug transmission and normal legitimate signals such as pagers, cellular, taxis etc. Size 70mm x 100mm. 9V operation..... £50.95

**QTX180 Crystal Controlled Room Transmitter**  
Narrow band FM transmitter for the ultimate in privacy. Operates on 180MHz and requires the use of a scanner receiver or our QRX180 kit (see catalogue). Size 20mm x 67mm. 9V operation. 1000m range..... £40.95

**QLX180 Crystal Controlled Telephone Transmitter**  
As per QTX180 but connects to telephone line to monitor both sides of conversations. 20mm x 67mm. 9V operation. 1000m range..... £40.95

**QSX180 Line Powered Crystal Controlled Phone Transmitter**  
As per QLX180 but draws power requirements from line. No batteries required. Size 32mm x 37mm. Range 500m..... £35.95

**QRX 180 Crystal Controlled FM Receiver**  
For monitoring any of the 'Q' range transmitters. High sensitivity unit. All RF section supplied as pre-built and aligned module ready to connect on board so no difficulty setting up. Output to headphones. 60mm x 75mm. 9V operation..... £60.95

## ★★★ Specials ★★★

**DLTX/DLRX Radio Control Switch**  
Remote control anything around your home or garden, outside lights, alarms, paging system etc. System consists of a small VHF transmitter with digital encoder and receiver unit with decoder and relay output, momentary or alternate, 8-way d.i.l. switches on both boards set your own unique security code. TX size 45mm x 45mm. RX size 35mm x 90mm. Both 9V operation. Range up to 200m.  
Complete System (2 kits)..... £50.95  
Individual Transmitter DLTX..... £19.95  
Individual Receiver DLRX..... £37.95

**MBX-1 Hi-Fi Micro Broadcaster**  
Not technically a surveillance device but a great idea! Connects to the headphone output of your Hi-Fi, tape or CD and transmits Hi-Fi quality to a nearby radio. Listen to your favourite music anywhere around the house, garden, in the bath or in the garage and you don't have to put up with the DJ's choice and boring waffle.  
Size 27mm x 60mm. 9V operation. 250m range..... £20.95

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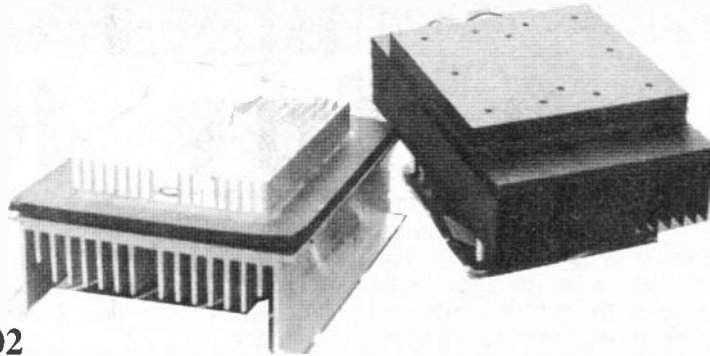


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E93.57 + vat = 109.95 or 10 + 89.32 + vat = 104.95

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40MP size 39x38x23mm spy camera with a fixed focus pin hole lens for hiding behind a very small hole.

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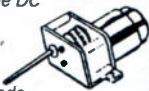
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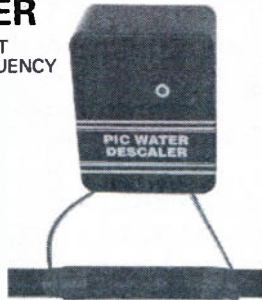
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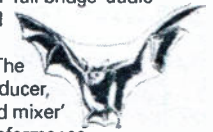
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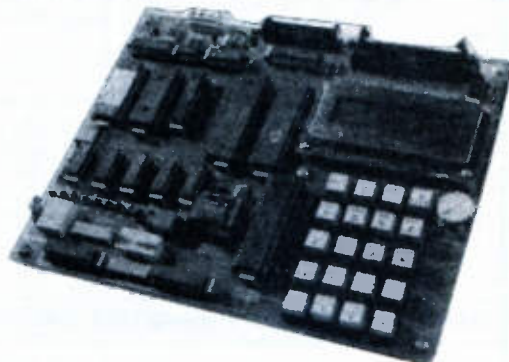
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**BY LEAPS . . .**

Every so often there seems to be a giant leap forward in hobby electronics. Back in the mid-sixties transistors really put the hobby on the map and *Practical Electronics* was born on the back of the "new" semiconductor revolution. Everyone started building simple battery powered stripboard projects using transistors, which overcame the previous problems of metal bashing large chassis to take valves and their associated heavy power supplies which generated highly dangerous d.c. voltages.

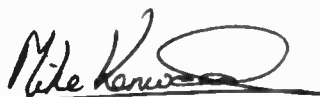
Later, in the seventies and eighties, along came inexpensive i.c.s and the hobby took a large step forward both in sophistication of projects and into digital electronics. The magazine published calculator and even computer designs - those were the days when you could build your own computer from component level for less than half the cost of a ready-made unit. Sadly the popularity of the home computer, which has grown steadily over the last twenty or so years, has resulted in the gradual decline in the number of electronics hobbyists.

**. . . AND BOUNDS**

Now, however, some of those long lost readers are returning. Fed up with playing games and with a fledgling interest in programming, the computer buff is beginning to realise how useful a PC is in developing electronic projects, and how his knowledge of computing can help him on the way to building simple projects that can perform sophisticated tasks to meet his exact requirements. The PIC - or more correctly the microcontroller - is signalling the next leap forward for our hobby.

As regular readers will know, we publish four or more projects in each issue and over the years we have become reasonably adept at assessing which projects will be the most popular. Whilst we were sure the *PIC Tutorial* series would be popular - we were not prepared for the interest being shown in this series. Suffice to say that it is more popular than anything else we have published in recent years; so popular, in fact, that we will probably need to republish the series in book form within a few months, just to satisfy the on-going demand.

Of course, PICs are not the only programmable i.c.s around, and next month we will also take a look at the 8051 family of microcontrollers. Stay with us - it could be another interesting leap into the future.


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## DICE LOTT

JOHN MORTON

*Want to dice with the lottery?  
Let technology and your  
personal touch roll out the  
winners!*

**T**HERE ARE many random number generators around which simulate dice, or perhaps a bingo machine, or even help you choose your lottery numbers. This design, though, encompasses all of these and more, including the exclusive "Vibes Sensor", which means that the numbers it gives are your own personal numbers with a special message accompanying each number.

Dice Lott offers five basic modes of operation: 1 to 6 (one dice), 1 to 12 (not two dice, because all 12 numbers are given equal probabilities), 1 to 6 and 1 to 6 (two dice), 1 to 99 and finally a lottery mode, which produces your six lottery numbers between 1 and 49, with no repeats.

While your finger is touching the contacts to select the numbers, the segments on the displays chase round and round. Furthermore, the device will automatically turn off if left unused for a few minutes, and likewise turn on when the Mode select button is pressed.

This multitude of options is made possible through the use of a PIC microcontroller, in this instance the PIC16C71 is used (not the PIC16C84, as you might have expected!) because we need its analogue inputs to measure the resistance of the finger which touches the contacts.

### VIBES SENSOR

You must be wondering how on earth the Dice Lott is going to sense your "vibes". Here's the secret, in order to get a number, you touch two contacts with your finger. The chip uses the resistance of your skin, which is particular to you only (and your "vibes"), to select the random number and the accompanying message word.

The PIC16C71 is capable of having its RA0 to RA3 pins used as analogue inputs to an internal ADC (analogue to digital converter). In the Dice Lott, pin RA0 of the PIC16C71 is used to detect the voltage in the middle of the potential divider produced by your skin resistance across the touch pad in series with a resistor.

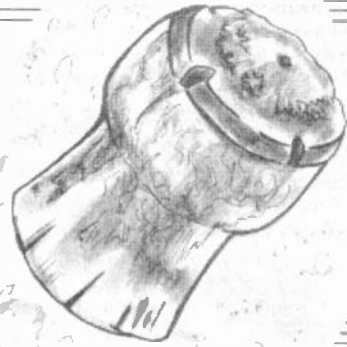
The PIC constantly tests the voltage at this pin and when it rises above a certain critical level (i.e. when the resistance between the contacts falls sufficiently) it assumes that the contacts have been bridged.

When there is no finger between the contacts, the resistance is practically infinite, and thus the voltage at pin RA0 is practically 0V, being tied to that level via a resistor.

Once the PIC has established that a finger is across the contacts, it waits for a short period of time for the situation to stabilise, and then records the voltage at RA0, storing it for use in the number and message selection processes.

### MODE SELECT

There is only one switch on the model. It is used to change between the five modes, and also to turn the model on from its low power standby mode, called SLEEP. This is possible because it is connected



to the PIC's external interrupt pin, RB0, which will wake it up from SLEEP.

When sleeping, the PIC uses a minute current of a few microamps, so it will be quite friendly to the batteries.

The initial problem with the Mode switch was the age-old pain of switch-bounce. To solve this problem, the program was written so that the PIC won't react to the switch being pressed until a tenth of a second has passed since it was last released.

### CIRCUIT DESCRIPTION

The complete circuit diagram for the Dice Lott is shown in Fig.1.

## COMPONENTS

### Resistors

R1 to R4,	
R13	2k2 (5 off)
R5 to R11	82Ω
R12	100k
R14	680k
R15, R17	10k (2 off)
R16	1k

All 0-25W 5% carbon film

### Capacitors

C1, C2, C5	100n ceramic disc (3 off)
C3	22p ceramic disc
C4	1μ elect. radial, 10V
C6	470μ elect. radial, 10V

### Semiconductors

D1	1N1418 signal diode
TR1 to TR4	BC184L npn transistor (4 off)
IC1	PIC16C71 microcontroller, preprogrammed (see text and Shop Talk)

### Miscellaneous

S1	s.p. push to make switch, p.c.b. mounting
X1, X2	dual 7-segment displays, common cathode (2 off)

Printed circuit board, available from the EPE PCB Service, code 192; touch contacts (see text); plastic case 155mm × 80mm × 33mm, with integral battery compartment and viewing cutout (Maplin YK24B); 18-pin d.i.l. socket, 9-pin s.i.l. socket (4 off); p.c.b. supports (see text) (3 off); AA-size 1.5V cell (2 off); red plastic filter; solder etc.

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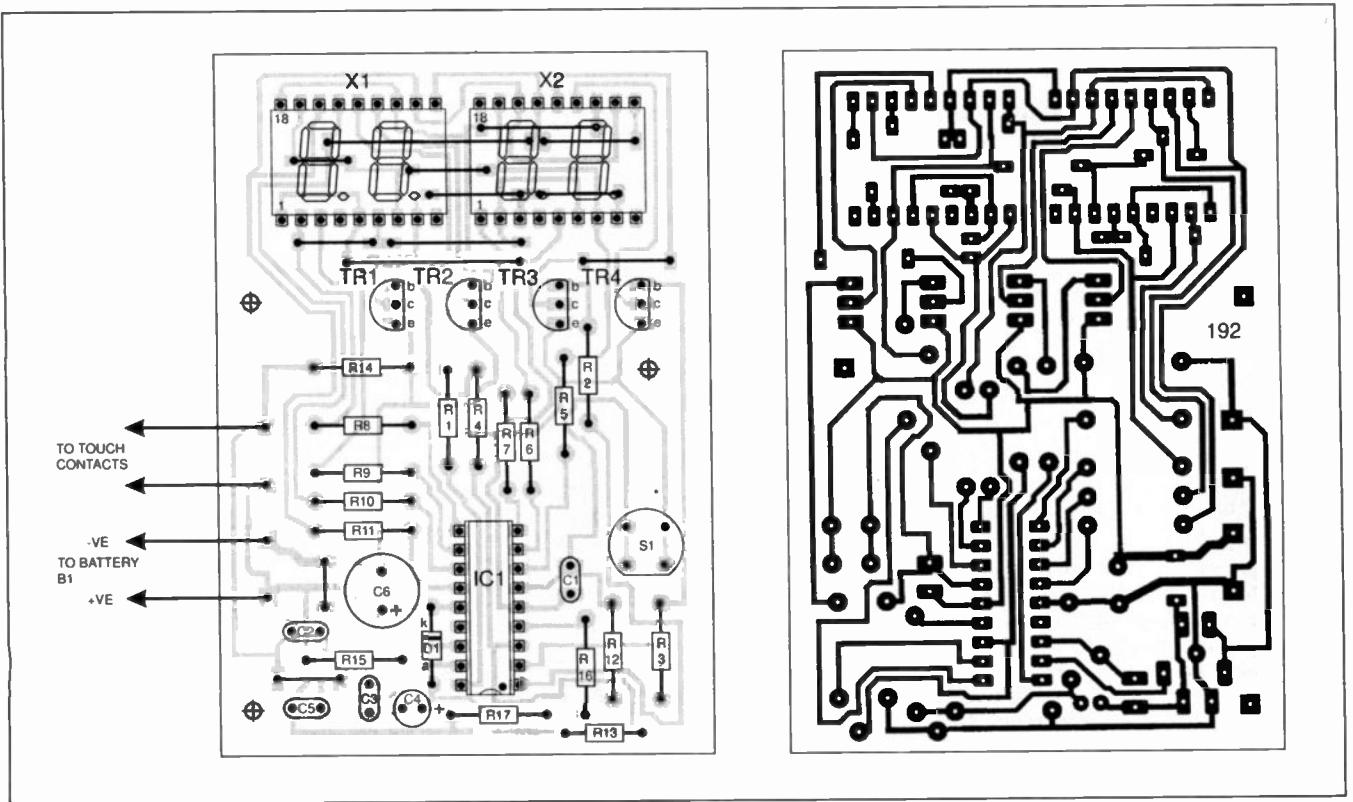


Fig.2. Component layout and full size track master foil layout for Dice Lott.

## SOFTWARE FLOW

As with the start of any software program, we must first set up the necessary settings for the microcontroller (such as telling it which pins we wish to use as inputs, and which as outputs).

The software then enters a cycle in which the PIC constantly tests for the contacts being touched – i.e. has the voltage at the analogue input pin risen above a certain level (as explained in the “Vibes Sensor” section).

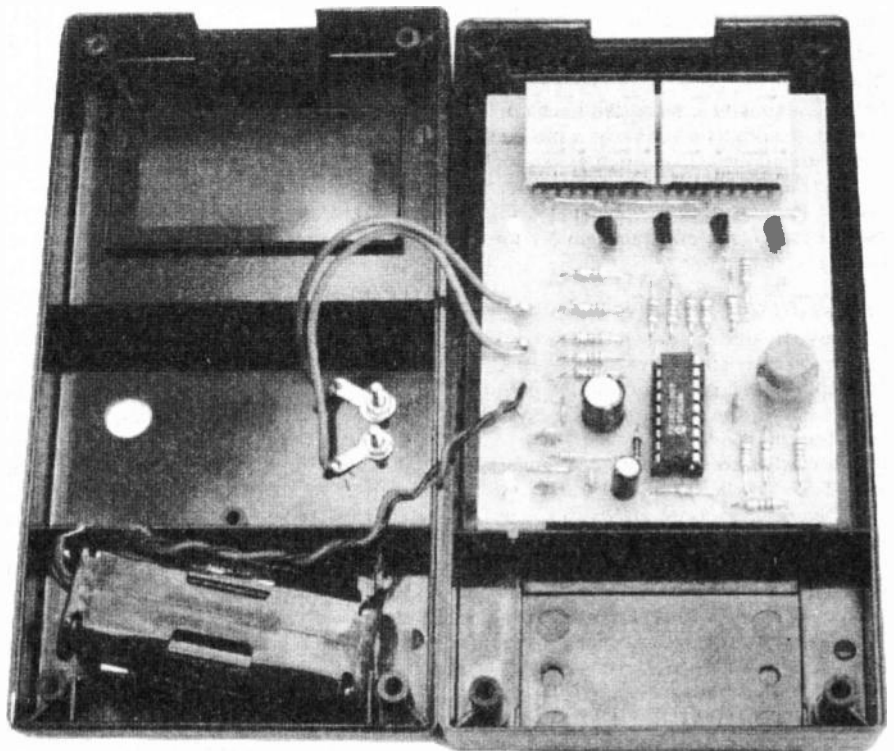
As the displays are being strobed, we need to be constantly turning a new one on as the previous one is turned off. The idea behind strobing is turning one display on with the correct character on it while all the others are off for a short period of time, and then doing the other ones, one at a time. This all happens so quickly it looks as if they are all on at the same time.

While waiting for the contacts to be touched, the PIC also checks to see whether a three minutes time-out period has been reached, after which it should go to sleep. Each time the contacts are touched, the counting registers being used to keep track of how much time has passed are reset.

The PIC then waits a short while before storing the “Vibes” value.

While the contacts are being touched, the software creates a chase pattern on the displays. On their release, a message is displayed for three seconds, the wording depending on the “Vibes” value detected.

A common problem we encounter when designing electronic random number generators is the simple fact that machines (least of all PICs) are not random in any respect. Here we use a random human factor to help create the number, using the amount of time for which the contacts are pressed.



This, however, is measured in cycles of thousandths of a second, so that you cannot consciously decide whether the number is to be high or low. In the Dice Lott, the time value is a number between 0 and 255. The value obtained from the “Vibes” sensor is added to the time, creating the “random” value (again, between 0 and 255).

Software then converts this value into a number between a smaller range (e.g. 1 to 6, 1 to 12, etc.). This is done by adding 6,

12, 49 or 99 to the number until it passes 255 and loops back to zero ( $0 = 256$ , therefore  $254 + 3 = 1$ ). In this way we get a number between 0 and 5, or 11, or 48 etc. We simply add one to this value to get a number in the correct range (you can work all this out on paper if you want!).

There is, though, the complication of making sure that the lottery numbers don't repeat in any group of six numbers, but apart from that, that's all there is to the

program – except for the RB0/Mode interrupts, of course, but these were explained in the Mode Select section.

## MESSAGE CHANGING

If you have access to PIC programming equipment, you can program the PIC to produce different message words with relatively ease.

The messages are generated in sub-routines which are accessed according to the "Vibes" value detected. For example:

```
cool    call    _C
        movwf  dig1
        call   _o
        movwf  dig2
        call   _o
        movwf  dig3
        call   _L
        movwf  dig4
        return
```

By substituting your own letters (in a similar format) for the C, o, o and L in the above chunk of program, you can get your own words to appear.

The software includes a lookup table to tell it what your letters mean in terms of codes output to the displays (don't forget the underscores).

Obviously not all letters can be produced by 7-segment displays. Here is a list of the ones that the software creates (including the different cases they can have):

A, b, C, c, d, E, F, G, g, H, h, I, i, J, L, l, n, O, o, P, q, r, S, t, U, u, y

plus a blank space (written blank with no underscore).

For simplicity's sake, don't rename the labels of any section (e.g. the word cool in column 1 of the above program extract is a "label"). Substituting a new label to represent the new phrase would muck things up elsewhere in the program, requiring changes there as well.

## ADDING WORDS

It is slightly more complicated to add extra words, but nevertheless perfectly possible. There is a section in the program which decides in what range the "Vibes" input result falls.

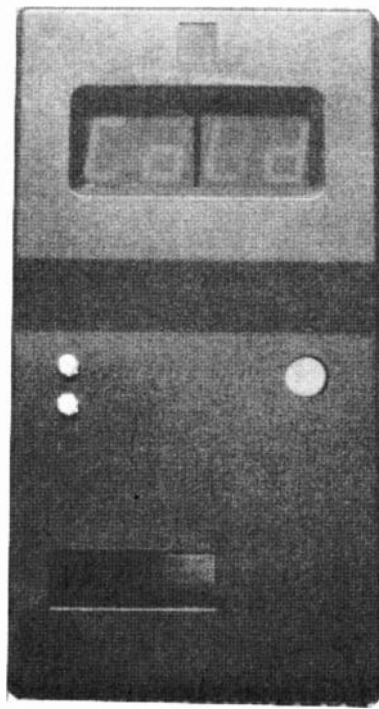
As written, there are fourteen ranges: 11 to 12, 13 to 14, 15 to 16, 17 to 18, 19 to 20, 21 to 22, 23 to 24, 25 to 26, 27 to 28, 29 to 30, 31 to 33, 34 to 35, 36 to 50, and 50+.

To get more words, simply change the ranges. It is very unusual for the result to be above 50, so you are better off making all the ranges smaller if you want to add more. You are also advised to have more small ranges at the lower end, as low values are more common.

An example routine to determine whether the number (held in a data register named "Skin"), is less than 12 is as follows:

```
movlw  d'12'    ; is Skin less
                ; than 12?
subwf  Skin, w  ;
btfss  STATUS, C
goto   sad      ; yes, so goes to the
                ; section labelled sad
```

For the PIC to acknowledge that a finger has been placed on the contacts, the value in Skin must be greater than 10, and thus



testing to see if the number is less than 12 tells us whether it is between 11 and 12.

The routine after the one above would be identical, except that instead of a 12, there would be a 14 (because now it is testing to see whether or not the value is between 13 and 14), and instead of going to the routine labelled place called "sad", it would go to "bad" – the word associated with the range 13 to 14.

You can, therefore, add sections like this to create your own ranges, each with their own place to go to. Naturally it is advisable to name these sections according to the word involved.

You should know how to write a section which produces a word, from reading the previous section. Just copy out the instructions quoted, putting the correct letters in the appropriate places.

## DIY SYMBOLS

As you know, the current program offers a limited number of letters, but you may well want other symbols to appear on the displays. A total of 128 (2<sup>7</sup>) combinations of the seven segments are possible.

Each segment is assigned a letter, a to g, allocated as shown in Fig.3. The segments are controlled via the PIC's RB1 to RB7 pins as shown in Fig.1, in order of g (RB1/bit 1) to a (RB7/bit 7).

In the program there is a routine which starts like this:

```
_A  retlw  b'11101110' ; letter A
_b  retlw  b'00111110' ; letter b
_C  retlw  b'10011100' ; letter C
_c  retlw  b'00011010' ; letter c
```

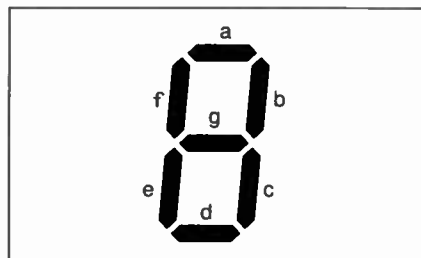


Fig.3. L.E.D. segment designations.

Remember that when a binary number is written, bit 0 is at the right, and bit 7 is at the left.

The segments you want turned on should contain a 1 in the correct position of the controlling binary code, and those that should be off should contain a 0.

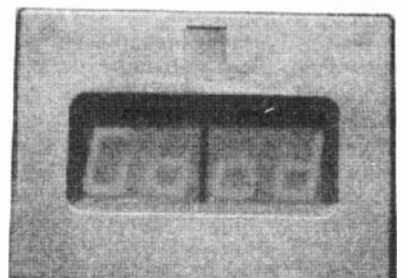
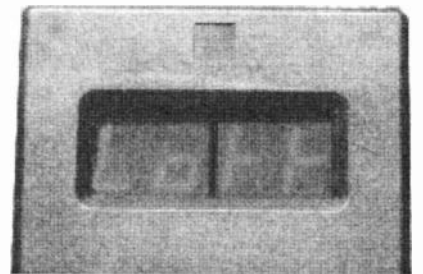
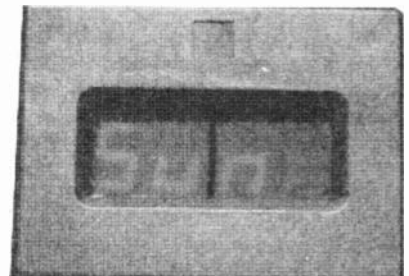
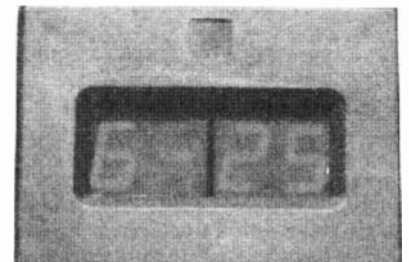
For example, if you wish to create a symbol which looks like a degrees sign (°), whereby segments a, b, f and g are turned on, you would insert the following statement into the routine that contains all the letters:

```
_deg retlw b'11000110' ;degrees
```

In this way you can choose to display any symbol you want. It does not matter in which order your new symbols are placed (the PIC treats them as sub-routines), but obviously it makes sense to list them alphabetically where appropriate.

You can now choose the contents of the messages displayed, choose how many messages can be displayed, and choose the letters and symbols which the messages are to contain. You can personalise them, and thus make the device into a brilliant present.

Moreover, never again need you suffer the stress of choosing lottery numbers, simply use Dice Lott to "PIC" them!



## AN END TO PROJECTION?

Cinemas without film projectors? Could be if secret digital experiments work out. Barry Fox screens the evidence.

**B**RITISH Telecom is conducting a secret experiment in Ealing, West London, to find out whether cinema-goers can be fooled into thinking they are watching film when actually they are seeing video. BT wants to offer the movie industry an electronic delivery service. Instead of printing movies onto 35mm film stock, and delivering bulky film cans round the country by van, BT will pipe the movies down optic fibre links from a central control centre.

If BT can make video projection the norm, it can deliver live video pictures of big fights, football finals and concert specials, for cinema audiences to pay to view. At present cinemas must install a video projector and satellite system, just for one event.

It currently costs Hollywood \$2000 for each 35mm film print. Delivery and collection is slow and expensive. Film prints wear, and get damaged. Past attempts at replacing film projectors with video projectors have failed because picture quality has been so poor that audiences complain.

### Secret Venture Revealed

BT's Broadcast Services Division has formed a secret joint venture with Virgin Cinemas, Channel 4 television, JVC of Japan and British electronics specialist Snell and Willcox, to put together an electronic delivery system which matches film quality. BT's John Blumberg is in charge of the project, but declines to comment. It is "confidential" says a BT spokesman. But by testing it on guinea pig audiences, BT has let the secret slip.

Channel 4's role is to transfer wide screen movies from 35mm film to digital video tape. C4's control centre in Horseferry Road, South West London, had installed Panasonic D5 format digital video recorders and high definition telecine equipment to prepare movies for its PALplus TV transmissions. Although in itself PALplus flopped, the equipment turns out to be ideal for BT's experiment.

Until BT installs optic fibre links, C4 is shipping D5 cassettes to the Virgin cinema in Ealing where they are played on a recorder in the cinema. The projection box has also installed a light valve video projector, developed by Japanese company JVC in cooperation with US aerospace giant Hughes. This projector uses a small l.c.d. screen instead of film. The l.c.d. displays a high resolution

video image while a powerful arc lamp beams light through a projection lens and onto the cinema screen. Although the screen is full cinema size, the lamp is bright enough to fill it.

### Enhanced Line Standard

The picture quality so far available from video projectors has been limited by the number of horizontal scanning lines, 625 in Europe, which make up the electronic image. The latest JVC projectors are designed to handle computer graphics with much higher resolution than TV standards.

Although the D5 tapes use the 625 line standard, the signal is fed through a system called an Interpolator, developed by British broadcast electronics company Snell and Willcox. This doubles the number of picture lines, by analysing the picture information contained in

each of the 625 lines and building extra lines which smoothly bridge the gaps - like joining individual points on graph paper to plot a smooth curve.

BT and Virgin have been testing the system, by using the cinema out of normal hours for special screenings. Audiences are asked to say what they thought of the film, and how it looked.

The acid test for line doubling is how the system copes with intimate close-ups, when there is fine and subtle detail, and with fast moving action, especially when the camera is panning across a scene. BT's project members claim privately that the video quality closely matches projected film on undemanding material. BT has not yet felt secure in demonstrating the system to independent specialists, with switched comparisons between film and video on a wide range of picture material.

## Maplin's CD-ROM

YOU can't have failed to notice that Maplin have made their catalogue available on CD-ROM as well as in paper form. No doubt many of you will have already obtained the CD-ROM and discovered the benefits of being able to use its search facilities to find the products you are looking for (and there are over 22000 to choose from).

There is also the enormous benefit of the extensive data sheet library on the disk which can be read either through the Maplin catalogue routines or independently through Adobe Acrobat.

The CD-ROM costs just £1.95 plus p&p and Maplin are to be congratulated on their first issue of this electronic catalogue. Get a copy - it's well worth it! (The paper cat is still available for those without a CD-ROM drive, costing £3.99 plus p&p.)

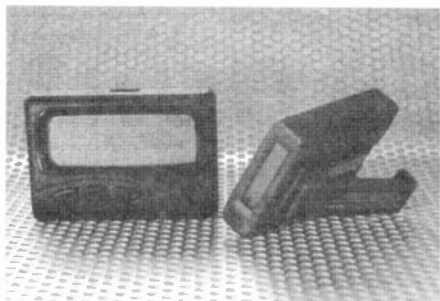
We know that some users, though, are experiencing difficulties getting out of Maplin's program as the usual Windows exit options have not been activated (we strongly recommend they should be). Maplin say you should look for the red-circled "Q" (for Quit) on the pages, clicking on it to exit.

Incidentally, CB radio users will be interested to know that Maplin have recently signed a membership deal with the UK's leading organisation for CB radio, the British Citizen's Band Confederation (BCBC), which was formed in 1997 to represent the needs of licensed CB users, manufacturers and retailers. Acceptance by the BCBC signifies formal recognition of Maplin both by CB manufacturers and users.

For more information, contact any of Maplin's 48 stores nationwide, or their H.Q. at PO Box 777, Rayleigh, Essex SS6 8LU. Tel: 01702 554000. Fax: 01702 554001. Web: <http://www.maplin.co.uk>.



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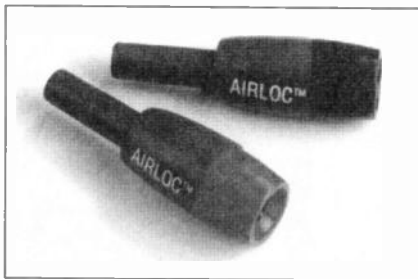
For more information contact Radio-Tech Ltd., Dept EPE, Coward Popplewells Building, High Road, Thornwood Common, Epping, Essex CM16 6LP.

Tel: 01992 576107. Fax: 01992 561994. Web: <http://www.radio-tech.co.uk>.

## Audio Excellence QED

QED Audio Products ask if you have ever got the sneaky feeling that your hi-fi system is mysteriously deteriorating, slowly sliding into boredom?

Well, they claim to have a cure called Airloc, which offers the perfect long-term connection between cable and connector, and they've applied it to their latest BFA "reverse" 4mm plug.



They draw people's attention to the new EC regulations which have virtually outlawed ordinary 4mm plugs and sockets for hooking up speakers to amps. The British Federation of Audio (BFA) came up with their touch-proof "reverse" 4mm system which has been adopted by several major amplifier manufacturers. However, available plugs all use low-tech connection systems which can deteriorate over time, spoiling the sound of the whole system.

Now QED has brought together its Airloc crimped termination and BFA's plug design to create what they describe as the ultimate BFA connector - one which will hold its fine performance for many years, both electrically and mechanically, and is ideal for hi-fi or A/V systems alike.

For more information contact QED Audio Products Ltd., Dept EPE, Ridgeway Close, Lightwater, Surrey GU18 5XU. Tel: 01276 451166. Fax: 01276 452211.

E-mail: [panic@qed.co.uk](mailto:panic@qed.co.uk).

Web: <http://www.i-way.co.uk/~qed>.

WOULDN'T it be nice to sit in the comfort of your office chair yet immediately keep your finger on the pulse of the key activities at locations well away from you? Radio-Tech believe you can - with their new paging system. Indeed, Radio-Tech exclaim that in effect you can be in 12 places at once! RTL's MIT series provides telemetry and on-site paging through a multi-tier intelligent combined RTcom SCADA and Wire-Free system. Featuring an alphanumeric

## NEW PICS

MICROCHIP have announced their new Enhanced PICmicro™ Architecture which offers up to two million words of program memory address spacing for its popular PICmicro family of 8-bit RISC microcontrollers. They have also unveiled a "road map" of 11 OTP and Enhanced Flash-based micros incorporating the new high performance PIC16C1XX architecture.

Definitive device code numbers have not been announced but the PIC16C1XX will be available, later this year, in 28- and 40-pin packages, have 68 instructions, up to 2M words of program memory and up to 4K bytes of data memory.

The flash-based devices are electrically erasable (EEPROM) allowing the same ease of reprogramming as associated with the PIC16C84.

For more information, contact Arizona Microchip Technology Ltd., Dept EPE, 505 Eskdale Road, Winnersh Triangle, Wokingham, Berks RG41 5TU. Tel: 01189 215858. Fax: 01189 215835.

Web: <http://www.microchip.com>.

## RS/Electromail On Web

RS Components have launched their own web site, providing fast search, retrieval and on-line ordering of their entire catalogue of 100,000 products. Full product and pricing information plus colour photographs, line drawings and pinouts are available. Of enormous benefit is easy access to their data library, which holds around 10,000 documents. Anything you previously did with RS by phone, fax or mail can now be done via this site.

The same facilities are open to those who normally deal with Electromail, the retail side of RS Components - anyone can use the site.

Credit card orders can safely be placed via the site. It is VeriSign certified and uses Netscape's industry standard Secure Socket Layer protocol (SSL) to encrypt all transaction details, ensuring your security.

Of historical interest, RS Components was formed in 1937 as Radiospares Limited by J.H. Waring and P.M. Sebestyen, selling radio spares under their own brand label. RS are now part of Electrocomponents PLC. Other divisions include Electrosped, Electromail and Outsource Procurement Services.

The RS web site is at <http://rswww.com>.



## What a Handylink!

HOUSEHOLDS with multiple TVs, SKY satellite TV, cable, video or hi-fi equipment can now operate the whole system from any room in the house, thanks to the Handylink remote control extender system introduced by TV equipment company Labgear.

Handylink allows the user to operate multiple systems from any room in the house without having to point the remote control directly at it.

It works by receiving the signal from the user's existing remote control handset in the additional room. It then sends it via coax cable to a base unit located in the main room, and from there to "sender buttons" attached to the equipment to be controlled. These buttons retransmit the signal and operate the equipment.

The Handylink is available from Argos Superstores nationwide and selected Dixon's stores.

For more information, telephone the Labgear helpline on 0800 616481.

# New Technology Update

Varying voltages cause monochrome I.c.d.s to behave as colour-selective reflectors, allowing lower pixel densities for colour displays. Ian Poole reports.

**D**ISPLAYS are a very important area in the field of electronics. With equipment becoming more sophisticated, the demands being placed on the man-machine interface are more crucial.

The cathode ray tube (c.r.t.) is still the most widely used form of display. Its life started in 1897 when Ferdinand Braun in Germany developed the basis of the cathode ray oscilloscope. In turn this was a development of the earlier discovery of cathode rays by Crookes and Hittorf.

However, it has several disadvantages. First of all it is bulky. This is easily demonstrated by looking at any PC monitor or television set. The tube itself is approximately as deep as the screen is wide. This is clearly unsatisfactory for many applications, including laptop computers that have been forced to use other types of display.

Cathode ray tubes also require the use of very high voltages. Values of 20kV and more are not uncommon. This requires the provision of extra supplies, again increasing the bulk of the overall display system. The c.r.t. is very power hungry. This is another reason why it is not used for portable applications.

Against these disadvantages, though, the c.r.t. gives a good picture that can be seen even in relatively high ambient light conditions. It also responds quickly to any changes making it ideal for television.

## Liquid Crystal Displays

There are a variety of other types of display that can be used, including the liquid crystal display (I.c.d.) that has gained widespread acceptance.

Unlike the cathode ray tube, the I.c.d. does not generate light. Instead, it reflects it. By far the most common type of I.c.d. is called a twisted nematic display that works by means of polarising light.

The basic principle hinges around the fact that if light polarised in one direction tries to pass through a piece of polaroid glass that is polarised at 90 degrees to it, then no light pass through. If they are polarised in the same plane then the light will pass through.

The cross-section of an I.c.d. is shown in Fig.1. Here it can be seen that there are two pieces of glass with a small separation. The gap between them is filled with the liquid crystal. The inside layer of each piece of glass is coated with a very thin layer of a transparent conductive coating. The pattern of the coating enables the required display to be produced.

The liquid crystal has the property that it rotates the polarisation of the light passing through it. The amount of rotation is dependent upon the thickness and the exact composition of the liquid.

Behind the I.c.d. there is a piece of reflective polarising material, and in front a piece of clear polarising material. The planes of polarisation of these materials are at 90 degrees to one another. If no liquid crystal was present then no light would be reflected out of the display. However, the twist imparted by the liquid crystal means that light is reflected back. This means that the display appears transparent.

However, when a voltage is applied across the electrodes the liquid crystal ceases to twist the polarisation of the light. This means that no light escapes

the colour of reflected light. In this way the number of pixels required in a display can be reduced by a third, and the cost vastly reduced.

The basic idea uses an oscillation in the electron density at the interface between a metal and dielectric. At this resonant frequency the surface reflection disappears. The frequency at which this occurs depends upon the metal and the dielectric being used.

It is also possible to change the resonant frequency by changing the characteristics of the dielectric. These materials are known as electro-optical materials. In the case of a liquid crystal display, applying a voltage to the liquid crystal does just this.

An experiment was undertaken to prove whether the principle worked. A 50nm thick layer of silver was used for the metal, and a 4mm liquid crystal as the electro-optical dielectric. A prism was used on top of the display to enable easy analysis of the reflected light.

The experiment demonstrated that with no voltage applied the filter absorbed red light with a wavelength of around 650nm. Then, as the voltage increased, the wavelength of the absorbed light was reduced until, with an applied potential of about 30V, blue light with a wavelength of 450nm was absorbed.

This is not the complete solution because this is a notch filter, which rejects a band of wavelengths of light. Instead a band-pass filter is required to allow though a certain band of wavelengths of light. This can be achieved by sandwiching the liquid crystal between two prisms with metal coatings to create a symmetrical structure.

By doing this, the wave travelling on one side is coupled to the other being re-radiated with the same frequency as the incident light. In this way the non-reflected light is transferred from one side to the other creating a band-pass filter.

## Possibilities

The idea is still in the research stages, but it is expected that it should be possible to easily generate a colour I.c.d. using a monochrome display as the basis. This will considerably cheapen I.c.d.s, because the monochrome display only requires a third of the number of pixels of a colour one. As their complexity is one of the main factors contributing to the cost, the new I.c.d.s should be considerably cheaper.

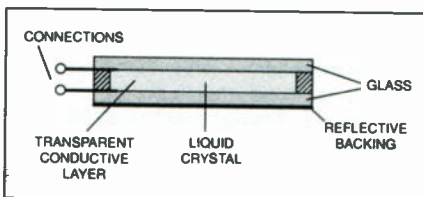


Fig.1. Section through an I.c.d.

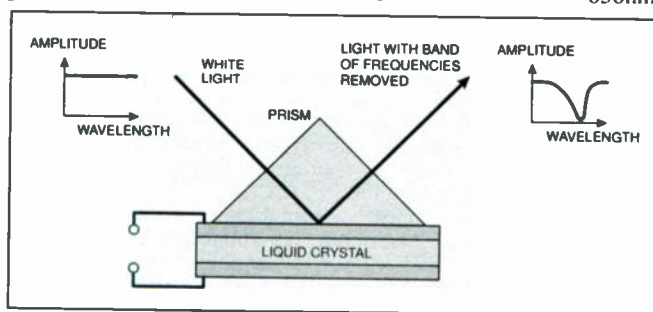


Fig.2. Experimental I.c.d. with colour notch filter.

from the display and the area occupied by the electrode now appears dark.

The electrodes can be any shape that is required. High definition displays can be made by creating a large number of different electrodes which can be addressed separately. Large scale integration techniques enable these to be controlled and driven, although the displays are not very cheap in view of their complexity.

## New Developments

Like many other forms of display, colour I.c.d.s can be made. This increases their cost and in view of their widespread use, any methods of making cheaper colour displays would pay large dividends.

A new idea for a colour I.c.d. is being developed at the Jet Propulsion Laboratory at California Institute of Technology. The idea hinges around a filter which controls

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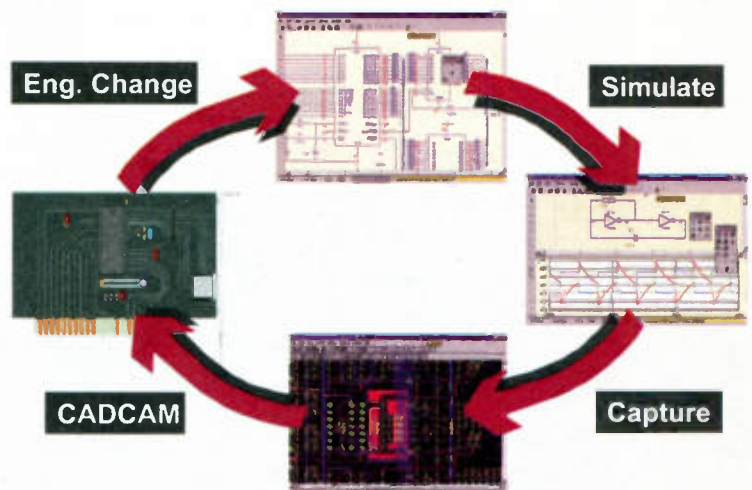
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Use the multi layer autorouter, and/or manual routing to complete your PCB together with copper fill, etc as required. Finally print your design, or create CAD/CAM files suitable for manufacture (we even include a Gerber viewer for checking).

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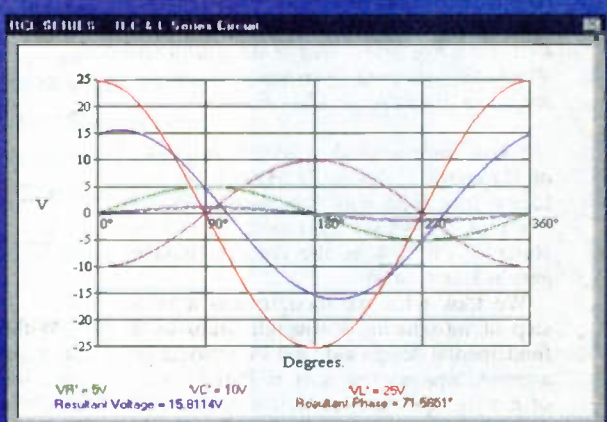
Electronics Principles 5.0 is a significant upgrade of our popular electronics educational software. Now containing even more analogue, digital and microcomputer theory. PLUS over a hundred new mathematics topics to further your understanding of formulae and calculations. Telephone for a comprehensive list or upgrade details.

This software has been developed to teach electronics and is suited to both the complete novice and the more advanced student or hobbyist wanting a quick revision and access to hundreds of electronics formulae. It is extremely easy to use. Just select a topic, which is always presented as a default diagram (no blank screens!) and input your own values. Alternatively, use those from any standard electronics text book to see the results as frequency response curves, calculations, logic states, voltages and currents etc.

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Electronics Principles software is currently used in hundreds of UK and overseas schools and colleges to support City & Guilds, GCSE, A-Level, BTEC and university foundation courses. Also NVQ's and GNVQ's where students are required to have an understanding of electronics principles.



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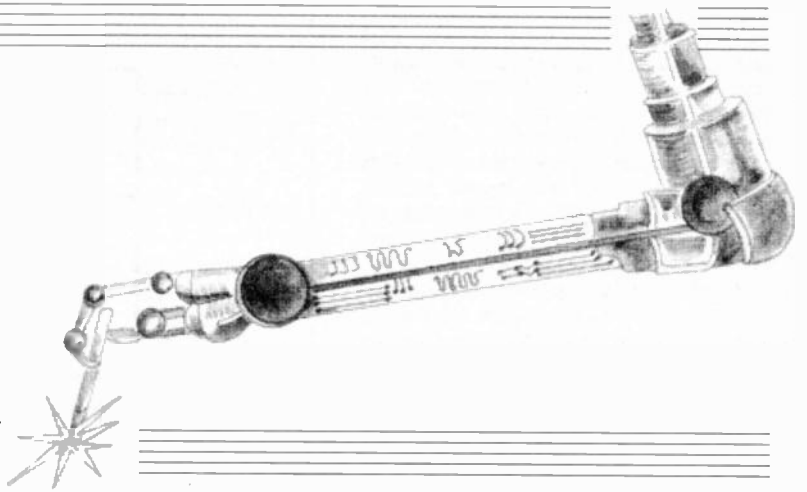
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# CIRCUIT SURGERY

ALAN WINSTANLEY



*This month's selection of readers' queries and feedback re-visits our Teach-In series, looking at Karnaugh Maps. We continue with our discussion started last month, of a logic system which counts 100 switches, and we are also hot on the trail of wirewrap sockets.*

## Those flipping K-Maps

Our postbag and E-mail have been red hot with a variety of topics, so let's start by returning to those frightening-looking Karnaugh Maps to which we introduced the *EPE* readership in *Teach-In Part 5: An Introduction to Digital Electronics*.

Martin Baxter writes (via AOL):

*Generally I have enjoyed and learnt a great deal from your Teach-In series. I would like to refer to Part Five; Logic Design Aids. Although I have little difficulty with Boolean Logic/algebra, your explanation of Karnaugh Maps frankly baffles me. At the top of page 207 is the "RUL" truth table. You "flip" this table to draw a Karnaugh Map. Can you break down this "flipping" process into several stages so that I can see the connection?*

Some understandably found the topic of Karnaugh ("car-no") Maps a bit too heavy compared with the foundation articles of the series. However, Part 5 is about as difficult as the theoretical side gets in *Teach-In 98*.

We took what we thought was a bold step of introducing Karnaugh Maps as a fundamental design aid, and we introduced a simple analogy first seen in Part 4 – that of getting wet because it had rained and you didn't have an umbrella. This analogy is more clever than some people probably realise, because it also cunningly introduced the "NOT" logic function (in-verse) without you even realising it.

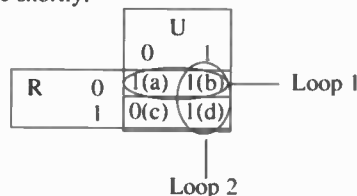
Critically, K-Maps bridge the gap between specifying a logic application and actually implementing it with hardware. *Lab Work 5* is a brilliant example of how K-Maps are used to design an array of logic gates. Let's try to shed a little more light in the way they are created.

Below is the Truth Table which *Teach-In* readers will recognise. This shows the logic states of "L" – a value of 1 for L means the door is locked. The wardrobe/closet door is only unlocked (L=0, to allow a change of clothes) if it is raining AND we're not using an umbrella. Extra

letters a-d have been inserted alongside, as shown, to help explain the sequence of events.

R (it is raining)	U (using an umbrella)	L (door on wardrobe is locked)
0	0	1 (a)
0	1	1 (b)
1	0	0 (c)
1	1	1 (d)

The idea behind "flipping" the table is to re-draw it, showing L as the "result" of all the available combinations of the values of R and U. From that point on, all we are interested in is those "results" which represent L=Logic 1, as you will see shortly.



With R now on a horizontal axis and U on a vertical axis, where they both intersect, the logic values of "L" are plotted, assuming that R and U can either be Logic 0 or Logic 1. Match the letters written alongside with those in the Truth Table, and you will see where it all came from in the truth table. When R and U are 0, L is 1(a), etc.

The whole point of the Karnaugh Map is to help you to identify the Boolean Logic needed to define L using R and U. The next stage concerns drawing the loops. Here, the idea is to encircle all the values for L of Logic 1. In this case, we were able to draw just two loops – recall that you can't draw diagonal loops, but you can run them off the edge of the Map and back on to the other side (as shown in *Lab Work 5*, Map c).

Having "captured" the Logic 1s in loops, set about defining them with Boolean Logic. In Loop 1, L is 1 whenever

R is 0. So L is the inverse of R. Hence,  $L = \bar{R}$ . In Loop 2, L is 1 whenever U is 1. So we also know that  $L = U$ .

Putting them together with an OR statement (+ sign),  $L = \bar{R} + U$ . You can apply this to the truth table and you will see that L is indeed defined by this Boolean logic statement.

*Lab Work 5* showed how in a real application, larger loops, and sometimes more than two, are needed to capture all the Logic 1s plotted by the K-Map. The secret is to make the loops as large as you can so that you capture all the 1s. Those "don't care" states (X) can also be grabbed and treated as 1s, until you are eventually blocked by a 0.

● A brilliantly illustrated and compulsive book which we don't hesitate to recommend, for Karnaugh Map and logic fans everywhere, is *Bebop to the Boolean Boogie*, by Clive "call me Max" Maxfield. The book is so good that we convinced the *EPE Direct Book Service* to import it from the USA. Details in the DBS advertisement in last month's issue.

## 100 switches click into place

Last month, helped by the *Teach-In* co-writers at the University of Hull, we offered a combinatorial solution to a logic problem posed by a reader: how to count the number of switches operated by a class of pupils when they each enter the classroom. Each switch must operate an i.e.d., and the reader said he had tried several methods with partial success. This month, Ian Bell continues his discussion.

The "add-one" combinatorial approach we described in Fig. 5 of the April issue can be converted to use BCD (binary coded decimal) but requires a slightly more complex circuit as shown in Fig. 1.

How did we get this circuit? Firstly, we assumed that only valid BCD values will be input, so that the only input value which results in behaviour different from the binary circuit "add-one" is decimal 9 (1001 binary). If the input is 9 then the add-one circuit must output four 0s plus a carry out to the next digit.

Detecting a decimal 9 at the input is straightforward; we need a 4-input AND gate and a couple of inverters to indicate when the input is 1001. We actually only need this condition when the one-bit-to-be-added input is 1, so this is signal connected to a fifth input on the AND gate. Studying the binary counting bit patterns reveals that the "toggle if all lower bits are one" rule is broken for BCD for the 2s and 8s bits in the 9+1 case.

Here we need an extra toggle for the 8s and must prevent the toggle of the 2s. Stopping the toggle on the 2s is easy, we just add the input to the existing AND gate and drive this from an inverted 9+1 detected signal. To add the extra toggle to the 8s bit we use an OR gate on the 9+1 signal with the existing toggle control as shown in the diagram.

The reader's problem requires 2-digit BCD (plus carry for the 100). A multi-digit BCD add-one circuit is simply obtained by connecting the carry-out of one unit to the add-one input of the next significant digit. The BCD version of the add-one circuit requires less increase in complexity over binary than the BCD adder approach, see the block diagram of Fig. 2.

Both the binary and the BCD add-one approaches require slightly larger circuits at the higher number end of the chain. At slightly extra cost, the same circuit could be used for each switch allowing a neat modular approach to construction. Each module could have the switch, i.e.d. and logic capable handling inputs from 0 to 99.

The first module could have all its binary inputs connected to 0 and the final

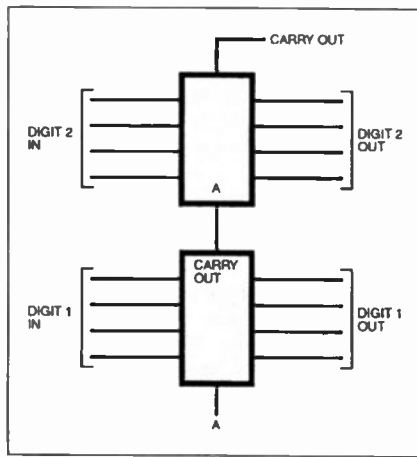


Fig. 2. BCD version of the add-one circuit.

module's output (including carry) could be connected to the display. The modules could be daisy-chained together but the order in which they were connected would not matter.

If this were a commercial product, the advantage of simple modular construction from one basic unit and hence easy manufacture, test and repair may outweigh the extra component cost. This is not a usual consideration for a hobbyist but the complexity of this circuit may make it worth thinking about.

Interestingly, there are a number of problems which can be solved using 1- or 2-dimensional arrays of the same circuit. Even though the repeated circuit may be complex (it may be a processor) once you have designed it, it is relatively easy to put hundreds or thousands of them on a chip. Typical applications of real 'array circuits' include image processing where circuitry is connected to an array of photodetectors on a chip. The arrayed circuit may be combinational, but in real applications is more likely to be sequential or possibly even an analogue circuit

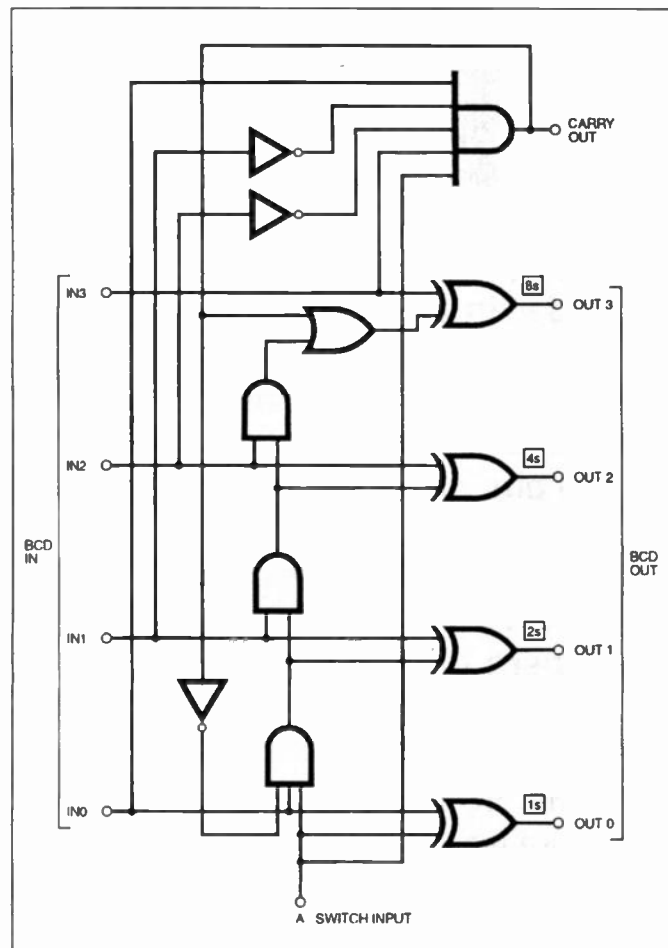


Fig. 1. An "add-one" combinational logic solution with BCD and carry outputs.

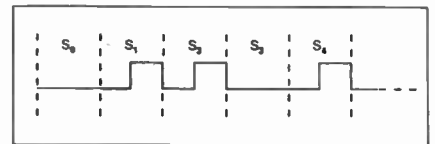


Fig. 3. Signal for clocking a BCD counter.

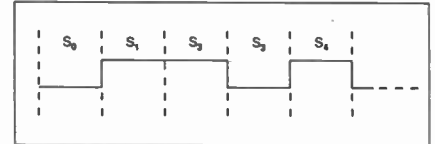


Fig. 4. Signal for controlling the "enable" input of a BCD counter.

inspired by the neural circuitry in our brains.

## Sequential Solution

Let's now move on to looking at sequential solutions. A obvious approach would seem to be to use a 3-digit BCD counter – but what would it count? The switches provide 100 separate and simultaneous signals, which differs from the single series of pulses which we apply to a counter.

We have to convert the static switch inputs into a sequence which can be counted. This sequence could either be a clock for the counter, or a control for a "count enable" input, with the counter clocked separately.

The latter method is less sensitive to glitches on the switch sequence input. A signal suitable for clocking the counter is shown in Fig. 3 and one for controlling an enable in Fig. 4.

In both cases the waveform is divided into "time slots", one per switch, during which either a clock edge or a logic 1 occurs if the switch is on, and logic 0 occurs if the switch is off. The enable-controlled version would require the counter to be clocked in the middle of every time slot.

To get the waveforms shown in Figs. 3 and 4, we have to "scan" the switches in some way. One very interesting possibility is shown as an outline schematic in Fig. 5. This uses a 100-stage parallel-in serial-out (PISO) shift register with a switch connected to each of the 100 parallel inputs (P0-P99).

The shift register's mode of operation, either parallel load or serial shift, is controlled by the shift/load control (S/L). The shift register is usually in "shift" mode, with the serial input (SI) held low and it

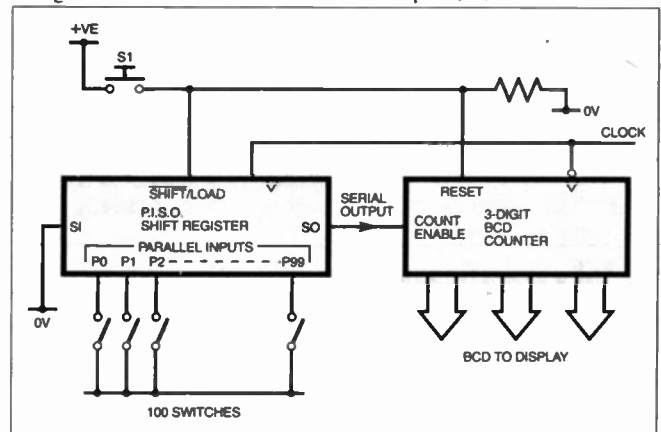


Fig. 5. Method of scanning switches using a 100-stage PISO shift register.

will therefore "empty" after 100 clock cycles producing only zeros on its serial output after this point.

When switch S1 is pressed the shift register is put into "load" mode and stores the current state of the switches. The shift register will keep on loading the switch state repeatedly while S1 is held, but this does not matter. When S1 is released, the shift register will return to shifting, and will shift out the data loaded from the switches, producing a waveform like that in Fig. 4 on the serial output.

In order to count the sequence from the shift register properly the counter must start at 0. This is easily achieved by resetting the counter when the shift register is being loaded.

The shift register and counter are clocked on opposite edges of the clock so that new data from the shift register has time to stabilise before the counter is clocked. After 100 clock pulses the serial output will remain low so the counter will not count any further.

Unlike the combinational solution, Fig. 5 does work at "the throw of a switch", and for clock rates above about 5kHz the response will be just about instantaneous from a human point of view. The display could be blanked while S1 is being pressed so that the reset 000 is not displayed.

You'll see that the circuit in Fig. 5 is much simpler than the combinational circuits we saw last month, but it still requires a large number of chips (to make

the 100 input shift register). A neater solution to the scanning problem involves connecting the switches in a "matrix" arrangement - an approach which is often used for keyboards, and something I'll describe in *Circuit Surgery* next month. Ian Bell.

### Let's wrap some wires, man!

Wirewrapping is not something which everyone feels is an appropriate or justifiable way to prototype a circuit board. It isn't necessarily cheap but nevertheless it has wide acceptance for developing experimental circuitry in a variety of electronics industries.

Armed just with a circuit diagram and wirewrapper tool, you don't need to resort to PC CAD software to produce a one-off board, when you can instead wire it up as you go along. Many beers and cheers to **David Harrison** who wished to complain in the strongest possible terms:

*Sir - Shock. Horror. Horrendous state of affairs, etc., ye gods, how low could the industry sink? Ahem. In short, wirewrap sockets. Can't get them for love nor money, not unless I buy in large (read: expensive) quantities. The prospect of having to send to the United States for wirewrap i.c. sockets and ID labels etc. is not a pleasant one, postage wise. Can the might of EPE be brought to bear upon this issue?*

*Yours, Disgruntled of Sussex*

I needed some wirewrapping sockets *desperado* for the *Teach-In "Check Out: Wirewrapping"* feature last month, and the only place I found them was (once again) in the catalogue of Farnell Components (Internet web site <http://www.farnellcomponents.com>).

These sockets are indeed very hard to get, and you are not the first to comment about this. Those long-legged wirewrap i.c. sockets also have other uses, such as standing an i.c. off a board for whatever reason.

Come on, suppliers, you're missing out! Meantime, according to the Farnell Catalogue, you want Cat. No. 170-456 *et al.*, 8-way wirewrap sockets start at £0.58 each + VAT.

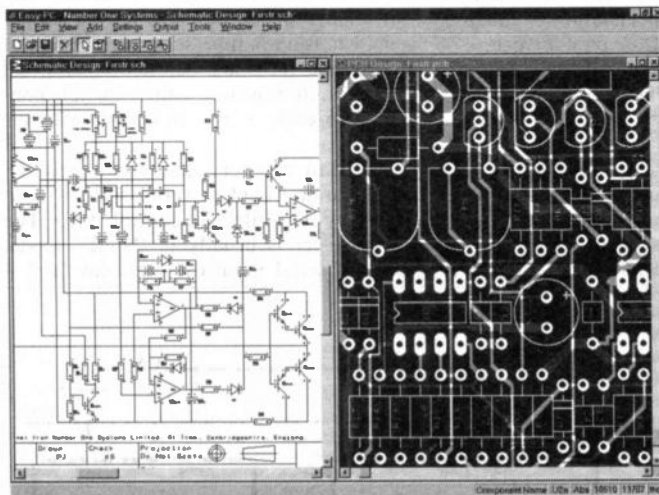
You also asked about those ID labels, and Farnell stock *Wrap-ID*® labels which fit on the underside (wiring side) of the board, and they enable you to identify the pin numbers of chips without doing mental gymnastics. Contact Farnell by phone on 01132 636311. They say they will send you a catalogue, free. I hope you have a large letterbox!

• More readers' letters, comments and queries next month.

### 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](mailto:alan@epemag.demon.co.uk).

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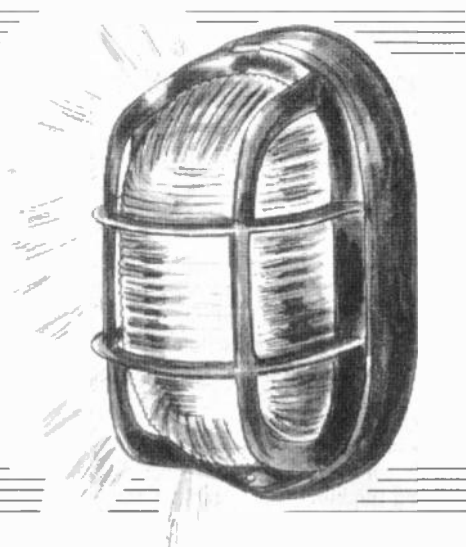
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# SECURITY AUTO-LIGHT

TERRY de VAUX-BALBIRNIE



*Switches on at dusk – goes off automatically! Scare the lights out of would-be intruders!*

**S**UPPOSE you were unexpectedly delayed and arrived home late. Wouldn't it be nice if a lamp had switched on automatically to welcome you?

This circuit will operate an exterior porch lamp, or a light inside the house, at dusk and switch it off again a few hours later. With the light under automatic control, it will continue to switch on and off day after day and operation may be forgotten.

## BURGLAR DETERRENT

As well as giving a pleasant appearance to the home and lighting up dim areas, this system will give the impression that there are people about and so deter burglars. It will switch on at variable times according to the ambient light level and this means that the *off* times will also change to some extent. This gives a realistic "lived in" appearance to any potential intruder and will be of particular value when the house is left unoccupied – when the family is away on holiday, for example.

Although the circuit will operate any lamp up to 100W rating, it is recommended that it is used in conjunction with a modern "low energy" bulb (this is a major advantage over most commercial automatic porch lights). If this was rated at, say, 13W (providing the same light output as a 60W tungsten filament type), it would only cost £2 a year approximately to operate (based on a usage of 6 hours per day).

Whereas the traditional type of bulb would probably need to be replaced at least once during the course of a year, the low energy variety should provide several years of service. *Note that this unit is not suitable for use with halogen security-type lights.*

The 100W limit has been imposed chiefly to take into account the large surge of current which occurs when a filament lamp is first switched on. This is due to the cold filament having a much lower resistance than one at working temperature.

An excessive surge of current could burn out or seriously reduce the life of the relay contacts used in this circuit. A further point is that a heavy surge on the mains sometimes causes a "spike" on the supply to the circuit and could cause false triggering. Also, certain copper tracks on the p.c.b. carry mains current and these have a limited capability.

## TIME SETTING

The Security Auto-Light is housed in a small case having a mains on-off switch mounted on the front panel. There is also a three-position slide switch and two push-button switches.

The time delay after which the lamp switches off is set by the slide switch. In the prototype, the timings are 2, 4 or 6 hours but it would be a simple matter to modify these to suit the application. The pushbutton switches provide *Manual on* and *Cancel* functions.

Ambient light is detected by a sensor mounted remotely and connected to the unit through a piece of twin wire. The sensor will probably be attached to the

inside of a window frame so that it can "look" at the sky. The light level at which switching occurs is set by a control inside the case at the end of construction.

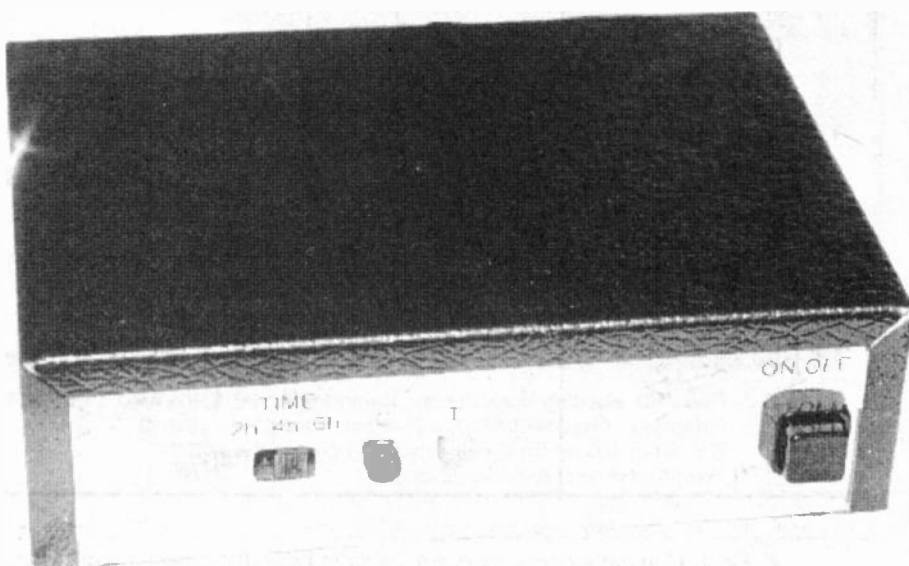
Normally, all that will be needed is adjustment to the *off* delay every eight weeks or so to compensate for seasonal variations in light level (so that the lamp goes off at a reasonable time) and to suit any occasional changes which the user wishes to make.

**Warning:** *Construction of this circuit involves making mains connections. Anyone who is not certain that he or she can make a safe job must consult a qualified electrician.*

## OPERATING MODES

The unit may be used in one of two ways – to operate either a portable or a fixed light. To control a free-standing lamp such as a reading light this, together with the light sensor, are connected to the unit which is placed on a window sill or shelf. The Auto-Light is then plugged into a nearby mains socket.

For a fixed lamp, such as an exterior porch light, the unit must be mounted permanently on a wall inside the house. Fixed wiring is then taken to a wall-mounted double-pole switched and fused mains outlet. From here, connections are made to the unit using flexible cable.



The photographs show the free-standing version.

## CIRCUIT DESCRIPTION

The entire circuit for the Security Auto-Light is shown in Fig.1. A low-voltage d.c. supply is derived from the conventional arrangement of mains transformer T1, bridge rectifier REC1 and smoothing capacitor C1.

The result is a supply of approximately 16V which operates the rest of the circuit. Both primary and secondary transformer circuits are fused using FS1 and FS2 respectively and the Live Input carries an on-off switch S1.

Operational amplifier (op.amp) IC1 and associated components are responsible for light sensing while IC2 performs the timing function. Consider the light sensing section first.

The op.amp IC1 is used as a voltage comparator and works in the following way. If the voltage at the non-inverting input (pin 3) exceeds that at the inverting input (pin 2), then the output at pin 6 will be high (positive supply voltage). In other cases it will be low (0V).

Each input receives a voltage from a potential divider. For the non-inverting one this comprises equal resistors, R3 and R4 (ignoring resistor R5 for the moment). This input will therefore receive a voltage equal to one-half that of the supply (nominally 8V).

Pin 2, inverting input, receives a voltage derived from the potential divider consisting of fixed resistor R1 and preset potentiometer VR1 (connected as a variable resistor) in the top arm and light-dependent resistor R2 in the lower one. As the light level falls, the resistance of R2 will increase and the voltage appearing at pin 2 will rise.

## LIGHT LEVEL

With suitable adjustment to preset VR1, during daylight hours the voltage at pin 2 will be less than that at pin 3. The op.amp will then be on with pin 6 high (positive supply voltage).

Diode D1 will block this state and there will be no further effect. As the light level falls, at a certain point the voltage at pin 2 will exceed that at pin 3 and pin 6 will suddenly go low.

The light level at which switching occurs is set by VR1 and this may be adjusted to work over a wide range of intensity and with practically any l.d.r. (light dependent resistor). Resistor R5 applies a little positive feedback to the system and this sharpens the switching action.

Note, the operating point will be unchanged if the supply voltage varies slightly. This is because both op.amp input voltages are derived from potential dividers connected across the same supply. Thus, any variation in voltage will be reflected at both inputs so the relative conditions will be virtually unchanged.

## LOW PULSE

When the output pin 6 goes low, light emitting diode (l.e.d.) D2 operates with current limited by resistor R6 and sinking into IC1 pin 6 via diode D1. This l.e.d. is used for testing and setting-up purposes.

Additionally, a low pulse is transferred via capacitor C2 to the trigger input (pin 1) of timer IC2 and this initiates a timing cycle. Output pin 3 of IC2 will then go high for a set time and revert to low after this period.

Any further trigger pulses arriving during this time period will have no effect. In the absence of a trigger pulse, IC2 pin 1 is maintained in a normally high condition through resistor R7 and this prevents possible false operation.

Precision timer IC2 can provide very long periods with relatively low value timing components. These are capacitor C4 connected between pin 13 and the 0V line and the resistance appearing between pins 13 and 14. Ignore resistors R11 to R13 for the moment (one or more of these will appear in parallel with R10 depending on the setting of switch S4, but their effect is negligible).

For practical purposes, the timing will therefore be related only to the value of resistor R10. While timing capacitor C4 repeatedly charges through R10 then discharges through internal circuitry. Each time this happens, a counter registers the number of events. When this reaches 4096, pin 3 goes low again.

## VOLTAGE REGULATION

To enable IC2 to provide accurate time delays despite variations in supply voltage, on-chip voltage regulation is needed. This operates in conjunction with resistor R9 to give a 5V supply for the chip. The difference between 5V and the supply voltage (11V approximately) exists across this resistor.

Since resistor R10 has a relatively low value, each charge/discharge cycle will be very short (about 10ms) and the whole sequence will last for 40 seconds approximately. This is only used for testing purposes and to get the final timing approximately correct. After that,

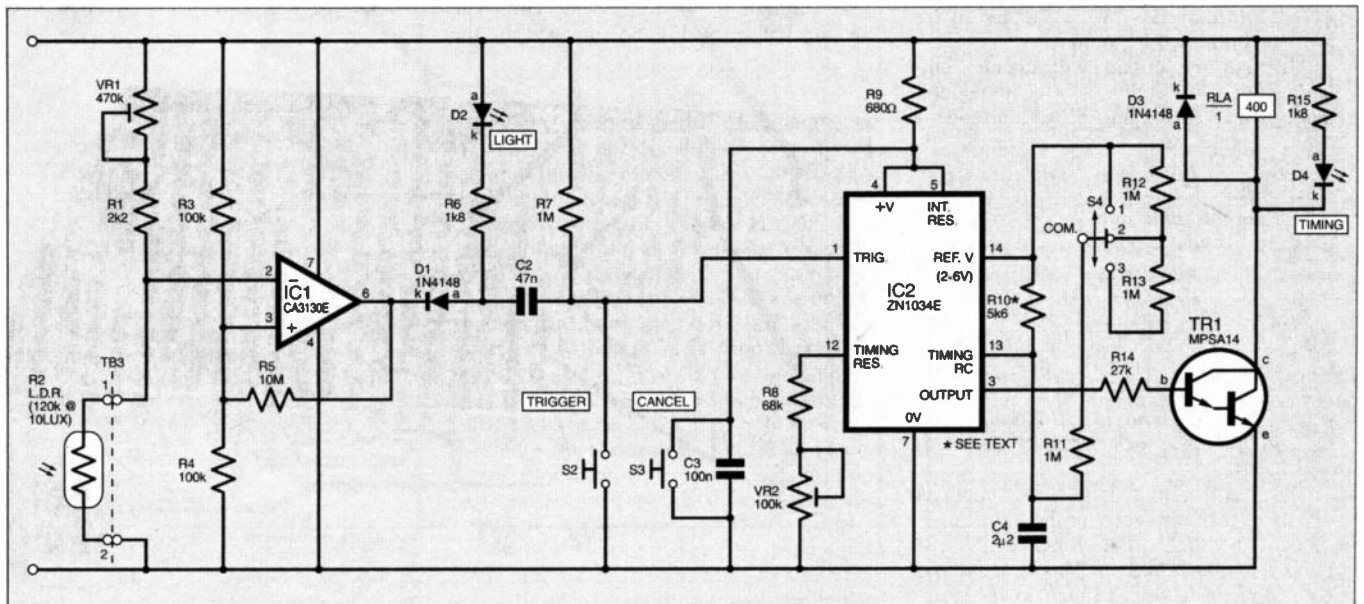
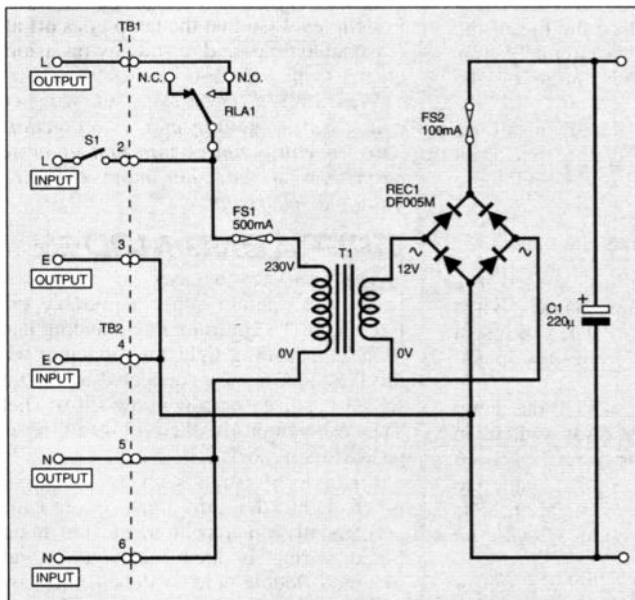


Fig.1. Complete circuit diagram, including suitable power supply (above left), for the Security Auto-Light.

one of the wire connections to R10 is cut to remove it from the circuit.

Timing is now set by either resistor R11 alone (with switch S4 in position 1) or R11 + R12 (position 2) or R11 + R13 + R12 (position 3). These resistors have much higher values than R10 so the timing will be correspondingly greater. Also, since their values are equal, the timing will rise in equal steps giving nominally 2 Hours, 4 Hours and 6 Hours.

The resistance connected between IC2 pin 12 and the 0V line acts as an adjustment to the timing. With the components specified, preset VR2 can vary it between -33% and +33% approximately. For timings outside this range of adjustment, capacitor C4 could be substituted with one having a different value - raising it would increase the timings in proportion and vice versa.

## RELAY DRIVE

With IC2 pin 3 high during the course of timing, current flows through current-limiting resistor R14 to the base (b) of Darlington transistor TR1. Collector current then operates the relay RLA. The contacts of the relay, RLA1, close allowing current to flow from the mains Live Input to the Lamp.

During this time, i.e.d. D4 connected in parallel with the relay coil will light with current limited by resistor R15. This i.e.d. will be useful during the preliminary testing stage because the circuit may be operated and adjusted using a 9V battery before connecting it to the mains. More will be said about this later.

Diode D3, also connected in parallel with the relay coil, prevents the potentially destructive effect of the high-voltage pulse which occurs briefly when the magnetic field in the relay core collapses.

The timing cycle may be initiated manually by pressing Trigger switch S2 at any time. This applies a low pulse to IC2 pin 1 independently of the state of IC1 pin 6.

Cancel switch S3 works by connecting pins 4 and 5 to the 0V line. This effectively short circuits IC2 so it loses its power supply. Current through S3 contacts is limited to a low value (about 24mA) by resistor R9.

If this switch is operated after the circuit has been manually triggered during the daytime, the lamp will switch off. If (as is more likely) it is pressed while the circuit is operating at night, it starts the time period again. The lamp then only goes off briefly while the switch is pressed. This is useful to extend the on period for a party, for example.

### WARNING

Potentially lethal voltage exists at certain p.c.b. tracks while the circuit is connected to the mains. Great care must therefore be taken with the transformer connections and all aspects of construction. If in doubt, a qualified electrician must be consulted.

All testing and adjustment must be carried out using a battery as a power supply. The unit must only be connected to the mains when the circuit panel has been mounted in the box and the lid secured.

## CONSTRUCTION

Details of the printed circuit board (p.c.b.) are shown in Fig. 2. This shows the topside component layout and full size underside (copper track) view. The board is available from the *EPE PCB Service*, code 189.

Construction is straightforward because all the components, apart from mains on-off switch (S1), the l.d.r. (R2) and possibly the transformer are mounted on the board. Readers who cannot source the p.c.b. mounting transformer used in the prototype may use a small chassis type mounted separately on the base of the metal case.

## MAKING A START

Begin by soldering the transformer (if of the p.c.b. type), relay, fuseholders and screw terminal blocks TB1 and TB2, each having three sections. Add the p.c.b.

mounting switches S2, S3 and S4 also the two i.c. sockets as indicated.

The switches should be soldered so that the lever of S4 and the buttons of S2 and S3 form a straight line. With those used in the prototype, this means that slide switch S4 should be mounted close to the board, while the two pushbutton switches should be soldered with maximum clearance - that is, with only the minimum amount of end leads pushed through the holes to make good soldered joints. Although not essential, this will give a good appearance when the unit is mounted inside the box (see photograph).

Follow with the link wire, all resistors (including both preset potentiometers) and capacitors. When soldering resistor R10, mount it so that one of its end leads may be easily cut. Note that capacitor C1 is of the electrolytic type and it is essential to observe its polarity.

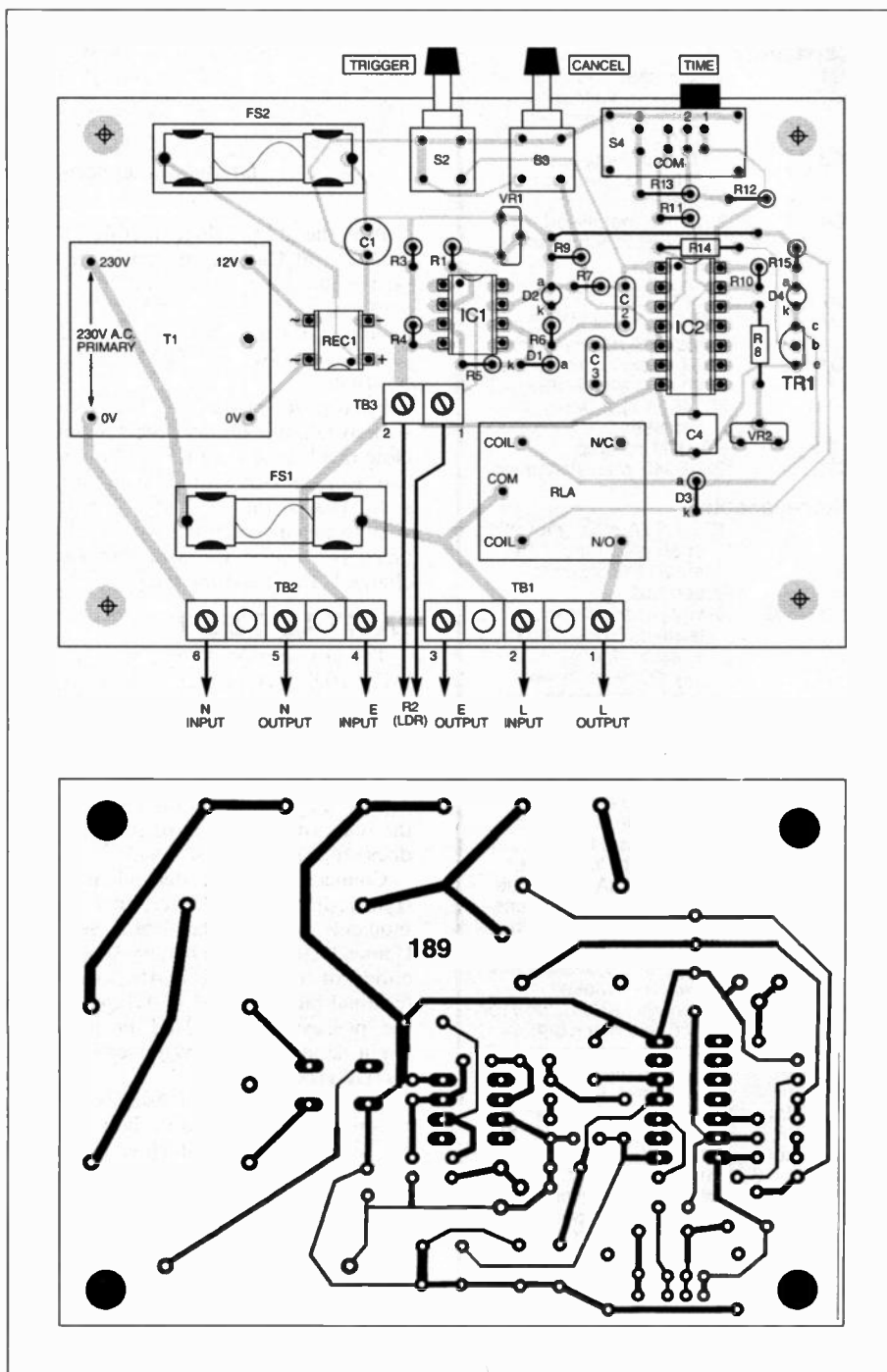


Fig.2. Printed circuit board component layout and full size copper foil master. Beware, some copper tracks carry mains voltage.

# COMPONENTS

## Resistors

R1	2k2
R2	Miniature light-dependent resistor – resistance at 10 lux 120k approx. (see text).
R3, R4	100k (2 off)
R5	10M
R6, R15	1k8 (2 off)
R7, R11, R12, R13	1M (4 off)
R8	68k
R9	680Ω
R10	5k6 (see text)
R14	27k

All 0.6W 1% metal film, except R2

## Potentiometers

VR1	470k min. enclosed carbon preset, vertical
VR2	100k min. enclosed carbon preset, vertical

## Capacitors

C1	220μ radial elect. 25V
C2	47n min. metallised polyester, 5mm pin spacing
C3	100n min. metallised polyester, 5mm pin spacing
C4	2μ2 min. metallised polyester, 5mm pin spacing

## Semiconductors

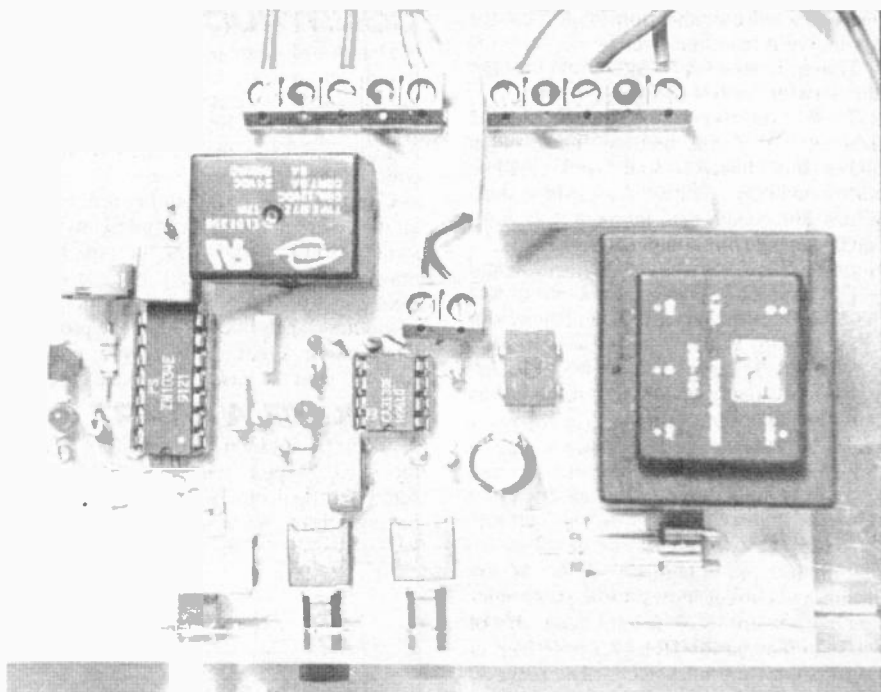
REC1	DF005M 1A 50V bridge rectifier, d.i.l. type
D1, D3	1N4148 signal diode (2 off)
D2, D4	3mm red l.e.d (2 off)
TR1	MPSA14 npn Darlington transistor
IC1	CA3130 op.amp
IC2	ZN1034E precision timer

## Miscellaneous

T1	12V 1.2VA p.c.b. mounting or chassis-mounting mains transformer – see text.
TB1/TB2	3-way p.c.b. screw terminal block, 10mm spacing (2 off)
TB3	2-way screw terminal block, 5mm spacing
RLA	12V 400 ohm coil min. relay, with 230V a.c. 5A "make" contacts.
FS1	20mm p.c.b. fuseholder with insulating cover and 500mA ceramic mains-type fuse.
FS2	20mm p.c.b. fuseholder and 100mA glass fuse.
S1	s.p.s.t. pushbutton mains switch, 3A rating min.
S2, S3	Min. p.c.b. mounting right-angle pushbutton switch – "make" contacts (2 off). One red and one black button.
S4	Min. p.c.b. mounting right-angle 3-position slide switch

Printed circuit board available from the EPE PCB Service, code 189; aluminium, two-piece, case, size to choice; 12.5mm (½in.) plastic stand-off insulators (4 off); one section of 3A screw terminal block (for fixed version only); strain relief bushes (2 or 3 as required – see text); materials for light sensor housing (see text); solder tag; small fixings; solder, etc.

See  
SHOP  
TALK  
Page



Layout of components on the completed circuit board.

Add the d.i.l. bridge rectifier, i.e.d.s, diodes, and Darlington transistor, again, taking care over the orientation of these components. Adjust VR2 to approximately mid-track position. Adjust VR1 fully clockwise as viewed from IC2 position.

Finally, insert the two i.c.s into their sockets taking care over their orientation. Note that the i.c.s are CMOS components and it is possible to damage these by static charge on the body. It would be wise to touch something which is earthed (such as a water tap) to remove any such charge before handling the pins.

## INITIAL TEST

The circuit panel should now be tested using a 9V battery such as a PP9 type.

**Do not perform this initial test using the mains – the exposed mains connections at certain p.c.b. tracks would make this extremely dangerous.** Note that a 9V supply may not be sufficient to operate the relay (no click may be heard) but this does not matter at this stage.

Connect the light dependent resistor (l.d.r.) direct to TB3 terminals for the moment keeping the leads separated. Connect the negative battery snap wire to either of the mains Earth positions at terminal blocks TB1/3 or TB2/4. Connect the positive battery lead to the outlet (right-hand side) of fuseholder FS2 using a small crocodile clip.

Providing there is a reasonable amount of light reaching the l.d.r., the Light l.e.d. D2 should be off – it should come on when the l.d.r. is covered by the hand.

A timing cycle should now be initiated and Timing l.e.d. D4 will operate for 40 seconds approximately. Repeat and adjust preset VR2 until the timing is within one or two seconds of this figure. Clockwise rotation of the sliding contact (as viewed from the lower edge of the p.c.b.) will increase the period. Once done, this should produce eventual timings of approximately 2, 4 and 6 hours.

## BOXING UP

If all is well after completing the initial tests, the unit may be mounted in the metal case. Choose a suitable box according to whether the unit is to be free-standing or wall-mounted, see Fig.3 and Fig.4. Also, taking into account whether the transformer is mounted on or off-board. **The box must be made of metal and earthed as described.**

Cut one end lead of resistor R10 and separate the free ends so that they cannot touch. Disconnect the l.d.r.

Measure the positions of the switches and, using some pieces of cardboard or wood as spacers, support the corners of the p.c.b. so that it stands 12.5mm (½in approximately) above the base of the box. Mark the switch positions on the front panel side. Remove the p.c.b. and make these holes ensuring that the one for the slide switch is wide enough to allow the lever to be moved to all positions. Support the p.c.b. in position again, with the switches engaged in their holes, and mark the mounting holes on the bottom of the box. Remove the p.c.b. and drill these holes.

Make holes in the rear panel for the strain relief bushes to be used on the input and output wires and for the sensor (see photograph). For the fixed version, only two strain relief bushes will be used but one hole will need to be larger to accommodate a strain relief bush sufficient for 4-core mains wire (see later).

Drill a separate hole for the "earthing" solder tag (but not if the transformer is to be mounted off-board). If the unit is to be wall-mounted, drill two holes in the back taking care to avoid the p.c.b. position. If using a chassis-mounting transformer, drill the mounting holes and attach it securing the solder tag under one of its fixings.

Check carefully the proposed position for mains on-off switch S1 and cut its hole. In the prototype, a "push-on push-off" type was used but various other

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switches having 3A minimum mains-rated contacts will do. Attach it to the front panel and make sure that its tags are at least 10mm clear of anything else.

If the transformer is on-board, the p.c.b. may now be mounted using plastic stand-off insulators on the bolt shanks. Check again that the soldered connections on the bottom of the p.c.b. are at least 5mm clear of the base of the box.

Attach the buttons to switches S2 and S3 – red for S2, black for S3. Insert the ceramic mains-type fuse in fuseholder FS1 and the glass one in FS2. Fit the insulating cover to fuseholder FS1. Attach self-adhesive plastic feet if the box is of the free standing type.

## OFF-BOARD

If the mains transformer is mounted off-board, make the following connections *direct* on the *underside* of the p.c.b. The brown 230V primary wire to the output side (left-hand side) of fuseholder FS1 and the blue one to TB2/6. **Make certain these connections are secure.**

Connect the white (secondary) wires to the "0V" and "12V" copper pads. Cut the black (centre tap) wire short, double the end over and insulate it with p.v.c. tape.

The p.c.b. may now be mounted in position using plastic stand-off insulators on the bolt shanks. Double check that all soldered connections on the underside are at least 5mm clear of the metalwork.

## Light Sensor

*Note that, in theory, the l.d.r. wiring could become live under catastrophic failure of the mains transformer. It is therefore necessary to use light-duty mains-type double insulated twin wire (that is, an outer sheath and the wires inside individually insulated) for the connection between screw terminal block TB3 and the light dependent resistor. The l.d.r. itself must be fully enclosed in a plastic tube so that it is impossible to touch any bare wires.*

Although a miniature type of l.d.r. is specified for R2, a full-size ORP12 type could be used instead. However, this would need to be mounted inside a small plastic box. With the miniature type, it may be housed inside the casing of an inexpensive mains neon indicator. This gives a good appearance and protects the delicate end wires.

To make the sensor housing, cut off the end of the neon indicator having the terminals, using a small hacksaw. Remove the neon tube itself together with its series resistor then file the edge of the tube smooth. Shorten the l.d.r. end leads to a length of about 8mm. *Do not reduce their length more than this because, when soldering, the heat from the soldering iron could conduct along them and damage the device.*

Measure off sufficient wire to reach between the light sensor and main unit position. Solder the l.d.r. leads to one end of the wire, gripping the individual wires between the l.d.r. body and the joint using fine-nose pliers. This will act as a simple heat shunt and minimise the risk of damage referred to above.

Keeping the wires separated, insert the l.d.r. into the tube so that the soldered joints are well inside and the l.d.r. window faces upwards. Now seal the end using quick-setting epoxy-resin adhesive. This should not

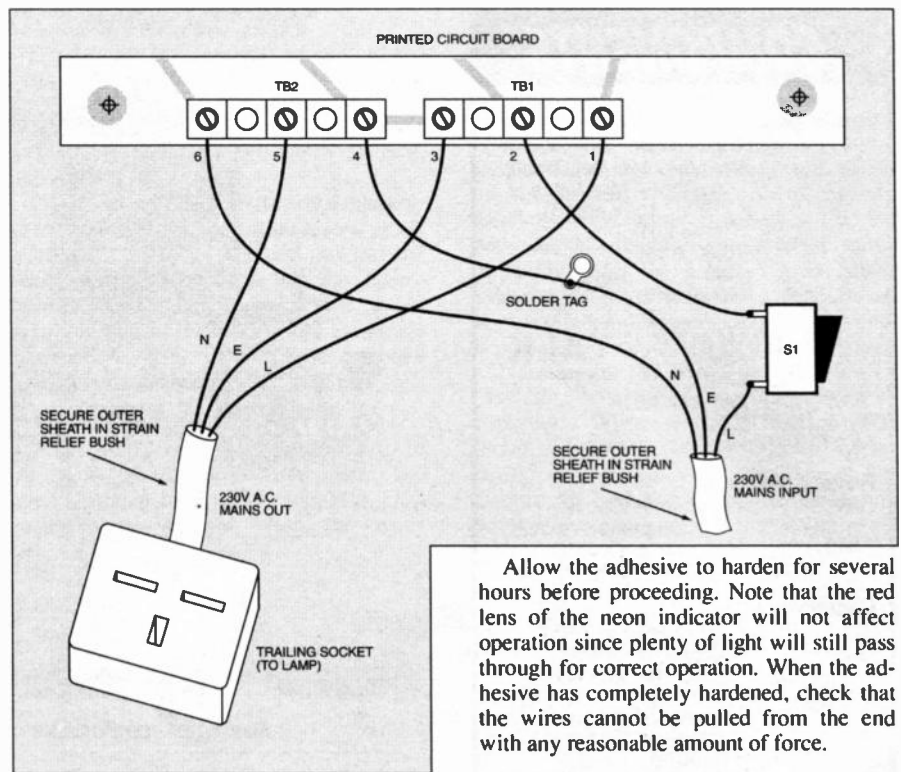


Fig.3. Wiring arrangements for a portable lamp set-up. The Earth solder tag is bolted to the base of the metal case.

be allowed to fill the tube and reach the l.d.r. – the end 5mm is sufficient. This will keep the wires separated and secure the output lead in place.

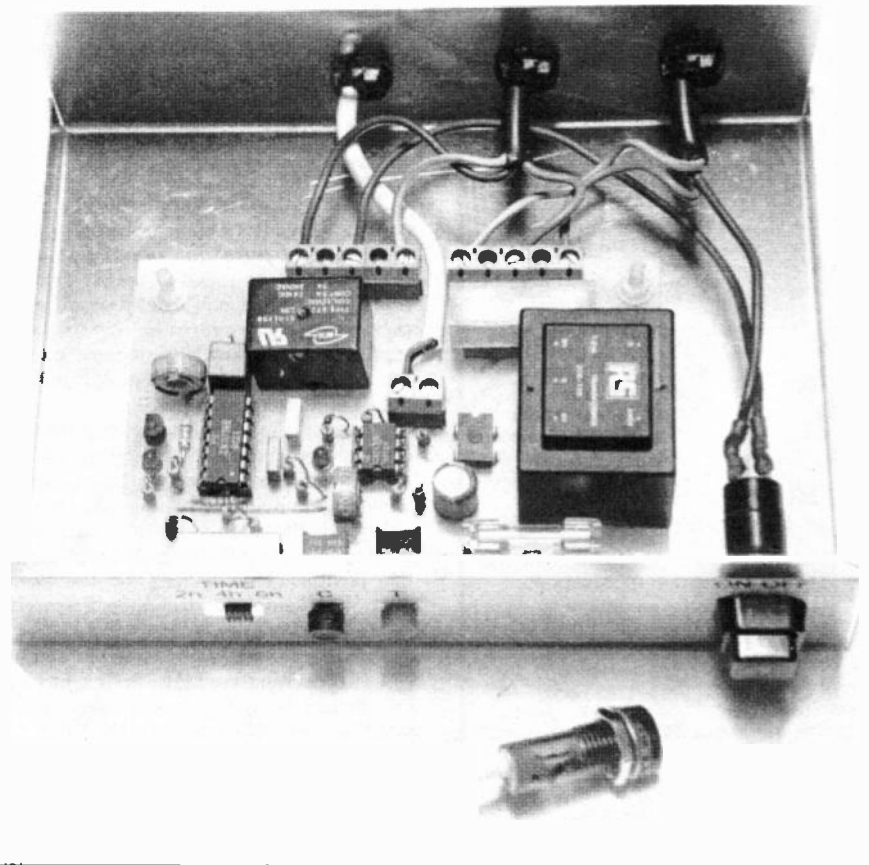
Allow the adhesive to harden for several hours before proceeding. Note that the red lens of the neon indicator will not affect operation since plenty of light will still pass through for correct operation. When the adhesive has completely hardened, check that the wires cannot be pulled from the end with any reasonable amount of force.

## INSTALLATION

**Important:** The light sensor and main unit must both be situated in a dry indoor location.

## Portable Light

If the unit is to be used to operate a portable light, refer to Fig.3. Cut off a piece



Finished Security Auto-Light showing positioning of components inside the metal case. The light sensor (foreground) is housed in a disused mains neon indicator housing and connected to the p.c.b. through a piece of double-insulated mains cable.



of mains-type wire of 3A rating minimum and fit a 13A trailing-type socket on one end. Secure the other end through one of the strain relief entry bushes and, leaving some slack, connect it to TB1 and TB2 screw terminal blocks in the following way: Live to TB1/1; Neutral to TB2/5 and Earth to TB1/3.

A similar piece of 3A mains-type wire is used to connect the unit to the mains input plug. Secure the wire through one of the remaining strain relief bushes and connect it in the following way: Live to one terminal of S1 and the other switch terminal to TB1/2; Neutral to TB2/6 and Earth to the solder tag hence to TB2/4.

Note that fully insulated receptacles should be used on the switch tags. Alternatively, soldered joints may be made and insulated using heat shrinkable sleeving. Check that the earth connections at the solder tag are secure.

Fit the mains plug with a 2A or 3A fuse. Check also that the fuse in the lamp plug has a similar rating. Attach the lid of the box.

## Fixed Light

Before proceeding switch off the mains at the fusebox and remove the appropriate fuse.

Refer to Fig.4 for the Fixed Light interwiring details. The fixed wiring for the lamp and a mains feed are taken to a wall-mounted double-pole switched and fused mains outlet. Note that the exact positions of the terminals on the back of this vary with the manufacturer.

The main unit is mounted on the wall nearby and a short piece of 4-core mains-type flexible wire is used to connect it to the outlet. Secure the wire through the strain relief bush. The Live mains output is taken to switch S1 and hence to terminal block TB1/2. The Live feed for the lamp is taken to TB1/1 using a piece of screw terminal block to make the connection.

The Neutral mains output is connected to the lamp Neutral wire and TB2/6 and the Earth to TB2/4. Two terminals are left unused, TB1/3 and TB2/5. The switched outlet should be attached in position with the piece of screw terminal block inside the box and a 2A or 3A fuse fitted.

## LIGHT DETECTOR

The light sensor should be attached to a window frame using a small spring clip

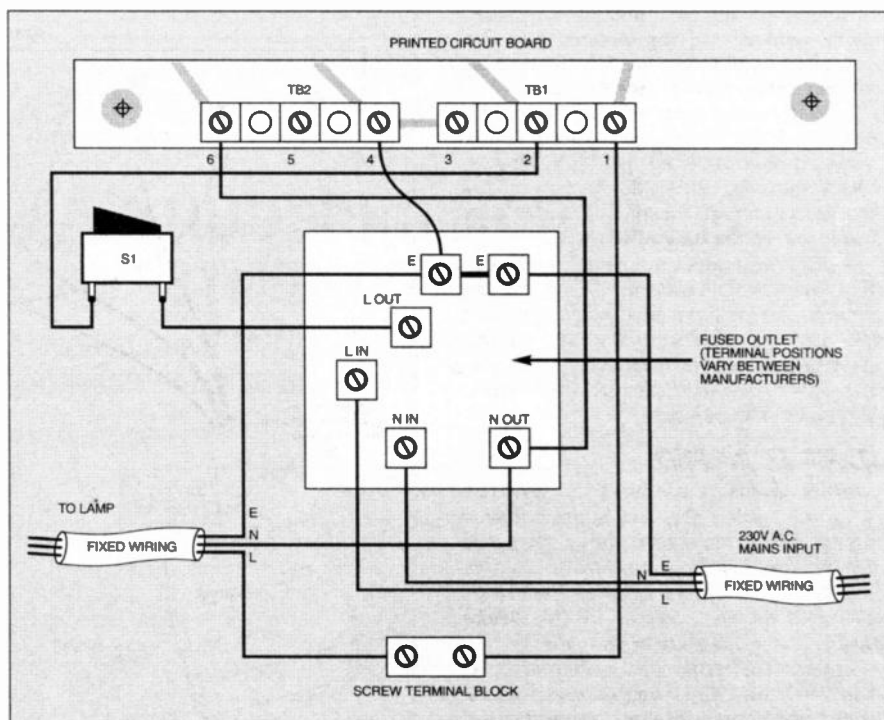


Fig.4. Fixed light interwiring details. The fixed wiring for the lamp and mains feed are taken to a wall-mounted switched and fused outlet box.

so that it points towards the sky or at least away from the light which it controls or any other source of light. The wires should be secured through the remaining strain relief bush and connected to TB3.

It is important to note that false re-triggering may result if the sensor can "see" the light which is controlled by the unit or any other light (such as a halogen security light). The position of the sensor must be chosen with care if false triggering is to be avoided. This will tend to happen when any light which it "sees" goes off.

## FINAL CHECKS

Adjustments to presets VR1 and VR2 must be made in a series of small steps with the unit isolated from the mains each time. With the free-standing circuit this means unplugging it from the mains. For the fixed version, it must be switched off at the outlet and the fuse removed. The lid must be replaced before making a trial.

Check that the unit works correctly on all three time settings. VR2 may be adjusted as

required but there is no point in trying to obtain very accurate timings. Even if you did, they would change to some extent with temperature and other factors.

Adjust preset VR1 over a period of a few days for the correct light operating level. Only a very small anti-clockwise rotation will probably be needed if the sensor can "see" direct daylight. It only remains to make a label for the front of the unit and put it into service.

## FLUORESCENT LIGHTS

If the sensor wiring is more than a few metres in length, it may be found that the unit triggers when nearby fluorescent lights are operated. It appears that the sharp electromagnetic pulse produced by these units when they switch on may be picked up along the wiring.

This effect may be eliminated by using miniature screened wire to make the connection. The inner conductor should be connected to TB3/1 and the screening to TB3/2.

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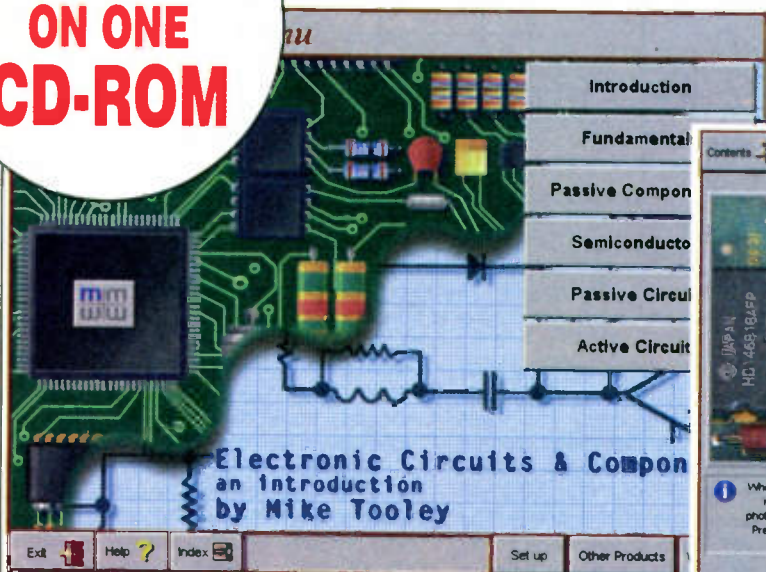
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**PEAK**

# READOUT

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

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## WALZING THROUGH BASIC HISTORY

Streaming down the Net recently came a lengthy document from Steve Walz (great stuff Steve, thanks!) a computer and electronics guru, and Alan Winstanley's (Network) right-hand man in Silicon Valley (Santa Cruz, USA). Alan sends him a copy of EPE every month.

The missive was full of fascinating observations on BASICs in general and specific gripes about many in particular. It was in response to the Readout letter from R.L.A. Latham (An End to GW-BASIC, Dec '97). There's no way we could repeat

Steve's comments in print without consulting our lawyers (and a dictionary of what we take to be Net-slang - or is Net Slag-off a better term?)!

What we can offer you is Steve's *Evolution of Basic* (got any dates Steve?):

### DARTMOUTH:

B.A.S.I.C. Invented by Prof. Kemeny from a FORTRAN source code. Stands for "Beginner's All-purpose Symbolic Instruction Code".

### CPM:

MBASIC. MBASIC.COM numberline interpreter inside or by argument.

BASCOS. BASCOS.COM powerful compiler, compiling either .INT files or stand-alone .COMs using the /O (object code) flag.

### PC-DOS:

BASIC. Interpreter in ROM, fall-in if boot-fail or init program to run it call BASIC.COM.

BASICA. Similar to above BASIC; call BASICA.COM; graphics in software for the same ROM BASIC.

BASCOS (DOS). BASCOS.COM powerful compiler as above CPM.

### MS-DOS 3.0/3.3:

GW-BASIC. Interpreter in software. Call GWBASIC.COM; runs programs .BAS internal or by argument after it. Stays in to edit or exits if SYSTEM is called.

BASCOS (DOS). BASCOS.COM powerful compiler as above PC-DOS; still in use till QuickBASIC.

QuickBASIC Versions 2.0/3.0/4.0/4.5 compiler with WordStar edit set interactive development environment and now classic MS interactive editor window with compile in RAM and run on the fly or compile to .INT or free-standing .COM/.EXE files.

### MS-DOS 4/5/5.5C:

The (deleted Walz observation!) OS versions, full of bugs! Only the final 5.5C was almost stable and well-behaved!! The QBASIC interpreter using new "QuickBASIC Compiler" style MS Window Editor interactive environment. Handy, as output files could run directly in QuickBASIC compiler and become .OBJ code files!

### MS-DOS 6/6.2:

Finally a stable OS with some new stuff in it worth having!

QBasic. Interpreter as above DOS 4 etc. VisualBASIC. New Windowing and Windows apps environment. Major upgrade to an entirely new level in creation of cheezy Windowing ops in DOS and for WINDOWS through 3.1.

### WINDOWS (DOS 7):

VisualBASIC. Upgraded VisualBASIC to greater Windows icon capability. Now can be used to generate even 32-bit apps!

Steve Walz, [rsteve@armory.com](mailto:rsteve@armory.com)

## ★ LETTER OF THE MONTH ★

### BUDGET AND CRAFT WISE

Dear EPE,

I write this letter having in mind all electronics enthusiasts of all levels, and mainly those with a limited budget and/or those like myself who have some limited knowledge as a whole.

My own personal involvement in electronics is as a Radio Amateur, having within the last few years decided to sit for the Radio Amateurs Examination Certificate.

For about 35 years I have enjoyed building radio receivers from various of the monthly periodicals, and have also built home-brew radio receivers of my own design, and also many items of equipment described in *EPE*.

For the most part I am self-taught and miss out on most of the latest technology and its practical application, due to not being employed in the electronics industry. This situation is probably true of many of us, and we rely very heavily on excellent magazines like *EPE* to update our knowledge.

Being involved with building radio reception and transmission equipment requires some DIY test gear. I say DIY because professional test equipment is outside of the range of my own personal finances, and I tend to look for inexpensive ways of doing tests and measurements.

I do own test equipment, such as scopes and digital voltmeters and the like, but do not have complete knowledge in their use and I find that most published books do not teach us the clever little tricks that the professionals have in using these items to the fullest of their capability.

One case in mind is that of measuring inductance down to minute values that are encountered in VHF RF circuitry. Until I recently read one particular book, I never

realised that capacitance and inductance could be measured to extreme accuracy and to less than 1pF and 1μH respectively using only a bog-standard scope, a simple signal generator and £1.50 worth of components.

Perhaps some knowledgeable *EPE* reader will come up with a complete inductance/capacitance tester incorporating this technology and digital readout.

Also, how about a series of articles about the different tricks that can be used with test equipment, bearing in mind the limited budgets of some of us enthusiasts.

**Bill Jackson, G7VPL,**  
(skint but willing to learn),  
Blackburn, Lancs

*We do try to cater for the wide range of capabilities and budgets of our readers. For example, Robert Penfold's informative series of Techniques - Actually Doing It and Interface offer advice on simple and usually inexpensive ways of achieving practical ends.*

*Many of you probably have "good bodes" you have evolved for your own constructional and testing use, and which you could share with us. We throw open the forum on this - readers, offer us the benefits of your experience in using down-to-earth and inexpensive techniques suited to amateur workshops, or kitchen tables!*

*As an aside, one wonders how much those involved in electronics industry actually do have a feel for the wider electronics picture. Do they, perhaps, have to become so specialised in their field that knowledge of other fields remains sparse? Sometimes we feel that those who publish electronics periodicals might have the benefit of a broader view, being bombarded with press releases about new products and services from all directions.*

## BYTING BACK!

Dear EPE,

In the *EPE PIC Tutorial Part I* (March '98), you state that "There is a common misconception that a byte is comprised of eight bits".

I'm a software professional with two decades of experience, and this jarred with me. To me, a byte is a collection of eight bits addressable as a single unit.

Sherilyn, via the Net

*The sources I consulted prior to writing that statement define a byte as:*

\* A sequence of consecutive binary bits ... it commonly contains eight bits (Butterworths Dictionary of Electronics)

\* A single unit of information handled by a computer; usually eight bits (Penguin Dictionary of Science)

\* A data word composed of eight bits is normally called a byte (Newnes Microprocessor Pocket Book)

\* A sequence of adjacent bits treated as a unit (Illustrated Dictionary of Electronics)

\* A fixed number of bits, often corresponding to a single character and operated on as a unit (Chambers Science and Technology Dictionary)

None specifically state that a byte only consists of eight bits. It is accepted that common usage regards a byte as eight bits, but my point was that "it ain't necessarily so"!

Readers, we invite your informed input on this subject, complete with source references and definitions!

## CONFIDENCE FOUND

Dear EPE,

I am currently studying Electrical and Electronic Engineering at university and have found your course on Digital Electronics quite interesting. Having covered all the theory in my first and second years I wasn't really exposed to the practical side and have never built any circuits before on my own outside of the university.

Following the *Teach-In* has given me confidence to design my own circuits using my knowledge at the university. I am also following the course on PICs as they seem to be the "in thing" at the moment. I must thank you and ask you to keep up the good work.

Robin Smith, via the Net

*Your lack of exposure to practical aspects compliments Mark McGuinness's comments in Readout April '98.*

*If you want more advice on practical constructional techniques, read Alan Winstanley's Build Your Own Projects series, Nov '96 to Mar '97.*

*Incidentally, although PICs are highly useful devices, don't ever think that they are the only microcontrollers that are available. Many manufacturers have broad families of micros, all with their own benefits and facilities. PICs are, though, to the hobbyist market particularly easy to use.*

*We shall be taking a look at a different family of micros from another manufacturer in the next issue, examining Atmel's*

*broad and versatile 8051 family, and describing a programmer to suit its EEPROM variants.*

## SUPPLEMENTARY BENEFIT

Dear EPE,

Many, many thanks for your excellent *PIC Tutorial*. After searching for a long time, you have been the first people to address the need to learn PIC programming from scratch.

At long last I can now get a PIC to do something and, what's more, I can understand what I am doing. I can honestly say that after subscribing to your magazine for the last eight years, the *Tutorial* supplement was certainly worth the subscription on its own.

Pete Grundy, via the Net

*Gratifying to hear it!*

## CROME ON THE NET!

Derren Crome, author of the *Simple PIC16C84 Programmer* article of Feb '96, has informed us that he has his own PIC web site and that at his address [www.djc224.demon.co.uk/picprog](http://www.djc224.demon.co.uk/picprog) he has a suite of revised PIC programming routines.

You might care to browse them and, perhaps, have a "chat" with Derren.

We at *EPE* have another PIC programmer suite coming along in the July issue. Called the *PIC toolkit*, it also converts between TASM and MPASM.

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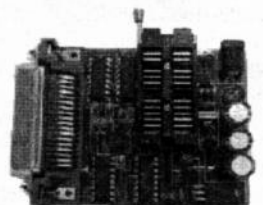
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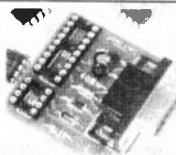
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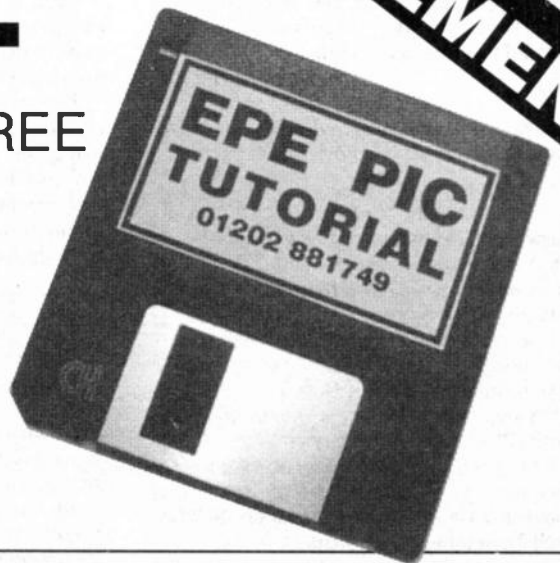
# EPE PIC TUTORIAL

JOHN BECKER PART THREE

Quite simply the easiest way to learn about using PIC Microcontrollers

You probably feel you know about PICs now! But there are still a few more commands to discover and some sophisticated examples of how to use PICs in grander systems.

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## TUTORIAL 21 CONCEPTS EXAMINED

Using 7-segment I.e.d. displays  
Showing hours, minutes and seconds

### PROGRAM - TUT26 SWITCH SETTINGS - as in Fig.21.

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

Another choice is the use of 7-segment I.e.d. displays, and that is the route we now take. First, though, we must examine how the output from PORTB needs to be coded to drive a single 7-segment I.e.d. We shall then extend the principle to multiplexing

four such displays to show a full 24-hour clock.

Each segment of a 7-segment I.e.d. display has to be controlled by individual PIC data lines. It does not matter in which order the data lines are connected to the display since the way that they are activated can be set from within the PIC's controlling program.

For convenience, here we use PORTB lines RB0 to RB6 connected in their natural order to segments *a* to *g*.

In Fig.22 are shown the segments and code letters required to form the ten numerals 0 to 9. Also shown are two lines of binary code. The first one shows the bits which need to be taken high if a common cathode display is used. The second is for a common anode display, each line being taken low to turn on the segment. It is a common anode display that we use here; its pinouts are shown in Fig.23. Connect it to the p.c.b. as shown in Fig.24. But, for the moment, connect I.e.d. line D1 to +5V, not to TR1. The equivalent circuit diagram for this single digit is shown in Fig.25.

Now load TUT26.OBJ and run it. You will see the individual numerals being shown on the left-hand digit on a cyclic basis from 0 to 9. The rate of display is at one unit per second. In other words, it can be regarded as being a seconds counter.

Referring to Listing 26, you will see that the counting routine is very similar to that in Listing 25 (Part Two), but only dealing with units of seconds. Now, though, instead of the count being sent to individual I.e.d.s it is converted in the TABSEG table to the requisite 7-segment code for that numeral when used with a common anode display.

Since we know that the value held in W when the table is called can never be greater than nine, an AND command is not needed with this table.

Obviously, to show the tens of seconds as well we need a second 7-segment display. However, it is not possible, of course, to use the same PORTB data lines to control both displays simultaneously. Nor can we use PORTA for the second display, it hasn't enough lines.

What we can do, though, is to connect PORTB to both display digits and then

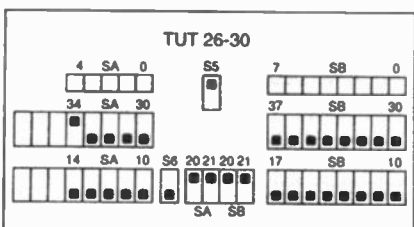


Fig.21. Switch settings for programs TUT26 to TUT30.

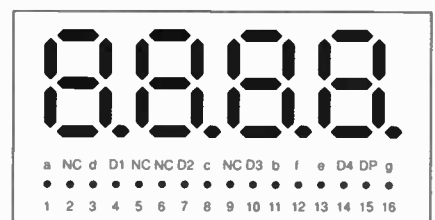


Fig.23. Pinouts for a typical 4-digit multiplexed 7-segment I.e.d. display.

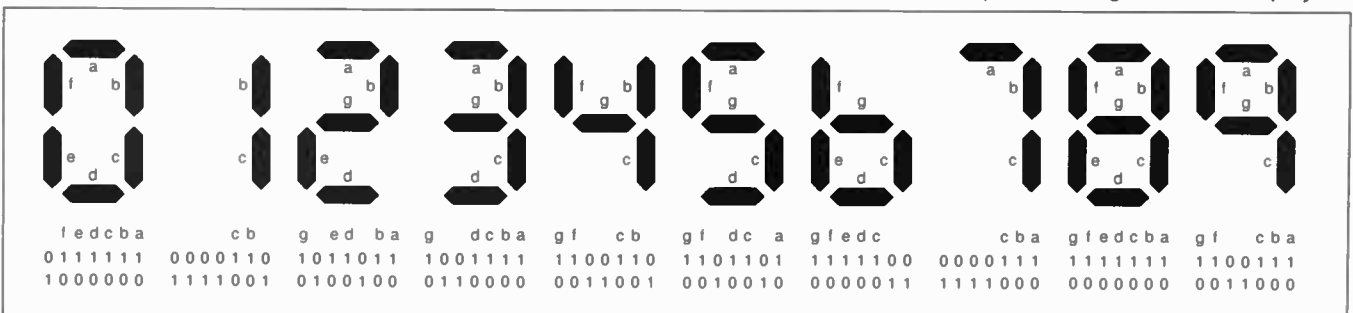


Fig.22. Numerals 0 to 9 represented on a 7-segment I.e.d. display, plus controlling binary codes for common cathode (middle line) and common anode (bottom line).

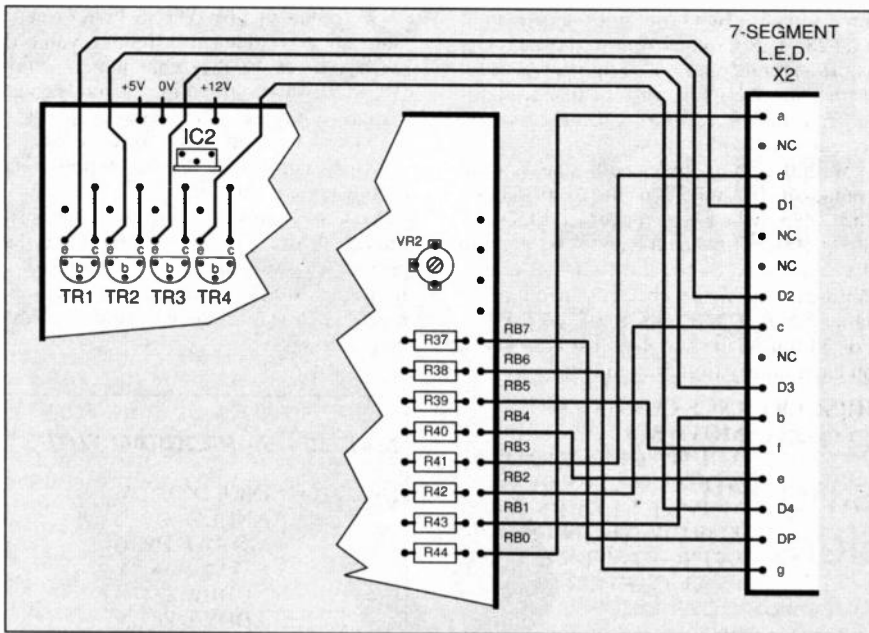


Fig.24. Wiring details for the 4-digit 7-segment l.e.d. display.

alternate the data being output between units and tens values, turning on each (via their common anode pin) only when the relevant data is being sent to them. If this is done at a fast enough rate, the eye is fooled into thinking that both displays are on simultaneously – persistence of vision.

This technique is known as multiplexing, and what we do in this instance is to put the common anode of each display under control of two separate data lines on PORTA, RA0 and RA1. To provide enough current to drive the displays (PORTA lines on their own do not have enough current available to achieve a sufficiently bright display), the port lines are buffered by transistors TR1 and TR2 configured as emitter followers.

**LISTING 26 - PROGRAM TUT26**

```
TABSEG: ADDWF PCL,F
        RETLW %11000000 ;0
        RETLW %11111001 ;1
        RETLW %10100100 ;2
        RETLW %10110000 ;3
        RETLW %10011001 ;4
        RETLW %10010010 ;5
        RETLW %10000011 ;6
        RETLW %11111000 ;7
        RETLW %10000000 ;8
        RETLW %10011000 ;9
```

; common anode codes

```
INTRPT: BTFSZ INTCON,2
        GOTO INTRPT
        BCF INTCON,2
        DECFSZ CLKCNT,F
        GOTO INTRPT
        MOVLW 25
        MOVWF CLKCNT
        INCF CLKSEC,F
        MOVF CLKSEC,W
        ADDLW 6
        BTFSZ STATUS,DC
        GOTO INTRPT
        CLRF CLKSEC

OUTPUT: MOVF CLKSEC,W
        ANDLW 15
        CALL TABSEG
        MOVWF PORTB
        GOTO INTRPT
```

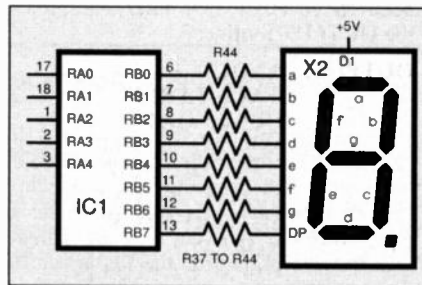


Fig.25. Equivalent circuit diagram for Listing 26.

The collectors are connected to the +5V line and the emitters are connected to the common anodes of the displays. The displays are turned on when PORTA lines go high.

Disconnect l.e.d. line D1 from the +5V pin and connect it to TR1 emitter, as shown in Fig.24. The equivalent circuit diagram of Fig.24 is shown in Fig.26, but note that for this example the active digits are the left-hand two, D1 and D2. Digits D3 and D4 are ignored.

The program which is now required to drive the two displays is shown in Listing 27. Load TUT27.OBJ and run it.

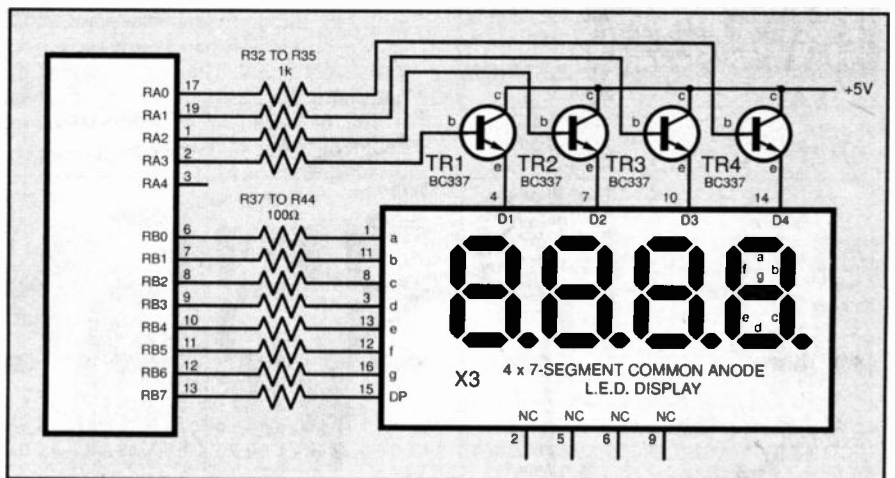


Fig.26. Equivalent circuit diagram for multiplexed control of the 4-digit 7-segment common anode l.e.d. display.

**LISTING 27 - PROGRAM TUT27**

```
INTRPT: CALL DIGSEL
        BTFSZ INTCON,2
        GOTO INTRPT
        BCF INTCON,2
        DECFSZ CLKCNT,F
        GOTO INTRPT
        MOVLW 25
        MOVWF CLKCNT
        INCF CLKSEC,F
        MOVF CLKSEC,W
        ADDLW 6
        BTFSZ STATUS,DC
        GOTO ENDTIM
        MOVWF CLKSEC
        MOVLW %01100000
        XORWF CLKSEC,W
        BTFSZ STATUS,Z
        CLRF CLKSEC
        GOTO INTRPT

ENDTIM: GOTO INTRPT

SECTEN: SWAPF CLKSEC,W
        GOTO OUTPUT

SECONE: MOVF CLKSEC,W

OUTPUT: ANDLW 15
        CALL TABLE
        MOVWF PORTB
        INCF DIGIT,W
        MOVWF PORTA
        RETURN

DIGSEL: INCF DIGIT,W
        ANDLW 1
        MOVWF DIGIT
        ADDWF PCL,F
        GOTO SECTEN
        GOTO SECONE
```

**PROGRAM – TUT27**

**SWITCH SETTINGS – as in Fig.21.**

Studying Listing 27, first note that (for the sake of demo) an XOR command is used to check for a count value equal to 60 (BCD).

Next, and significantly for two displays, digit alternating commands have been introduced. At label INTRPT, the command CALL DIGSEL is given.

In DIGSEL, a digit counter (DIGIT) is incremented, ANDed with 1, and the result of this increment is carried by W into the table that immediately follows. There are only two jumps in this table, GOTO SECTEN and GOTO SECONE.



Routine SECTEN extracts the tens of units value. Command SWAPF CLKSEC,W swaps the nibbles of the seconds and holds the result in W, putting the tens of seconds into the LSN position. The routine then jumps to OUTPUT, where command ANDLW 15 isolates that nibble, zeroing the MSN bits now in W.

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

Routine SECONDS is similar, dealing with the units of seconds. Here we can simply get the LSN by using MOVF CLKSEC,W, ANDing it with 15 at OUTPUT. The rate of alternation between the two digits is several kilohertz, slowing down briefly each time a time-out is detected.

Whilst one would like to use six digits in order to display a full 24-hour clock showing hours, minutes and seconds simultaneously, this is not convenient since we only have five lines on PORTA which can control individual digits. Therefore, we must compromise and continue to use a 4-digit display but which can now have its data sources changed when a switch is pressed.

In this way, we can show either hours and minutes together, or minutes and seconds. The program which does this is TUT28, part of which is shown in Listing 28. Load TUT28.OBJ and run it, then look at its listing.

#### PROGRAM - TUT28

##### SWITCH SETTINGS - as in Fig.21.

Each time the seconds roll over to zero from 59, the minutes need incrementing; each time they roll over to zero from 59, the hours need incrementing. The hours, though, need to roll over to zero from 23.

As far as incrementing each of the three counters is concerned, the easiest thing to do (but not the shortest) is to use

three separate BCD routines - as we do in TUT28. The minutes routine is the same as the seconds one, both requiring a count from 0 to 59, with routines to check for 10 and 60. The hours routine, though, requires slight alteration.

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

```

HRSClk: INCF CLKHRS,F
          MOVLW 6
          ADDWF CLKHRS,W
          BTFSC STATUS,DC
          MOVWF CLKHRS
          XORLW %00100100
          BTFSC STATUS,Z
          CLRF CLKHRS
  
```

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

```

OUTPUT: ANDLW 15
          CALL TABLE
          CLRF PORTA
          MOVWF PORTB
          CALL DIGSHW
          MOVWF PORTA
          MOVF DIGIT,W
          XORLW 1
          BTFSC STATUS,Z
          BCF PORTB,7
          RETURN
  
```

Minutes and seconds values are dealt with in the same manner. Minutes units, though, are accompanied by the decimal point bit. Seconds are processed similarly, but without any additional bit setting for colons or points.

In Tutorial 24 we shall show how a similar result can be achieved by using fewer commands. A loop plays an active role and a table is used when checking the roll-over values for the time.

In Listing 28, when switch SA4 is not

pressed (checked by BTFSS PORTA,4), a value of 2 is added to effective value of DIGIT, to cause the table jumps within DIGSEL to be to the minutes and seconds display routines. The decimal point is still turned on after the first (left-hand) digit. Pressing SA4 results in hours and minutes being shown.

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

#### LISTING 28 - PROGRAM TUT28

```

DIGSEL:  INCF DIGIT,W
          ANDLW 3
          MOVWF DIGIT
          BTFSS PORTA,4
          ADDLW 2
          ADDWF PCL,F
          GOTO HRSTEN
          GOTO HRSONE
          GOTO MINTEN
          GOTO MINONE
          GOTO SECTEN
          GOTO SECONDS

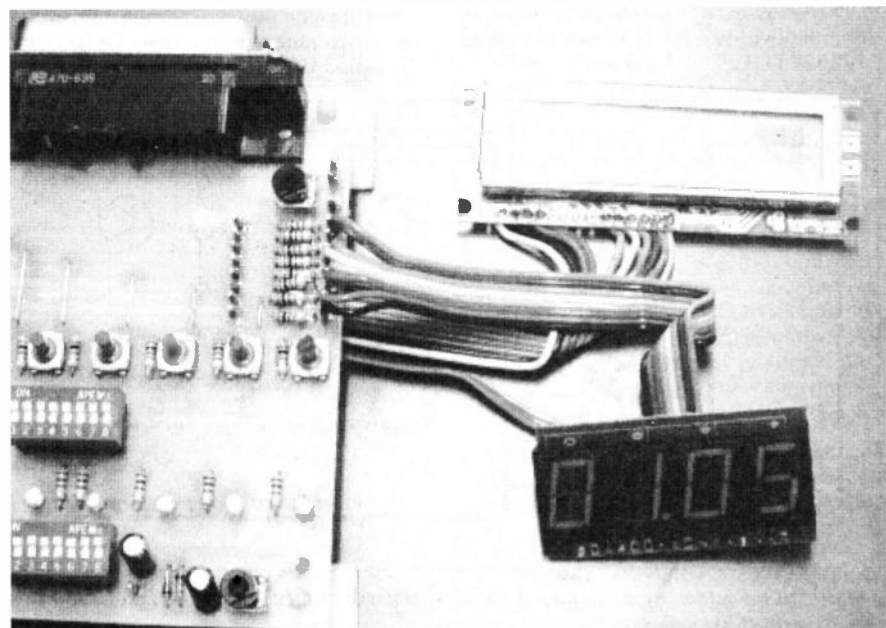
DIGSHW:  MOVF DIGIT,W
          ADDWF PCL,F
          RETLW 1
          RETLW 2
          RETLW 4
          RETLW 8

INTRPT:  CALL DIGSEL
          BTFSS INTCON,2
          GOTO INTRPT
          BCF INTCON,2
          CALL CLKADD
          GOTO INTRPT

CLKADD:  DECFSZ CLKCNT,F
          RETURN

          MOVLW 25
          MOVWF CLKCNT

SECCLK:  INCF CLKSEC,F
          MOVLW 6
          ADDWF CLKSEC,W
          BTFSS STATUS,DC
          RETURN
          MOVWF CLKSEC
          XORLW %01100000
          BTFSS STATUS,Z
          RETURN
          CLRF CLKSEC
  
```



#### EXERCISE 21

21.1. You will have noticed "ghost" images on the "off" segments for the active digits in TUT27, but not in TUT28. Study TUT28's full listing and amend TUT27 similarly to eliminate the "ghosts".

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

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

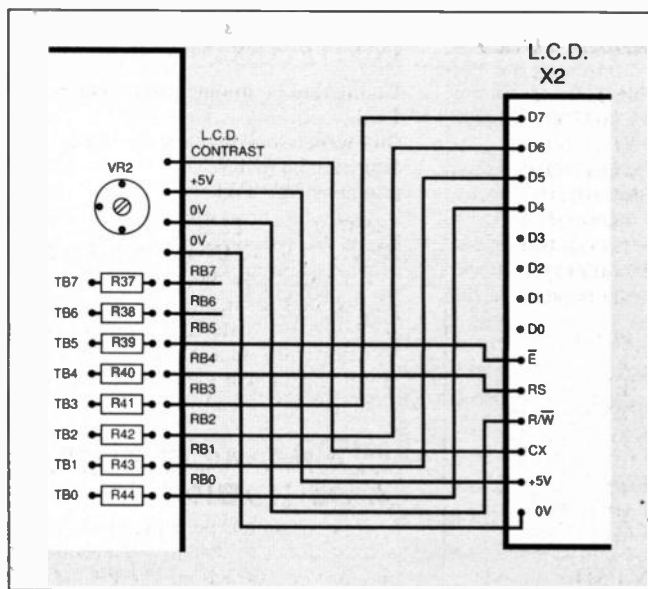


Fig. 27. Wiring details for the l.c.d.

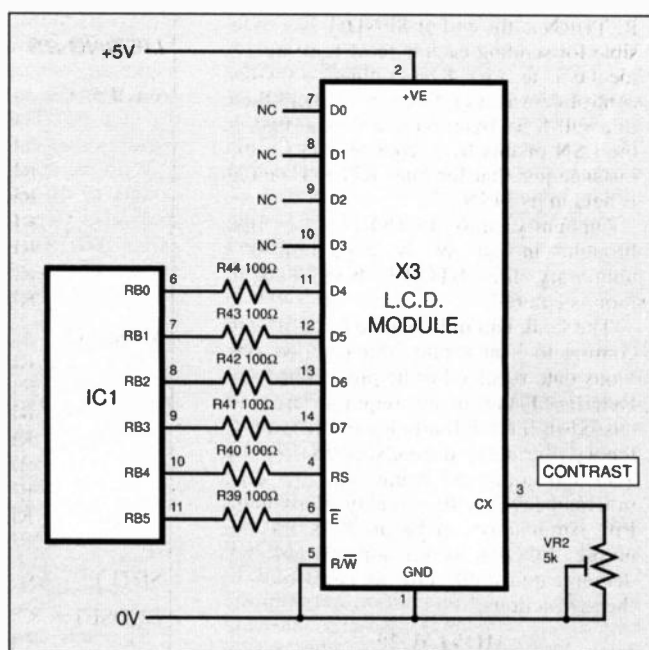


Fig. 28 (above). Equivalent circuit diagram for the l.c.d. connections.

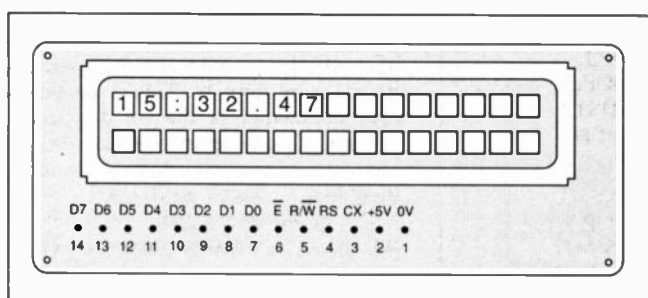


Fig. 29. Pinouts for a typical 2-line 16-character l.c.d.

## TUTORIAL 22 CONCEPTS EXAMINED

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

### PROGRAM - TUT29 SWITCH SETTINGS - as in Fig. 21.

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

The first requirement is to show the basics of how data is output to an l.c.d. from the PIC. We shall not cover the l.c.d. itself in any great detail - that was the subject of Julian Ilett's *How To Use Intelligent L.C.D.s* articles in *EPE* February and March '97, to which you are referred for more information.

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

Disconnect the l.c.d. module and connect the l.c.d. to the p.c.b. as in Fig. 27. The equivalent circuit diagram is shown in Fig. 28 (in a real circuit design resistors R39 to R44 would be omitted). The l.c.d. pinout diagram is shown in Fig. 29.

Load TUT29.OBJ and run it. While reading these next paragraphs, refer to Listing 29 as appropriate.

### L.C.D. CONTRAST

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

It is appropriate to mention here that some l.c.d.s, notably 2-line 8-character types, require a negative voltage applied to their contrast setting pin. A negative voltage can be generated using one of the PICs output lines and the circuit in Fig. 30. The chosen PIC line is connected to capacitor C6 (FREQ) and the wiper of VR2 (-VE) connected to the contrast pin (pin 3) of the l.c.d. Adjustment of VR2 then sets the contrast.

A negative voltage of about -3.5V is generated when the PIC line is toggled up and down at a fairly fast rate. The commands to do this can be placed anywhere within a frequently accessed part of the program. A suitable place in TUT29 would be within the INTRPT loop. Assuming the toggling line is PORTA RAO, the commands would be:

```
INTRPT:  INCF PORTA,0
         BTFS INTCON,2
         GOTO INTRPT
```

### DELAYED START

When the l.c.d. is under high speed control from a device such as the PIC, it is necessary to allow a minimum of 1/5th of a second between the circuit being

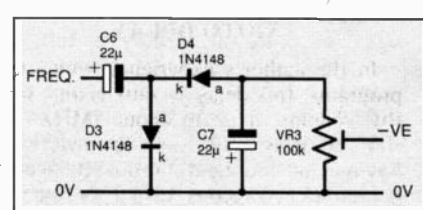


Fig. 30 (right). Circuit diagram for the negative voltage generator.

switched on and any data being sent to the l.c.d. So, following the PIC's initialisation, the program jumps to the routine at SETUP which, via sub-routine PAUSIT, creates this delay by making use of the prescaler.

The prescaler has been set for an INTCON.2 pulse every 1/25th of a second, so a loop beginning at PAUSE is used to wait for five of these pulses to be completed, i.e. 1/5th of a second.

Then a series of commands is sent to set the l.c.d. into the required 4-bit mode. (There are other command routines possible which achieve a similar result.) The commands are held in the table TABLCD, which is accessed from the routine at label LCDSET. The first command here clears the loop counter and the byte (RSLINE) which holds the RS-controlling bit.

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

Next, the loop counter is cleared, RSLINE bit 4 is set and used to inform the l.c.d. that the commands being sent to it are character data. Then the message held in the table MESSAG is sent via the routine headed LCDMSG. The l.c.d. displays this message on its first line, starting at the left.

Now, for the sake this demo, the perpetual loop at NOMORE is entered and no more actions occur. To replay the routine, slide the Reset switch (S2) on and off.

In both data sending routines, the l.c.d. output routine is called by the command CALL LCDOUT. The entire block between the start of LCDOUT and the final

RETURN at the end of SENDIT is responsible for sending each byte of 8-bit data to the I.C.D. as two 4-bit nibbles, to which control data is then ORed to expand them to a full 8-bit byte. Nibble data is held in the LSN of this byte, control data (in this instance just that for lines RSLINE and E) is held in its MSN.

On entry into LCDOUT, the data brought in on W is copied into a temporary file, STORE. Now a delay loop is entered.

The I.C.D. can only handle bytes of data coming to it at a rate which allows previous data received to be processed fully. Details of the delay required are discussed in the I.C.D. articles referred to. In theory, the delay depends on the type of data and command being sent, but on a practical level, a fixed delay of so many PIC commands can be used. In this example, LOOPA is set for 20 and then decremented until zero, as performed by the instructions:

```

MOVW 20
MOVWF LOOPA
DELAY: DECFSZ LOOPA,F
      GOTO DELAY

```

In the author's experience with many programs, this delay is satisfactory for a PIC running at up to about 5MHz. Too short a delay will result in erratic behaviour of the I.C.D., probably accompanied by erroneous display results. If this occurs, the loop value should be increased.

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

```

SWAPF STORE,F
MOVWF STORE,W
ANLW 15

```

The first command swaps the two nibbles within STORE, the second copies STORE into W, and then W is ANDed with 15 to isolate bits 0 to 3.

The result is ORed with the RSLINE bit and the byte is then output to the I.C.D. via PORTB. The E line is taken high and immediately low again, telling the I.C.D. to process the data on its data inputs. A return to the calling point occurs and then SENDIT is again called.

This time, the LSN is extracted from STORE and sent to the I.C.D. in the same way. After two RETURNS, the program returns to the original calling point.

It is important to note that the port bits which are used in these routines to control the RSLINE and E lines reflect the physical connections between the PIC and the I.C.D. as shown in Fig.28. It is permissible to use other PIC port lines for this purpose, but the controlling bits of the software must be changed accordingly.

## EXERCISE 22

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

22.2. When the I.C.D. is first initialised, it is possible (though not definite) that all its character positions (cells) will show as black squares. Sending the message will

## LISTING 29 - PROGRAM TUT29

```

TABLCD: ADDWF PCL,F
        RETLW %00110011
        RETLW %00110011
        RETLW %00110010
        RETLW %00101100
        RETLW %00000110
        RETLW %00001100
        RETLW %00000001
        RETLW %00000010

MESSAG: ADDWF PCL,F
        RETLW 'R'
        RETLW 'E'
        RETLW 'A'
        RETLW 'D'
        RETLW ''
        RETLW 'E'
        RETLW 'P'
        RETLW 'E'

SETUP:  CALL PAUSIT

LCDSET: CLRf LOOP
        CLRf RSLINE
LCDST2: MOVF LOOP,W
        CALL TABLCD
        CALL LCDOUT
        INCF LOOP,F
        BTfSS LOOP,3
        GOTO LCDST2
        CALL PAUSIT

LCDMSG: CLRf LOOP
        BSF RSLINE,4
LCDMS2: MOVF LOOP,W
        CALL MESSAG
        CALL LCDOUT
        INCF LOOP,F
        BTfSS LOOP,3
        GOTO LCDMS2

NOMORE: GOTO NOMORE

LCDOUT: MOVWF STORE
        MOVW 20
        MOVWF LOOPA
DELAY:  DECFSZ LOOPA,F
        GOTO DELAY
        CALL SENDIT
        CALL SENDIT
        RETURN

SENDIT: SWAPF STORE,F
        MOVF STORE,W
        ANLW 15
        IORWF RSLINE,W
        MOVWF PORTB
        BSF PORTA,5
        BCF PORTA,5
        RETURN

PAUSIT: MOVW 5
        MOVWF CLKCNT
        CLRf INTCON
PAUSE:  BTfSS INTCON,2
        GOTO PAUSE
        BCF INTCON,2
        DECFSZ CLKCNT,F
        GOTO PAUSE
        RETURN

```

correct that situation for the first eight cells. How could you ensure that the remaining eight cells on the top line are set to "clear" blanks? There are two methods; try both.

22.3. How would you now set the lower line to all blanks? (The answer is also given later - don't cheat!)

## TUTORIAL 23 CONCEPTS EXAMINED

Coding hours, minutes and seconds for an I.C.D.

Shortened clock monitoring code

Command SUBLW

Command SUBWF

### PROGRAM - TUT30

SWITCH SETTINGS - as in Fig.21.

Now we know how the I.C.D. can have data written to it, we will show how the method can be extended in order to display 24-hour clock data. Load TUT30.OBJ and run it, glancing at the display from time to time while you read on here.

## COMMANDS SUBLW AND SUBWF

Rather late on, perhaps, in the program we are about to display we encounter the first use of subtraction. The PIC16C84 has two subtraction commands, SUBLW (Subtract W from Literal) and SUBWF (Subtract W from File). The latter command is used with either the F or the W suffix, e.g. SUBWF (FILE),F and SUBWF (FILE),W.

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

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

```

MOVW 20
MOVWF DEMO
MOVWF DEMO,W
SUBLW 30
MOVWF DEMO

```

In this case, the answer is 10 (30 - 20), even though instinctively we might have expected 30 to be subtracted from 20.

In this next example, to illustrate SUBWF, again it is the value already in W which is subtracted from the value in file DEMO, the result being returned to DEMO. This is more logical. (Once more the first two commands are just to put an initial value into DEMO.)

```

MOVW 20
MOVWF DEMO
MOVW 5
SUBWF DEMO,F

```

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

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

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

What we have done by using the addition of 256, is to "borrow" the 256 in order to achieve the correct 8-bit result.

The same roll-over situation applies to subtraction of numbers greater than 1. Thus subtracting 20 from 10 produces an answer of 246 (256 + 10 - 20 = 246). We are quite used to "borrowing" in normal arithmetic, so the concept should be familiar to you, although we express the result of subtracting 20 from 10 as equalling -10.

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

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

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

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

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

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

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

You will see the use of SUBWF and the subsequent testing of the Carry bit for the occurrence of a borrow in TUT30.

## TIME OUT TO L.C.D.

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

With the 7-segment display, we had to use a table to convert from decimal to a code that it would show meaningfully. With the l.c.d., the conversion is much easier, we simply add the difference



between the decimal value and its ASCII value, i.e. we increase the value by 48.

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

The easiest way to set bits 4 and 5 is to either add 48 to the digit's value, or to OR 48 with it. In other words, to use either ADDLW 48 or IORLW 48 as the command. In this situation they both have the same effect. To use BSF would require two commands instead of just one.

In the following conversion example, the additive technique is used (IOR is used in the program):

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

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

Next, MOVF STORE2,W brings the entire byte into W. ANDLW 15 isolates the nibble which is in the correct LSN position. Again ANDLW 48 and CALL LCDOUT are performed.

Following that, the ASCII value for a colon (58) is sent to the l.c.d., using the single quotes method previously seen in tables.

## CLOCKING ON

Hours, minutes and seconds values are dealt with similarly, although minutes are followed by the decimal point (ASCII 46). Seconds are not followed by any character, although they could have a space character (ASCII 32) sent after the units.

The sequence of events, from individually incrementing time to outputting the data to the l.c.d. is shown in Listing 30.

Now compare this listing with that for outputting the time data to the 7-segment displays (TUT28). Look especially at the clock count section (from CLKADD to end of ADDCL2). The second version, of which the main part is shown here, is considerably more compact.

## LISTING 30 - PROGRAM TUT30

```
INTRPT:  BTFSS INTCON,2
         GOTO INTRPT
         BCF INTCON,2
         CALL CLKADD
         GOTO INTRPT

CLKADD:  DECFSZ CLKCNT,F
         RETURN

         MOVLW 25
         MOVWF CLKCNT
         MOVWF CLKSEC
         MOVWF FSR
         MOVLW 3
         MOVWF LOOP
         CLRF STORE1

ADDCLK:  INCF INDF,F
         MOVLW 6
         ADDWF INDF,W
         BTFSC STATUS,DC
         MOVWF INDF

ADDCL2:  MOVF STORE1,W
         CALL CHKVAL
         MOVWF STORE2
         MOVF INDF,W
         SUBWF STORE2,F
         BTFSC STATUS,C
         GOTO CLKSHW
         CLRF INDF
         INCF STORE1,F
         INCF FSR,F
         DECFSZ LOOP,F
         GOTO ADDCLK

CLKSHW:  MOVLW %11000000
         CALL LCDLIN
         MOVF CLKHRS,W
         CALL LCDFRM
         MOVLW ':'
         CALL LCDOUT
         MOVF CLKMIN,W
         CALL LCDFRM
         MOVLW '.'
         CALL LCDOUT
         MOVF CLKSEC,W

LCDFRM:  MOVWF STORE2
         SWAPF STORE2,W
         ANDLW 15
         IORLW 48
         CALL LCDOUT
         MOVF STORE2,W
         ANDLW 15
         IORLW 48
         CALL LCDOUT
         RETURN

LCDLIN:  BCF RSLINE,4
         CALL LCDOUT

         BSF RSLINE,4
         RETURN
```

After initialisation and general set-up, the program enters the INTRPT routine. At each 1/25th second time-out, CLKADD is called and the CLKCNT counter decremented, as we saw earlier. Only if CLKCNT is zero is the next routine entered.

After resetting CLKCNT, the address of CLKSEC is set in the indirect address register FSR, a loop (LOOP) is set for three operations and STORE1 is cleared for use as an up-counter. In the three steps round the loop, CLKSEC is dealt with first, then CLKMIN and then CLKHRS.

First time round the loop, at ADDCLK the first byte to be incremented is, of course, CLKSEC. This is then checked for a units value greater than nine and action taken accordingly.

Next, the value within STORE1 is copied into W and a table (CHKVAL – see full listing) is called, returning with the maximum permitted value for the byte being processed, storing it in STORE2. The value of the time byte (CLKSEC at this moment) is then copied into W, which is then subtracted from STORE2.

If the Carry flag is set, then STORE2 is greater than CLKSEC (there is no borrow) and an exit is made from the loop, no further action being needed, and a jump is made to the display routine (CLKSHW).

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

If CLKMIN is reset, the loop is repeated for the third occasion, this time for CLKHRS, after which the CLKSHW display routine is entered directly.

Two sub-routines are used with CLKSHW, to save repetition of too many commands. The routines are LCDLIN and LCDFRM. The former is responsible for setting the starting display cell position on the l.c.d. Since in a larger program this position could change frequently, it is worthwhile having a generalised routine for this purpose.

In this case, we want the time to be shown at the start of the second l.c.d. line, so the value %11000000 (the address of line 2 cell 0) is moved into W and LCDLIN called. All LCDLIN does is set the RSLINE flag for command mode, call LCDOUT, and reset the RSLINE flag to character mode.

Next, the value of CLKHRS is moved into W and LCDFRM called. This routine does the swapping, ANDing and ORing necessary for numerical conversion to the ASCII value. After this, the colon is sent directly to LCDOUT.

Similar commands are then given with regard to CLKMIN and CLKSEC. Notice that after the MOVF CLKSEC,W command, LCDFRM is entered directly by default. The program then returns to the INTRPT routine to begin again.

## EXERCISE 23

23.1. Extend the program so that the clock also keeps track of months and years. Hint, the author's *EPE Time Machine* clock does this. It's not cheating to examine it if you feel your experience is not yet up to creating your routines without help. It can often be useful to see how other people have solved a problem. That's one reason why we publish constructional articles.

## TUTORIAL 24

### CONCEPTS EXAMINED

Adding time-setting switches

PROGRAM – TUT31

SWITCH SETTINGS – as in Fig.31.

The clock program of TUT30 that is now being run is perfectly usable as a real-time clock, as is the 7-segment version. They both have a major problem though, the programs have to be started (reset) at exactly midnight for the time shown to be accurate. What we need is the ability to set the current time via switches, as with most other time-keepers. Here we will show how switched time-setting can be programmed into the l.c.d. version.

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

First, though, attention must be paid to the rate at which the digits are changed by the switches. We could easily insert a switch checking routine either on each 1/25th count, or on each second. However, the first is too fast for convenience, and the other too slow.

A better rate is on every half-second. This can be arranged by halving the prescaler rate, setting it for a ratio of 1:64 instead of 1:128. Thus, in the initialisation, instead of MOVW %00000110 and MOVWF OPTION, we use:

```
MOVW %00000101
MOVWF OPTION
```

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

Referring to Listing 31, you will see the command CALL GETKEY, which is then followed by INCF HLFSEC,F. Only if bit 0 of HLFSEC is 1 will the CLKADD routine be entered.

Imagine, now, that the switches on PORTA are designated as follows:

```
SA4 = seconds reset
SA3 = hours
SA2 = minutes
SA1 = plus (+)
SA0 = minus (-)
```

At GETKEY, if switch SA3 is pressed (hours), EVENT bit 0 is set to 1. This file value will be used when accessing the CHKVAL table for the maximum roll-over value for hours or minutes.

Now the address of CLKHRS is moved into W and TIMSET is called. At this routine, the plus (+) and minus (-) keys are read for their status, and the addition (ADDTIM) or subtraction (SUBTIM) routine is jumped to and processed.

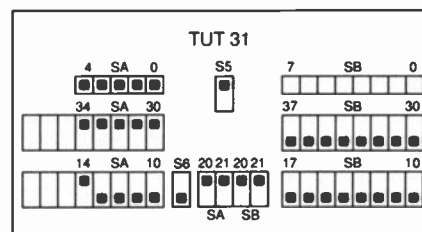


Fig.31. Switch settings for Program TUT31.

## LISTING 31 - PROGRAM TUT31

```
INTRPT:  BTFS INTCON,2
         GOTO INTRPT
         BCF INTCON,2
         CALL CLKADD
         GOTO INTRPT

CLKADD:  DECFSZ CLKCNT,F
         RETURN

         MOVLW 25
         MOVWF CLKCNT
         CALL GETKEY
         INCF HLFSEC,F
         BTFS HLFSEC,0
         CALL CLKIT
         RETURN

(Section from CLKIT to endof LCDLIN
omitted)

GETKEY:  BTFS PORTA,3
         GOTO CHKS2
         BSF EVENT,0
         MOVLW CLKHRS
         GOTO TIMSET

CHKS2:  BTFS PORTA,2
         RETURN
         CLR EVENT
         MOVLW CLKMIN

TIMSET:  MOVWF FSR
         BTFS PORTA,0
         GOTO SUBTIM
         BTFS PORTA,1
         RETURN

ADDTIM:  INCF INDF,F
         MOVLW 6
         ADDWF INDF,W
         BTFS STATUS,DC
         MOVWF INDF
         INCF EVENT,W
         CALL CHKVAL
         MOVWF STORE2
         MOVF INDF,W
         SUBWF STORE2,F
         BTFS STATUS,C
         CLR INDF
         GOTO CLKSHW

SUBTIM:  MOVLW 1
         SUBWF INDF,F
         BTFS STATUS,C
         GOTO SUBSET
         BTFS STATUS,DC
         GOTO ENDSUB
         MOVF INDF,W
         ANDLW %11110000
         IORLW 9
         MOVWF INDF
         GOTO ENDSUB

SUBSET:  INCF EVENT,W
         CALL CHKVAL
         MOVWF INDF

ENDSUB:  GOTO CLKSHW
```

In these routines, not only have the units to be checked for values greater than nine, but the overall BCD value has to be checked for greater than 23 (hours) and greater than 59 (minutes).

In the addition routine, the excess value is checked for, and the value is reset to zero if it is exceeded. In the subtraction routine, zero is checked for, in which case the maximum allowed value is moved into the byte as the reset value.

In both instances, the value within EVENT is moved into W and table

CHKVAL is called for the maximum value.

All the commands involved in these routines should by now be familiar to you without further explanation. Load TUT31.OBJ, run it and experiment with setting the time.

## EXERCISE 24

24.1. Using one of the switch paths not yet used, create a routine that will also show how many hours, minutes and seconds there are until midnight (00:00.00 hours or 24:00.00 if you find it easier) when you press a switch, clearing the answer when the switch is released. The *EPE Time Machine* might give you hints on this.

## TUTORIAL 25 CONCEPTS EXAMINED

Dual use of port pins for input and output  
Configuring program for alarm system monitoring

### PROGRAM - TUT32

SWITCH SETTINGS - as in Fig.32.

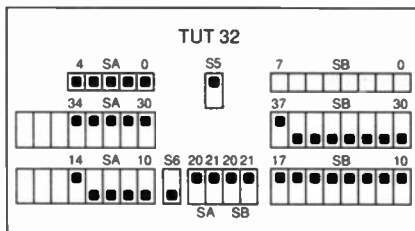


Fig.32. Switch settings for Program TUT32.

We turn now to extending the program of TUT31 for use as an alarm system monitor in which the time that the alarm is first triggered and which of four zones have been entered are shown on the l.c.d. screen.

The equivalent circuit diagram is shown in Fig.33.

In this operation, PORTA and PORTB are used as inputs in some routines, as outputs in others.

Referring to TUT32.ASM, after the usual initialisation routines, the only change at the beginning of the program is for the message table to be changed to ZONE ----, in which the number of any triggered zone will replace the appropriate dash, from 1 to 4.

The next change is the addition of CALL CHKZON (see Listing 32A) following the CALL GETKEY command in the CLKADD routine. The routine at CHKZON checks each of the four alarm zones (RB0 to RB3) to see if any have been entered:

Notice in particular the initialisation of the bell-on countdown. This involves two bytes, BELL1 and BELL2 which are set for a countdown period of approximately 10 minutes, after which the exterior bell is switched off (in another routine). It remains off and cannot be retriggered until after the

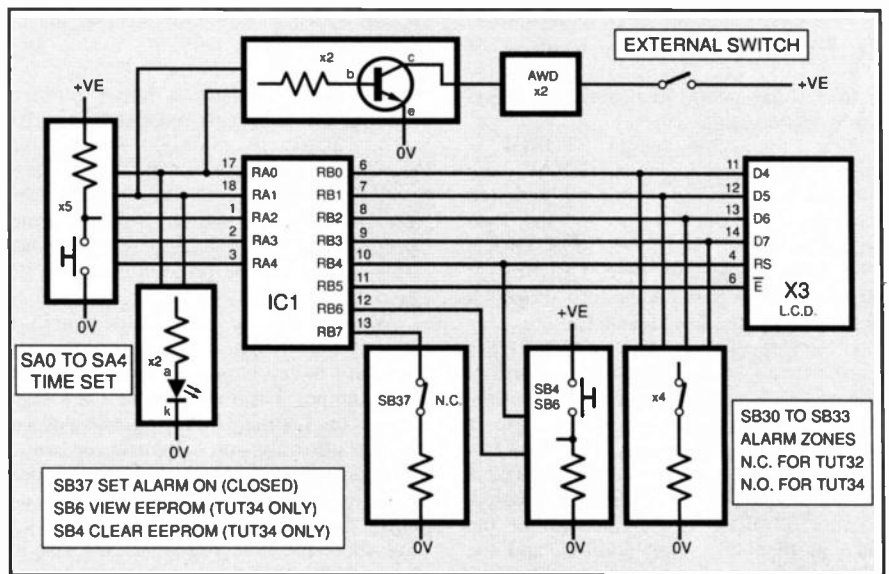


Fig.33. Equivalent circuit for Programs TUT32 and TUT34.

system has been reset. The program has been written this way to save potential annoyance to neighbours!

Following the ADDCLK routine (in the full program) is CHKBEL (see Listing 32B) which, if the alarm bell has already been triggered by a zone entry, is checked to see whether the bell's timed countdown has reached zero. If it has, the BELLON flag is cleared, signalling that the external bell should be turned off. The internal buzzer remains switched on until the system is manually reset.

If the alarm has just been triggered, the routine ALMSHW is entered immediately following CHKZON (see full program). Here, PORTB is set for all pins as outputs and the current time (the time at which the alarm has first been triggered) is output to the l.c.d. Note the commands which route the first character to cell 8 on line 1.

This routine is only used at this instant and the time remains showing until the alarm is reset.

Following ALMSHW, is routine ZONSHW. This shows the status of all four zones and is entered when the status of any zone changes.

Routine CHRST (see Listing 32C) is performed once every second and checks to see if the alarm is being reset via switch SB37 (in practice, this would be a key-switch combined with a switch in the bell and buzzer positive power line). If SB37 is off (up), the bell and buzzer are turned off, and the l.c.d. messages of the zone entered and the time of the alarm being triggered are cleared.

Load and run TUT32.OBJ. Referring to the equivalent circuit diagram for the alarm system mock-up in Fig.33, experiment with the switches, setting the alarm on with

### LISTING 32A - PROGRAM TUT32

```

CHKZON: CLRFB PORTB
PAGE1
MOVLW %11001111
MOVWF TRISB           ; Port RB5-RB6 as output, others as input
PAGE0
CLRFB PORTB
NOP
MOVFB PORTB,W
MOVWF ZONCHK
PAGE1
CLRFB TRISB           ; Port RB0-RB7 as output
PAGE0
BTFSZ ZONCHK,7        ; is alarm-on switch on (= 1)?
GOTO CHRST            ; no
COMFB ZONCHK,W
ANLW %00001111
XORWF ZONE,W          ; yes, has zone been triggered before?
BTFSZ STATUS,Z
RETURN                ; yes
IORWF ZONE,F          ; no
MOVFB BELLON,W
BTFSZ STATUS,Z        ; has bell already been set off?
GOTO ZONSHW           ; yes
BSFB BELLON,1         ; turn on buzzer flag
BSFB BELLON,0         ; turn on bell flag
MOVLW 3
MOVWF BELL2           ; set bell countdown MSB
BSFB BELL1,6          ; set bell countdown LSB (approx 10 min)

```

### LISTING 32B

```

CHKBEL:  BTFSS BELLON,0 ; is the bell on?
          GOTO CLKSHW   ; no
          DECFSZ BELL1,F ; yes, dec bell counter LSB, is it zero?
          GOTO CLKSHW   ; no
          DECFSZ BELL2,F ; yes, dec bell counter MSB, is it zero?
          GOTO CLKSHW   ; no
          BCF BELLON,0  ; yes, clear bell flag (leave buzzer on)

```

### LISTING 32C

```

CHKRST:  CLRF ZONE
          CLRF BELLON
          CLRF BELL1
          CLRF BELL2
          BCF ALMSET,0 ; clear alarm set flag
          MOVLW %10000100 ; clear alarm set-off time etc
          CALL LCDLIN   ; set address for line 1 (address 8)
          MOVLW 4
          MOVWF LOOP
RSTALM:  MOVF LOOP,W
          CALL MESSAG
          CALL LCDOUT
          INCF LOOP,F
          BTFSS LOOP,3
          GOTO RSTALM
RSTAL2:  MOVLW ' ' ; blank space (ASCII 32)
          CALL LCDOUT
          INCF LOOP,F
          BTFSS LOOP,4
          GOTO RSTAL2
          RETURN

```

SB37, entering zones (SB33 to SB30), etc. Do not use any other PORTB switches.

You can still set the time via PORTA switches, as in TUT31, although in a real system, the additional bell (a.w.d.) switch seen in Fig.33 would need to be switched off, otherwise using the switches on pins RA0 and RA1 would activate the bell and buzzer.

## EXERCISE 25

25.1. Modify the program of TUT32 so that five zones are monitored and their status displayed on the screen. Make one of them a normally-open detector (e.g. as would be found in a pressure pad). Why cannot you use pin RB5 as the fifth monitoring line while the l.c.d. is connected as shown, even though RB0 to RB4 are used jointly?

## TUTORIAL 26

### CONCEPTS EXAMINED

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

### PROGRAM - TUT33

#### SWITCH SETTINGS - none required

We have already found how convenient it is to be able to repeatedly change the program data within the PIC16C84. The demos and your experiments would simply not have been practical had we been using a microcontroller which required erasing by ultra-violet light each time a new program had to be loaded into it.

Now we come to another great advantage of the PIC16C84, the presence of an EEPROM data memory which can be written to and read from whenever we want, and which will not lose the data when the power is switched off.

We shall now show the commands needed for EEPROM data memory read/write operation and then embody them into the alarm program so that alarm trigger times can be stored and retrieved even if the power to the alarm has been switched off after the alarm has been triggered. The full program is on your disk as TUT33, its main contents are shown in Listings 33A and 33B. Note that this program cannot be run as it stands.

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

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

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

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

To transfer data from EEDATA to the EEPROM file pointed to by EEADR, an obligatory routine as specified in the *PIC Data Book* has to be performed. This routine initialises operations built into the PIC16C84 and which last for a predetermined time.

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

An example of how the writing routine is used is shown in Listing 33A. Prior to entry into the routine at SETPRM, the data to be written is temporarily placed in file STORE (or any name you like). Then the EEPROM address at which the data is to be stored is moved into W and the call to SETPRM is issued.

On entry to SETPRM, the contents of W are copied into EEADR, and then, via PAGE1, the command BSF EECON1,WREN is given, setting the EEPROM into write-enable mode, after

### LISTING 33A - PROGRAM TUT33

```

SETPRM:  MOVWF EEADR   ; Copy W into EEADR to set EEPROM address
          PAGE1
          BSF EECON1,WREN ; enable write flag
          PAGE0
          MOVF STORE1,W ; copy data from STORE1 into W
          MOVWF EEDATA  ; copy W into EEPROM byte
MANUAL:  PAGE1        ; These next 12 lines are according to
          MOVLW $55    ; Microchip manual dictated factors
          MOVWF EECON2 ; and cause the action required by
          MOVLW $AA    ; by the EEPROM to store the data
          MOVWF EECON2
          BSF EECON1,WR ; set the "perform write" flag
CHKWRT:  BTFSS EECON1,4 ; wait until bit 4 of EECON1 is set
          GOTO CHKWRT
          BCF EECON1,WREN ; disable write
          BCF EECON1,4   ; clear bit 4 of EECON1
          PAGE0
          BCF INTCON,6   ; clear bit 6 of INTCON
          RETURN        ; and return

```

### LISTING 33B

```

PRMGET:  MOVWF EEADR   ; copy W into EEADR to set EEPROM address
          PAGE1
          BSF EECON1,RD ; enable read flag
          PAGE0
          MOVF EEDATA,W ; copy EEPROM data into W
          RETURN        ; and return

```

which follows a reset to PAGE0. Data is then copied from STORE into W and then into EEDATA.

Now the routine specified in the *PIC Data Book* is started at label MANUAL. The 12 lines of this routine, from PAGE1 down to BCF INTCON,6 should be followed parrot-fashion in any other EEPROM-writing program. The final RETURN command could be replaced by a GOTO, or by the program immediately following on into another routine.

Reading data from the EEPROM is very simple, as Listing 33B shows. The routine is entered at PRMGET with the EEPROM file address held in W. This is copied into EEADR then, via PAGE1, the enable read flag is set (BSF EECON1.RD) and PAGE0 reset. The data required is immediately available to be copied into W by the command MOVF EEDATA,W.

## EXERCISE 26

There is no exercise for this Tutorial.

## TUTORIAL 27

### CONCEPTS EXAMINED

Integrating writing and reading EEPROM file data into TUT32 alarm system

### PROGRAM - TUT34

SWITCH SETTINGS - as in Fig.34

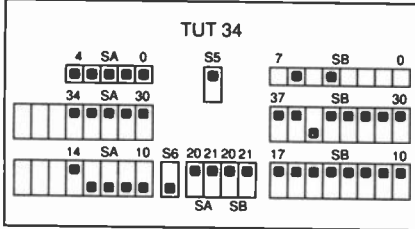


Fig.34. Switch settings for Program TUT34.

Program TUT34.ASM shows the way in which the read/write routines have been used in the alarm system. The writing routine is accessed from CHKZON and is headed STORIT. Reading back the data is called up by pressing switch SB6 which calls up the RECALL routine. Both routines are too long to be shown here. There is nothing unusual about them which needs to be explained.

Load TUT34.OBJ and run it. The equivalent circuit diagram of the system is shown earlier in Fig.33. Experiment with the switches as you did with TUT32, but also experiment with viewing the stored EEPROM entry time data (SB6), and with resetting it (SB4).

When first studying TUT34.ASM, note the number of variables that are specifically reset prior to the start of the program. This ensures that these counters and flags always start at zero. They could, otherwise, take up any value at switch on or when the reset switch (S2) is used. It is not necessary to do this for variables whose values are moved into them in some way while the program is running.

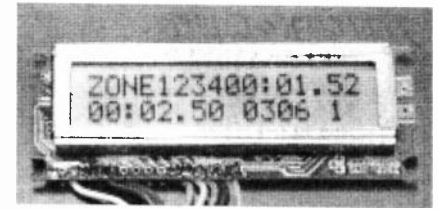
Of programming development interest is the way in which some aspects of the program have their results temporarily output to the l.c.d. The bell-off countdown, the alarm-on flag and an EEPROM reset/counter all have their results shown on the righthand side of l.c.d. line 2.

The author wanted to ensure that what he thought should be done by the routines in

### LISTING 34 - PROGRAM TUT34

```
RSTPRM:  BTFSS RSTKEY,0 ; has alarm been triggered?
          return        ; no
          BTFSS ZONCHK,4 ; is reset switch pressed
          return        ; no
          BTFSS ZONCHK,7 ; is alarm-on switch off (=0)?
          return        ; no
          CLRF LOOP     ; yes
          CLRF STORE1

RSTPR2:  MOVF LOOP,W
          CALL SETPRM
          INCF LOOP,F
          BTFSS LOOP,3
          GOTO RSTPR2
          CLRF RSTKEY
          INCF RSTCNT,F
          RETURN
```



question, was being done. These additional commands have been left in to show you how monitoring of program sections can be usefully done using a display of some sort.

It was especially important to make sure that the EEPROM was only being reset *once* when its reset switch was pressed. There is a finite limit to the number of times the PIC's EEPROM data memory can be written to (around one million times). If a programming error existed, it would be possible for the EEPROM to be written to by the reset routine many times during the running of the program. This would wastefully use up the EEPROM memory cells' life-time.

Whenever writing routines which send data to the EEPROM data memory, *always check* that the routine is being used only when it should be! Never trust your judgement that what you have written in a situation such as this, is going to be performed in the way that you had intended. Any programmer can, and does, make mistakes.

As an exercise, once you have studied TUT34.ASM, find out which aspects are used purely as a programming check, and delete them. Ensure that the l.c.d. screen shows blanks where the checking values had previously been shown.

The EEPROM reset routine is accessed from the CHKZON routine (CALL RSTPRM). EEPROM data storage and retrieval of the alarm set-off time are also accessed during CHKZON (CALL STORIT and CALL RECALL).

## CONDITIONAL RESET

Studying the EEPROM reset routine, note how three conditions have to be met before the resetting action occurs. The program extract is shown in Listing 34.

Before EEPROM resetting is allowed to happen, the alarm has to have been triggered by one or more of SB30 to SB33 (BTFSS RSTKEY,0), the EEPROM reset switch (SB4) has to be pressed (BTFSS ZONCHK,4), and the Alarm-on switch (SB37) has to be off (BTFSS ZONCHK,7). If all these conditions are true, a loop is entered in which the eight used bytes of the EEPROM (addresses 0 to 7) are programmed with zero.

At the end of the loop, RSTKEY is reset to zero so that the three conditions cannot be met until the alarm has been set on again and a zone entry has occurred. So that the author "knew" that

his logic was correct, a counter is incremented each time an EEPROM reset occurs (INCF RSTCNT,F). This counter's value is displayed in the far right cell of l.c.d. line 2 (during the CLKSHW routine).

Another trick was used by the author so that the correctness of the data storage in the EEPROM could be speedily checked. The time at which a zone is entered is normally stored just as hours and minutes. To have included seconds as well would not only be irrelevant in a real life situation, but would also mean that there would be insufficient l.c.d. cells available to show the recalled data in a meaningful manner.

During program development, to avoid having to wait for changes of minutes before triggering a zone entry via the switches, the author put in two commands which would place the seconds value in the hours byte. It was then possible to "enter" zones at intervals only seconds apart, and then to see that the data had been correctly stored in the allocated EEPROM bytes. Those commands are at the entry to STORIT:

```
STORIT:  MOVF CLKSEC,W
          MOVWF CLKHRS
```

Both commands may be deleted, but the label STORIT must remain.

Observe in the STORIT routine how the use of three commands extracts the latest zone to be entered so that only its time is stored in the EEPROM:

```
MOVF PRVZON,W;get prev zones
              ;triggered
XORWF ZONE,W ;XOR with current
              ;zones
MOVWF STORE2 ;store answer
```

Failure to take this action would result in the current time being stored in zone locations other than that (those) required.

Variable PRVZON holds the record of the zones previously triggered. It is updated once the current zone data has been recorded:

```
STOR4:  MOVF ZONE,W
          MOVWF PRVZON
          RETURN
```

## EXERCISE 27

27.1. Incorporate a fifth zone into this program, allowing its data to be recorded on the EEPROM and displayed on the screen.



Hint: if you lose the seconds resetting option, line RA4 becomes free for the fifth zone. Then the EEPROM playback display could alternate at a slow rate between different zone trigger details.

27.2. You will see that many commands are used in the STORIT and RECALL routines. Each byte is dealt with separately, but a loop could be written to perform the same actions in fewer commands. Rewrite each of these routines as a loop!

## TUTORIAL 28

### CONCEPT EXAMINED

#### Interrupts

#### PROGRAM – TUT35

SWITCH SETTINGS – as in Fig.35

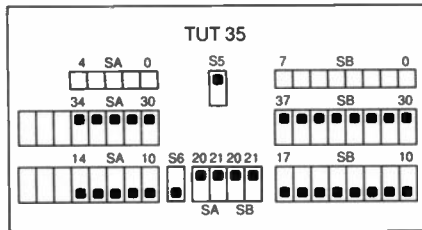


Fig.35. Switch settings for Program TUT35.

From here on, none of the commands examined directly relate to extending or modifying any of the foregoing programs. You do not need to disconnect the l.c.d. for these programs, although it will probably continue to show the last display.

## INTERRUPTS

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

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

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

There are other interrupt possibilities, but which are probably of more benefit to experienced programmers and which will not be detailed here. Readers wanting more information on interrupts are referred to the *PIC Data Book*.

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

First, the address to which the program must jump when interrupted has to be specified. This is where the `.ORG $0004` statement now comes into its own. Following that statement, and prior to the `.ORG $0005` statement, the jump address is inserted. Let's call the jump address `INTRPT`.

We have, in fact, been using the term `INTRPT` as an address label throughout the program examples so far. In the strict sense of the word, though, it has not been used as an Interrupt address, merely as a convenient term. Any other term could have been used in the examples shown.

So, at the beginning of the program listing we make the following statements:

```
.ORG $0004
GOTO INTRPT
.ORG $0005
```

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

We could actually allow the entire program to be performed *without* using a holding routine, jumping to the specified routine when the interrupt does occur. This is tricky, though, and can be dangerous to the correct operation of the main program. Allowance has to be made for a particular operation to be completed before the interrupt routine is performed.

The use of a holding routine, therefore, seems preferable. It can be as simple as:

```
START:  NOP
        GOTO START
```

The program would normally be constantly looping through the two commands `NOP` and `GOTO START`, waiting for an interrupt to occur. On its occurrence, the loop would be exited, and a jump made to the routine at `INTRPT`.

Obviously, at the end of the routine caused by the interrupt, a return to the program point from where the interrupt jump was made must be specified. There is a command which is used for this purpose, `RETfie`.

## TIMER INTERRUPT

A simple program which makes use of an internally timer-generated interrupt to increment a count on `PORTA` is shown in Listing 35.

Here, the timer is set in the same way as we have been doing previously. Then the `INTCON` register is told that an interrupt is to be generated when the timer rolls over to zero:

```
MOVLW %10100000
MOVWF INTCON
```

Setting bit 7 of `INTCON` enables the program to respond to any interrupts gen-

erated. Setting `INTCON` bit 5 enables the timer as the source of the interrupt.

The stage is now set and the `START` loop entered. Each time a timer interrupt occurs, a jump is made to `INTRPT`, `PORTA` is incremented and a return made to `START` by the command `RETfie`.

Because of the way in which the p.c.b. is connected, the fifth l.e.d. on `PORTA` will not be seen to function unless switch `SA4` is pressed (`RA4` is open-collector, remember).

To prove that the program is not just "dropping out" of the `START` loop, a command to increment `PORTB` has been included immediately following the `GOTO START` command. As you will see on `PORTB`'s l.e.d.s this routine is never performed.

Load and run `TUT35.OBJ` which illustrates this interrupt.

## EXTERNAL INTERRUPT

#### PROGRAM – TUT36

SWITCH SETTINGS – as in Fig.36

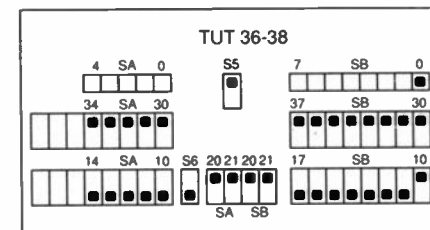


Fig.36. Switch settings for Programs TUT36 to TUT38.

If, instead of using the timer to generate interrupts, we want an external source to generate them, the usual pin used for this purpose is `PORTB RB0`, designated in the pinout diagram as `RB0/INT`. (Logic level changes on `PORTB RB4` to `RB7` are other possible interrupt sources.)

To use `RB0` as the interrupt source, `INTCON` bit 4 must be set, as follows:

```
MOVLW %10010000
MOVWF INTCON
```

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

Suppose now that we want an external interrupt on `RB0` to cause `PORTA` to be incremented. Each time this interrupt

#### LISTING 35 - PROGRAM TUT35

```
.ORG $0004
GOTO INTRPT
.ORG $0005

CLRF PORTA
CLRF PORTB
PAGE1
CLRF TRISA
CLRF TRISB
MOVLW %00000111
MOVWF OPTION
PAGE0
MOVLW %10100000
MOVWF INTCON

START:  NOP
        GOTO START

TEST:   INCF PORTB,F

INTRPT: INCF PORTA,F
        BCF INTCON,2
        RETFIE
```

#### LISTING 36 - PROGRAM TUT36

```
.ORG $0004
GOTO INTRPT
.ORG $0005

CLRF PORTA
CLRF PORTB
PAGE1
CLRF TRISA
MOVLW %00000001
MOVWF TRISB
MOVLW %01000111
MOVWF OPTION
PAGE0
MOVLW %10010000
MOVWF INTCON

START:  NOP
        GOTO START

INTRPT: INCF PORTA,F
        BCF INTCON,1
        RETFIE
```

occurs, the jump from the holding loop is performed as before. However, it is now INTCON bit 1 which is set on the interrupt and has to be cleared before returning to the holding loop, i.e. BCF INTCON,1.

Load and run TUT36 which illustrates this external interrupt. The interrupt can be generated using switch SB0.

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

If a signal generator is connected to RB0 (via resistor R37) and monitored on a scope, the triggering edge should be obvious when the generator's rate is set very slow. The signal generator must produce clean 0V to +5V pulses.

It is possible to change the interrupt response to occur on either edge of the external pulse. As illustrated in TUT36, it is in response to the rising edge. To use the falling edge, OPTION bit 6 must be cleared during the PAGE1 setup routine, e.g.:

```
MOVLW %00001111
MOVWF OPTION
```

Change TUT36 to respond to the falling edge and observe the result when you now press switch SB0.

Note that the setting of OPTION bits 0, 1 and 2 is irrelevant in this interrupt mode.

As you have seen, INTCON bit 7 is used for enabling (1) and disabling (0) the interrupts, in addition to any other bits required for an interrupt to be enabled.

It is possible that at the moment of wishing to disable the interrupts, however, that an interrupt could be in the process of occurring. This would result in the disabling command not taking effect. To ensure that all interrupts are fully disabled (except WDT - see later), the follow routine can be used:

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

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

## EXERCISE 28

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

28.2. You know that INTCON bit 1 and INTCON bit 2 are both flags for interrupts. Modify your program from 28.1 so it automatically responds to interrupts from RB0 and from the TMR0 timer.

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

## TUTORIAL 29

Concept examined:

Command SLEEP

### LISTING 37 - PROGRAM TUT37

```
.ORG $0004
GOTO INTRPT
.ORG $0005

CLRF PORTA
CLRF PORTB
PAGE1
CLRF TRISA
MOVLW %00000001
MOVWF TRISB
MOVLW %01000111
MOVWF OPTION
PAGE0
MOVLW %10010000
MOVWF INTCON

INTRPT: DECFSZ DELAY1,F
        GOTO INTRPT
        DECFSZ DELAY2,F
        GOTO INTRPT
        MOVLW 2
        ADDWF PORTB,F
        BTFSS STATUS,C
        GOTO BYPASS
        INCF PORTA,F
        SLEEP

BYPASS: BCF INTCON,1
        GOTO INTRPT
```

### PROGRAM - TUT37 SWITCH SETTINGS - as in Fig.36

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

The PIC can be awoken from SLEEP by a WDT time-out or through an external interrupt. The program which illustrates the latter is TUT37. Load and run it.

The program adds two to the count on PORTB's l.e.d.s from zero up to the roll-over at 256, at which point PORTA is incremented, its count being shown on its l.e.d.s. At this point, the program is told to SLEEP.

It can only be awoken by pressing switch SB0. Whereupon, the PORTB count resumes, until again it rolls over to zero and increments PORTA, then falling asleep once more. (This might remind you of your occasional behaviour on a Monday morning after "the week-end before"!)

Note the use of two delays (DELAY1 and DELAY2) slowing the program down by  $256 \times 256$  looped actions for the sake of the demo.

## EXERCISE 29

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

## TUTORIAL 30

Concept examined:

Watchdog timer  
Command CLRWDW

PROGRAM - TUT38  
SWITCH SETTINGS - as in Fig.36

The Watchdog Timer (WDT) facility is also probably one for which most readers are unlikely to find much use. The purpose of a WDT is to give the PIC a type of protection against becoming stuck in a perpetual loop.

This can happen in several ways, but particularly in the event of unforeseen program errors, or waiting for an external event to happen but which does not (for many and varied reasons, including equipment malfunction).

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

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

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

When the existing count value is of importance, rather than use the WDT, the program should be written so that an interrupt (from a switch, for instance) can cause the program to resume running without being reset.

However, if it doesn't matter that the program restarts from the beginning, as in some burglar alarm systems perhaps, then

### LISTING 38 - PROGRAM TUT38

```
.ORG $0004
GOTO TESTON
.ORG $0005

CLRF PORTA
CLRF PORTB
PAGE1
CLRF TRISA
MOVLW %00000001
MOVWF TRISB
MOVLW %00001111
MOVWF OPTION
CLRWDW
PAGE0
MOVLW %00000000
MOVWF INTCON

TESTON: BTFSS PORTB,0
        GOTO TESTON
        MOVLW 2
        ADDWF PORTB,F
        BTFSS PORTB,3
        GOTO TSTOFF
        INCF PORTA,F
        CLRF PORTB
        PAGE1
        CLRWDW
        PAGE0

TSTOFF: BTFSC PORTB,0
        GOTO TSTOFF
        GOTO TESTON
```

the WDT can be beneficially used. It should be pointed out that the alarm system discussed earlier is not suitable for WDT use since a real-time clock is an integral part of the program.

To use the WDT, the PIC has to be set for this function prior to the required operational program being loaded, using the PIC configuration program. You will recall that when configuring the PIC for RC and crystal modes, the question was asked if the WDT was needed, to which you replied *no*. Now, though, reconfigure the PIC and indicate *yes* to the Watchdog question. Then load TUT38 and run it.

### WATCH IT!

Observing the l.e.d.s on PORTB, repeatedly press SB0 on and off. At each press, the count value displayed on the l.e.d.s will be seen to increase. The idea is to reach a count of %00001000, at which point the WDT is reset with its starting value, the l.e.d.s on PORTA increment, and PORTB is reset to zero.

Should you not press the switch fast enough, the WDT will time-out and restart the program from the beginning, causing PORTA, PORTB and their l.e.d. counts to be reset to zero.

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

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

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

Be aware that during development of the Tutorials, it was found necessary to occasionally run the WDT configuration twice before the PIC would accept this mode. The reason is unknown. If TUT38 does not behave as expected, re-run the configuration for WDT.

### EXERCISE 30

30.1. Invent your own exercise for WDT!

### TUTORIAL 31 CONCEPT EXAMINED

Misc Special Register bits

We have examined the use of quite a few bits in the Special Registers, but not all of them (see Table 4). First, there are two bits in the STATUS register whose purpose and use seems obscure:

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

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

TABLE 4: STATUS REGISTER

(Courtesy MICROCHIP)

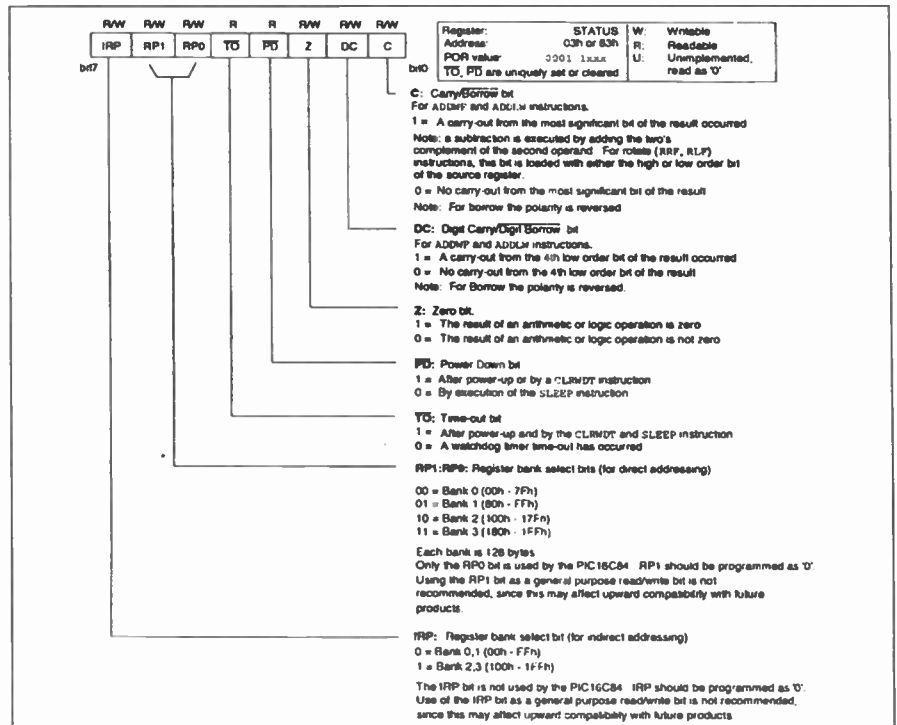
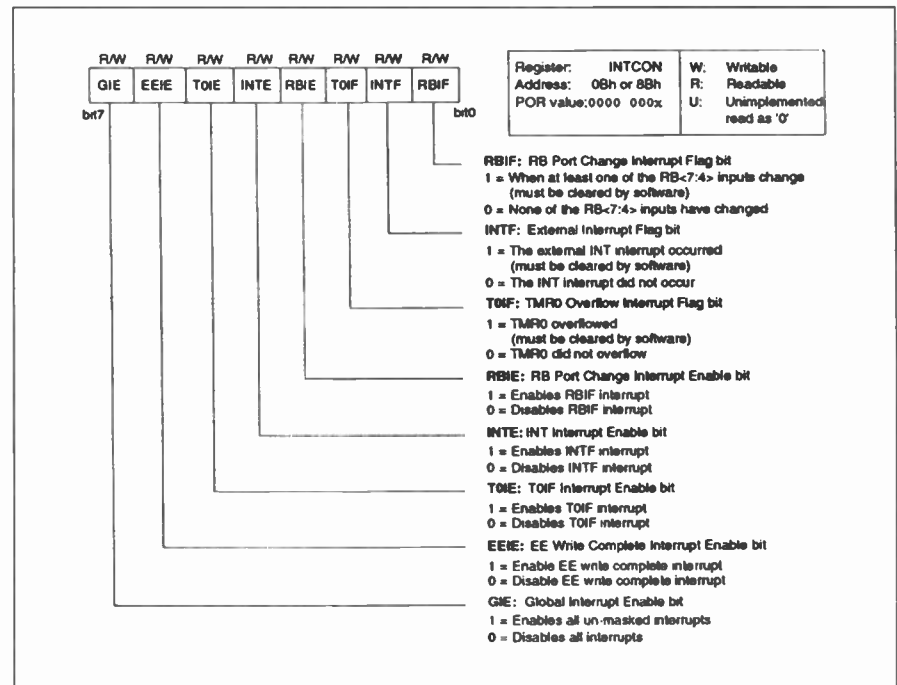


TABLE 5: INTCON REGISTER

(Courtesy MICROCHIP)



There are others which are similar in their setting to those that we have discussed, that their examination is not justified here. The bits are principally in the INTCON and OPTION registers, details of which are shown in the PIC Data Book (also see Table 5 and Table 6). A summary is as follows:

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

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

OPTION bit 5 (RTS): TMR0 signal edge response to signal on RA4/TOCKI pin;  
0 = increment on low-to-high transition;  
1 = increment on high-to-low transition.

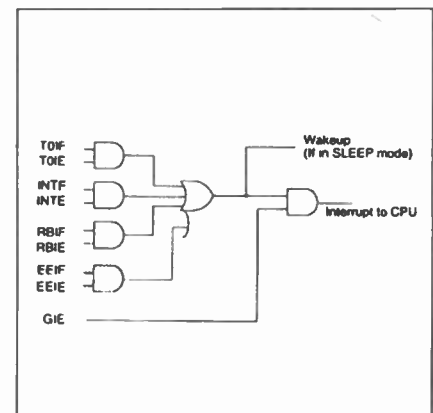


Fig. 37. PIC16C84 interrupt logic.

It is suggested that you write simple routines, along the lines of those that have been used in other demonstrations, to establish for yourself what can be achieved using these bits.

It is also well worthwhile reading through the PIC16C84 part of the *PIC Data Book* in its entirety. There are minor aspects relating to some of the commands that we have discussed that deserve recognition if you wish to delve more deeply into programming this device.

What has been discussed here is, we believe, more than enough to fulfil our intention to "get you started with the PIC16C84", but it is not the end of the story.

## TUTORIAL 32 CONCEPT EXAMINED

Programming  
PICs vs. Hardware  
Summing-up

## PROGRAMMING

To the uninitiated, it may seem that a software programmer simply sits down and writes all the commands in a single operation. If only it were that simple!

Before a single line of code is written, there is a great deal of thought involved about the overall objective and how each step on the way to achieving it might be performed. Part of this consideration relates not only to the logic of the software routines, but also to the control requirements of external interfaces.

There are two schools of thought about the planning. The first considers that the use of flow charts is an essential requirement. The other doesn't!

The advantage of using a flow chart is that it shows the questions and answers of each stage of the program in a diagrammatic form. Theory says that this chart then enables the code to be written to meet each of the requirements illustrated.

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

Additionally, there is always the possibility that some logical consideration has been omitted from the flow chart and which only comes to light once you try to run the program, requiring the chart to be redrawn as well as the software having to be rewritten.

The author finds that the detailed thinking about the program structure already builds up as a mental flow chart which does not require to be set down on paper.

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

However, let us not deter you from drawing up flow charts if you prefer to do

TABLE 6: OPTION REGISTER

(Courtesy MICROCHIP)

R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W																																																
RBFPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0																																																	
bit7 <span style="float: right;">bit0</span>																																																								
								<table border="1"> <tr> <td>Register:</td> <td>OPTION</td> <td>W:</td> <td>Writable</td> </tr> <tr> <td>Address:</td> <td>81h</td> <td>R:</td> <td>Readable</td> </tr> <tr> <td>POR value:</td> <td>FFh</td> <td>U:</td> <td>Unimplemented read as '0'</td> </tr> </table>	Register:	OPTION	W:	Writable	Address:	81h	R:	Readable	POR value:	FFh	U:	Unimplemented read as '0'																																				
Register:	OPTION	W:	Writable																																																					
Address:	81h	R:	Readable																																																					
POR value:	FFh	U:	Unimplemented read as '0'																																																					
								<table border="1"> <thead> <tr> <th colspan="3">PRESCALER VALUE</th> <th rowspan="2">TMR0 RATE</th> <th rowspan="2">WDT RATE</th> </tr> <tr> <th>PS2</th> <th>PS1</th> <th>PS0</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td><td>0</td><td>1 : 2</td><td>1 : 1</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>1 : 4</td><td>1 : 2</td></tr> <tr><td>0</td><td>1</td><td>0</td><td>1 : 8</td><td>1 : 4</td></tr> <tr><td>0</td><td>1</td><td>1</td><td>1 : 16</td><td>1 : 8</td></tr> <tr><td>1</td><td>0</td><td>0</td><td>1 : 32</td><td>1 : 16</td></tr> <tr><td>1</td><td>0</td><td>1</td><td>1 : 64</td><td>1 : 32</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>1 : 128</td><td>1 : 64</td></tr> <tr><td>1</td><td>1</td><td>1</td><td>1 : 256</td><td>1 : 128</td></tr> </tbody> </table>	PRESCALER VALUE			TMR0 RATE	WDT RATE	PS2	PS1	PS0	0	0	0	1 : 2	1 : 1	0	0	1	1 : 4	1 : 2	0	1	0	1 : 8	1 : 4	0	1	1	1 : 16	1 : 8	1	0	0	1 : 32	1 : 16	1	0	1	1 : 64	1 : 32	1	1	0	1 : 128	1 : 64	1	1	1	1 : 256	1 : 128
PRESCALER VALUE			TMR0 RATE	WDT RATE																																																				
PS2	PS1	PS0																																																						
0	0	0	1 : 2	1 : 1																																																				
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1	0	0	1 : 32	1 : 16																																																				
1	0	1	1 : 64	1 : 32																																																				
1	1	0	1 : 128	1 : 64																																																				
1	1	1	1 : 256	1 : 128																																																				
								<p>PSA: Prescaler Assignment bit 1 = Prescaler assigned to the WDT 0 = Prescaler assigned to TMR0</p> <p>T0SE: TMR0 Source Edge select bit 1 = Increment on high-to-low transition on RA4/T0CKI pin 0 = Increment on low-to-high transition on RA4/T0CKI pin</p> <p>T0CS: TMR0 Clock Source select bit 1 = Transition on RA4/T0CKI pin 0 = Internal instruction cycle clock (CLKOUT)</p> <p>INTEDG: Interrupt Edge Select bit 1 = Interrupt on rising edge of RBO/INT pin 0 = Interrupt on falling edge of RBO/INT pin</p> <p>RBFPU: PORTB Pull-up Enable bit 1 = PORTB pull-ups are disabled (overriding any port latch value) 0 = PORTB pull-ups are enabled (by individual port-latch values)</p>																																																

TABLE 7: RESET CONDITIONS FOR REGISTERS

(Courtesy MICROCHIP)

Register	Address	Power-On Reset	MCLR Reset during: - normal operation - SLEEP WDT timeout during normal operation	Wake up from SLEEP: - through interrupt - through WDT timeout
W	—	xxxx xxxx	uuuu uuuu	uuuu uuuu
INDF	00h	----	----	----
TMR0	01h	xxxx xxxx	uuuu uuuu	uuuu uuuu
PCL	02h	0000h	0000h	PC + 1 <sup>2</sup>
STATUS	03h	0001 1xxx	000? ?uuu <sup>3</sup>	uuu? ?uuu <sup>3</sup>
FSR	04h	xxxx xxxx	uuuu uuuu	uuuu uuuu
PORTA	05h	--u uuuu	--u uuuu	--u uuuu
PORTB	06h	xxxx xxxx	uuuu uuuu	uuuu uuuu
EEDATA	08h	xxxx xxxx	uuuu uuuu	uuuu uuuu
EEADR	09h	xxxx xxxx	uuuu uuuu	uuuu uuuu
PCLATH	0Ah	---0 0000	---0 0000	--u uuuu
INTCON	0Bh	0000 000x	0000 000u	uuuu uuuu <sup>1</sup>
INDF	80h	----	----	----
OPTION	81h	1111 1111	1111 1111	uuuu uuuu
PCL	82h	0000h	0000h	PC + 1
STATUS	83h	0001 1xxx	000? ?uuu <sup>3</sup>	uuu? ?uuu <sup>3</sup>
FSR	84h	xxxx xxxx	uuuu uuuu	uuuu uuuu
TRISA	85h	--1 1111	--1 1111	--u uuuu
TRISB	86h	1111 1111	1111 1111	uuuu uuuu
EECON1	88h	---0 0000	---0 ?000	---0 ?uuu
EECON2	89h	----	----	----
PCLATH	8Ah	---0 0000	---0 0000	--u uuuu
INTCON	8Bh	0000 000x	0000 000u	uuuu uuuu <sup>1</sup>

Legend: u = unchanged, x = unknown, -- = unimplemented bit, read as '0', ? = value depends on condition.

Note 1: One or more bits in INTCON will be affected (to cause wake-up).

Note 2: When the wake-up is due to an interrupt and the GIE bit is set, the PC is loaded with the interrupt vector (0004h).

so. You may well find that they help you to grasp what you are doing more readily than just relying on your mental "visualisation" processes.

To discuss flow charts more fully is beyond the scope of this Tutorial, but you will find examples of them in Microchip's *Embedded Control Handbook*. It has to be said, though, that even in that publication, which is full of program listings, flow charts are not widely used.

## STAGE BY STAGE

Whether or not you use flow charts, you should never attempt to write the entire program from beginning to end in one operation. That way can lead to extensive problems when you try to debug the program having found that it doesn't do what you expected.

Take each routine stage by stage. Get one small section of code working before

you move onto the next. Then get that next small section working before you try to join it to the previous part. *Be methodical* is the key command when programming.

In many ways, the manner in which this Tutorial has been presented has been along those lines. We have tried to show you individual structures which first stand on their own, and then are extended or joined to others to achieve a larger operational system.

Taking TUT2 as the effective starting point, that program used only 13 command lines. Gradually we developed other programs as stand-alone routines. Then things began to take a broader structure as concepts were integrated into a more sophisticated whole. With TUT34, nearly 500 commands were sent to the PIC – nearly half its capacity.

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

However, the author finds it very easy to check program operation when the code is in the PIC and the PIC is connected to its various interfaces. Had the PIC16C84 not been an EEPROM device, then this would not be an acceptable technique, but it is rapidly reprogrammable and so is usable as a live test bed. This is why the demo p.c.b. included with this article will be of such great use beyond the end of the Tutorial exercises.

One further point, when writing a program the author finds it useful to supplement its software file name with a suffix number, increasing the number at each save of a major addition or change to the previous code written. This allows an earlier version to be recalled should the need arise. Thus you would number as, for example, PICIT01.ASM, PICIT02.ASM, PICIT03.ASM, etc. Remember that MS-DOS only allows file names of up to eight characters long, plus a three-character extension (such as .ASM).

## PICS vs. HARDWARE

As enormously beneficial as the use of a microcontroller can be, there is the likelihood that it may be regarded by the inexperienced as the ultimate answer to all electronic circuit design. This is most definitely not the case.

All that a microcontroller will do is assist in using software commands to replace a fair number of operations for which many electronic components would otherwise be needed. It cannot substitute for all electronic requirements. Indeed, the demo p.c.b. that accompanies this Tutorial has proved the need for quite a number of hardware items as well as the PIC.

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

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

## SUMMING-UP

When writing software, you will find much frustration through the inability to immediately see the bug in a program routine. Eventually, though, you will spot it and the relief and exhilaration of at last getting that part to work is enormous.

In that frame of mind, you will move onto writing the next sub-routine with the utmost confidence and anticipation of not making a mistake on *this* one. Would that it were so! You can, and you will, make mistakes. But the ultimate satisfaction of a complete working design makes it all worthwhile.

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

Finally, remember that Murphy's Law has its most powerful influence when programming is involved. If the microcontroller or other computer *can* misunderstand what you *mean* by your commands, *it will*.

It is up to you to see the way in which each and every one of your commands will *actually* be interpreted. You are the intelligent one, the computer simply obeys your instructions!

## APPENDIX A: BUGGED TEASER

Now to give you understanding of PIC programming (and your logical thinking) a bit of a test!

Type in everything as stated in Listing 39. Add an appropriate initialisation routine at the beginning, and add a suitable set of l.c.d. operating routines as illustrated earlier.

Don't forget to add the final .END statement (failure to do so could result in TASM deleting your source code file!). Save the code as two slightly different file names, then work on the second file.

Listing 39 has a number of bugs *deliberately* included – your task is to debug the program and get it working as a frequency counter!

Some of the deliberate errors will be reported by TASM following assembly. These are *literal* errors which anyone might make while creating a PIC program – simple slips in thinking. The others, though, are *logical* errors – much more significant errors in a programmer's analysis of a situation and its interpretation, but still errors anyone could make.

First of all, get the l.c.d. to display the opening message correctly (and without the program "crashing"). Then, with the aid of a Signal Generator (0V/5V output logic level) set to about 10kHz (you must decide which input pin and d.i.l. switch settings to use), solve the remaining logical problems. You'll probably curse the author a few times before you solve it all, but keep at it!

## LISTING 39 - COUNTING BUGS!

```

TABLE:  ANDLW 7
        ADDWF PCL,F
        RETLW 'F'
        RETLW 'R'
        RETLW 'E'
        RETLW 'Q'
        RETLW ''
        RETLW 'C'
        RETLW 'O'
        RETLW 'U'
        RETLW 'N'
        RETLW 'T'
        RETLW 'E'
        RETLW 'R'
        RETLW ''
        RETLW ''
        RETLW ''

START:  CALL SETUP
        CLRf LOOPB

MESSAGE: MOVF LOOPB,W
        CALL TABLES
        CALL LCDOUT
        INCF LOOPB,F
        BTFSF LOOPB,4
        GOTO MESSAGE

INTCLR: MOVLW 50
        MOVWF CLKCNT
        CLRf COUNT0,W
        CLRf COUNT1,W
        CLRf COUNT2,W
        CLRf COUNT3,W
        CLRf COUNT4,W
        CLRf COUNT5,W
        BCF INTCON,2

INTRPT: MOVF PORTA,W
        ANDLW %00010000
        MOVWF STORE1
        XORWF COUNT0,W
        BTFSF STATUS,Z
        GOTO INT2
        MOVLW COUNT1,F
        MOVWF FSR
        INCF INDF,F
        ADDLW 6
        BTFSF STATUS,DC
        GOTO INT2
        CLRf INDF
        INCF FSR,F
        GOTO INTINC

INT2:   MOVF STORE1,W
        MOVWF COUNT0
        BTFSF INTCON,2
        GOTO INTRPT
        BCF INTCON,2
        DECFSZ CLKCNT,F
        GOTO INTRPT

INT3:   CALL LCD2
        MOVLW COUNT5
        MOVWF FSR
        MOVLW 6
        MOVWF LOOPB
        MOVF INDF,W
        IORLW 64
        CALL LCDOUT
        DECf FSR,F
        DECFSZ LOOPB,F
        GOTO SHOW2
        MOVLW "H"
        MOVLW "z"
        CALL LCDOUT
        GOTO INTCLR

LCD1:   MOVLW %10000000
        GOTO LCDLIN

LCD2:   MOVLW %11000000
        BCF RSLINE,4
        GOTO LCDOUT
    
```

Having solved it (and felt the satisfaction of success!), think about how switches and other routines could extend the counter's range.

## APPENDIX B: BASIC TASM AND MPASM DIFFERENCES

With regard to the use of the "official" mnemonic codes for the PIC16C84 as published in the *PIC Data Book*, there is no difference between TASM and MPASM. There are differences, however, in the way in which numerical values are expressed, and in some other significant matters.

Here we highlight some of the major differences to assist you in translating source codes from MPASM to TASM. The comments relate to the latest version of MPASM, V01.40 – earlier MPASM versions may have other differences.

For more details about MPASM, refer to Microchip's *MPASM User's Guide*.

### RADIX

You discovered in Part 2 that TASM requires the numerical formats as shown in the following examples:

**Decimal:** 153  
**Hexadecimal:** \$2B  
**Binary:** %10010110  
**ASCII:** 'C'

Decimal requires no prefix, hex and binary need \$ and % prefixes respectively, ASCII requires enclosing in "right-handed" single quotes (').

MPASM, though, uses styles that (usually) require both prefix letters and enclosing "right-handed" quotes:

**Decimal:** D'153'  
**Hexadecimal:** H'2B'  
**Binary:** B'10010110'  
**ASCII:** 'C' or A'C'  
**Octal:** 0'777'

Note the choice of two equivalent styles for ASCII, and that TASM has no equivalent for the Octal expression.

A significant difference for MPASM is that the user may choose to express decimal, hex or binary values without the use of a prefix and enclosing quotes, defining this requirement in an initialisation line which is prefixed with the statement "list".

The term *radix* is used in this respect, and the radix is then equated to be in decimal, hex or binary, according to the user's preference. This same line also states the processor for which the code is to be assembled. For example, the following line tells MPASM that the code is to be assembled for the PIC16C84 (p=16c84) and that the radix is decimal (r=dec):

list p=16c84, r=dec

Having specified the radix, any un-prefixed value encountered by MPASM during assembly will be taken to be in that notation. Thus if the radix is decimal (r=dec), 10 will be taken as decimal ten. If the chosen radix is hex (r=hex), then 10 will be taken as \$10 (decimal 16). For a binary radix (r=bin), 10 will be interpreted as %00000010 (decimal 2).

Thus, before translating source code from MPASM to TASM, always check the radix statement and convert values

accordingly. If no radix statement is made, the default radix is hexadecimal.

### OTHER LIST OPTIONS

Several other equational statements may occur following the "list" statement. These control the format process when MPASM is assembling the source code. They have no relevance to TASM and can be ignored in any translation. The following are the "list directive" options you might encounter:

free, fixed, b=, c=, f=, mm=, n=, st=, t=, w=, x= (where additional statements or values follow the equals signs).

### LABELS AND DOTS

Whereas TASM's labels need to be followed by colon (:), MPASM's do not (although MPASM seems to accept them).

A decimal point prefix is required by TASM, but not MPASM, in the following instances:

TASM	MPASM
.EQU	EQU
.ORG	ORG
.END	END

Additionally note that MPASM allows ORG statements to set the code to start at a variety of addresses and that these addresses may not be in numerical order. TASM does not allow this option (see Part 1).

### MACROS

MPASM permits routines to be defined as "macros" allowing them to be stored as library routines which can be called by name and processed during assembly run-time. Calls to these macros are made through the MPASM source code using the "#include" prefix. When converting to TASM source code, macro codes should be included as fully expanded lines of source code.

(TASM also allows macro use, as described in the text file supplied with it – TASM.DOC.)

### MPASM SHORTHAND

You may encounter mnemonics that are not included in the standard PIC command set but which are recognised by MPASM as legitimate commands during code assembly. They are a form of "definition" allowing one statement to be translated as one or more other statements – a shorthand form, in other words. An example is:

ADDCF f,d

which translates as Add Carry to File, and assembles as:

BTFSC 3,0  
 INCF f,d

The full list is too lengthy to be defined here but is covered in the *MPASM User's Guide*, Appendix D, Table 11 and in Chapter 3, Table 3.1.

Finally, be aware that code for one PIC processor type may not be suitable for use with another PIC type.

### PIC16F84

It seems increasingly likely that PIC16F84 devices will become more easily available than the PIC16C84. We re-iterate that in the context of this Tutorial and many other applications, the two versions can be regarded as fully interchangeable.

### FURTHER READING

*PIC1617 Microcontroller Data Book*, *Microchip Embedded Control Handbook*, *MPASM User's Guide*. These books are obtainable from Arizona Microchip, their distributors or via their website.

*Everyday Practical Electronics* magazine. Frequent articles on PICs in practical constructional designs.

### APPENDIX C: USEFUL PIC INFORMATION

Arizona Microchip Technology Ltd, Microchip House, 505 Eskdale Road, Winnersh Triangle, Woking, Berks RG41 5TU.

Tel: 0118 9211 5800. Fax: 0118 921 4820 (new details as from Feb '98).

Arizona Microchip: <http://www.microchip.com>

Arizona Microchip links to related web sites: <http://www.microchip2.com/wwwsites.htm>

Arizona Microchip links to enthusiasts' pages: <http://www.microchip2.com/enth.htm>

Arizona Microchip's UK sales rep: <http://www.arizona.co.uk/arizona>

Arizona UK Tech Desk (E-mail): [techdesk@arizona.co.uk](mailto:techdesk@arizona.co.uk)

EPE web site: <http://www.epemag.wimborne.co.uk>

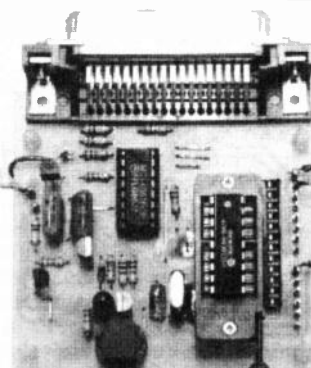
EPE FTP site: <ftp://ftp.epemag.wimborne.co.uk>

EPE PIC-project source code files: <ftp://ftp.epemag.wimborne.co.uk/pubs/PICS>

Macintosh PIC tools: <http://www3.sympatico.ca/numeral>

PIC-related Internet resources list: <http://www.eetoolbox.com/gatopix.htm>

PICpoint website: <http://www.picpoint.com>



## PIC TOOLKIT

Computer controlled Programmer, Disassembler and Language Translator – TASM and MPASM inter-conversion. Nine modes make it all possible for the PIC16C84 and PIC16F84. Can also be used with the PIC Tutorial board.

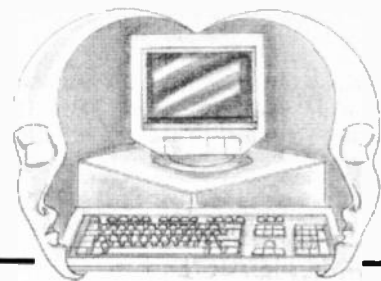
Coming in EPE July '98 issue.

ENSURE YOU READ IT!

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# INTERFACE

Robert Penfold



## ADDRESSING THE PRINTER PORT

A NUMBER of circuits featured in previous *Interface* articles connect to the parallel printer port of a PC, and more projects of this type are planned for the future.

Correspondence from readers suggests that some are having difficulty in using PC printer ports in their bi-directional mode, while others seem to have problems in using these ports at all. In this article we will, therefore, look at ways of using a printer port for general interfacing, and the problems that can arise.

### Properly Addressed

The subject of printer port addresses seems to be slightly more involved than had first been thought. The generally accepted wisdom is that printer port 1 is at addresses from &H378 to &H37A, and that port 2 is at addresses from &H278 to &H27A.

However, it would seem that the PC supports three printer ports, and that a third address range is available. This runs from &H3BC to &H3BE, and according to the textbooks it has its origins in the printer ports included on the old Hercules monochrome graphics cards. However, these days it seems to be in general use.

Many add-on printer port cards support this address range, and it can also be used for the built-in printer port of many computers. In fact it is sometimes used as the default address range.

It seems that the normal scheme of things is for &H378 and &H278 to be used as the base addresses for ports 1 and 2 respectively, and one might reasonably expect a port set to have &H3BC as its base address to be port 3. This does not seem to be the case though, and any port set to use this base address will probably be made port 1 by the operating system, even if this means changing the numbers of other ports.

Thus, although &H378 and &H278 are normally the base addresses for ports 1 and 2, they will be the base address for ports 2 and 3 if there is also a port at &H3BC. It seems that some computers are set up in the logical fashion with &H3BC used for port 1 right from the start, but most PCs are supplied with the printer port at &H378.

When using a printer port for general interfacing it is normally addressed directly, and its port number is of no importance. You do need to know its base address, though, so that you can use the correct input/output addresses when accessing the port.

One of the start-up screens produced by the BIOS program usually provides a detailed list of the ports present in the computer, and this should give the printer port base address or addresses. If you are not sure which address range is used by the port you wish to utilize, try the "suck it and see" approach.

Writing a value of 240 to the base address of the port should set outputs D0 to D3 low, and D4 to D7 high. For example, this line in GW BASIC would write a value of 240 to the port at &H378

```
OUT &H378,240
```

Obviously the address should be changed to &H278 or &H3BC where appropriate. If you do not know the base address of the port, try the three

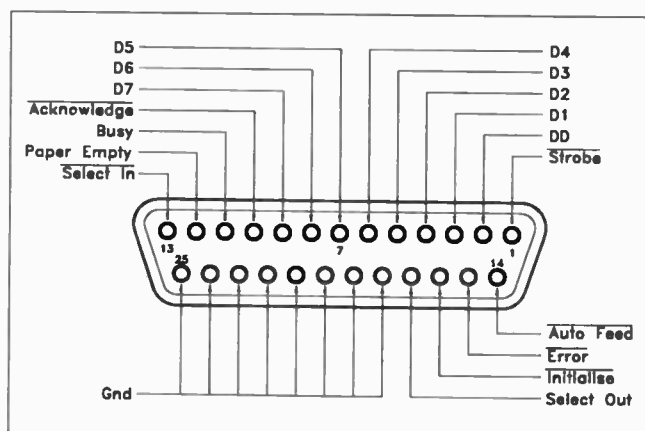


Fig.1. Connection details for a standard PC printer port. There are four handshake outputs and five inputs.

possible addresses one by one until the outputs respond. The standard connector for a PC printer port is the 25-way female D-type connector, and the pin functions are shown in Fig.1.

### Each Way Bet

The original PC printer ports were strictly output types, and there was no way of directly reading data via the data lines. Some of the early add-on printer cards could be modified to act as input ports, but this was not possible with all makes. Most PCs built in the last few years have enhanced printer ports that do have bi-directional capability, as do some older computers.

Enhanced printer ports probably have their origins back in the days of the IBM PS/2 PCs, about 11 years ago. It is not only built-in ports that have enhanced modes, and any reasonably modern printer port card should also have basic bi-directional capabilities.

How do you determine whether or not your computer can operate with the printer port in the input mode? It is really just a matter of trying it to see,

but it might be necessary to do some preliminary adjustment before the bi-directional capabilities can be used. If you are using an add-on printer port card it will probably default to enhanced operation.

There is more than one enhanced operating mode, and the card may have jumpers or a d.i.p. switch to enable the desired mode to be selected. The cards I have used offer two modes, which are SPP and EPP. These respectively stand for Standard Parallel Port and Enhanced Parallel Port. These both support bi-directional operation, and it does not matter which is selected.

Built-in printer ports are controlled via the BIOS setup program, which is usually entered by pressing the "Del" key during the boot-up process. Modern setup programs are quite complex, offering control over dozens of parameters.

The section of the program that deals with integrated peripherals usually controls the printer port. The exact options available depend on the BIOS manufacturer and vintage of the computer.

There may be various address options available, together with various operating modes. For bi-directional use it is SPP or EPP operation that is needed (or combined SPP/EPP operation).

There is another enhanced mode, which is ECP (Enhanced Capabilities Parallel port), but this does not seem to support the simple bi-directional operation that we require. Neither does any "Normal" mode, which simply provides old fashioned output only operation.

The setup program controls the built-in printer port by writing the appropriate values to a control register or registers. It is probably best to control the printer port via this approved route rather than directly accessing the hardware.

Even if you could find details of the control registers, it is easier and safer to use the setup program. By directly accessing the hardware you might set-up the printer port in the desired fashion, but disable other items of hardware in the process!

### Getting Input

One of the three addresses utilized by the printer port is primarily used to control the five handshake outputs. A sixth bit is used to control the direction of the data lines, and the other two bits are left unused.

Table 1 lists the function of each bit of the handshake output register. Note

that three of the four output lines have built in inverters, and produced a logic level that is the opposite of the value written to the register.

The interrupt enable bit enables interrupts on the acknowledge handshake input, and this would normally be set to zero so that interrupts are disabled. The data direction bit is set to zero for normal output operation or to one if the data lines are to be used as inputs. Unfortunately, there is no individual control over the functions of the data lines, and they must all operate in the same mode.

It is very easy to check whether or not a port supports bi-directional operation, and the first step is to run this simple GW BASIC program. Obviously, where appropriate, the addresses used must be changed to suit those used by your printer port.

```
10 OUT &H378,0
20 OUT &H37A,32
30 PRINT INP(&H378)
40 GOTO 30
```

**Table 1: Handshake Output Register Functions (&H27A, &H37A, or &H3BE)**

Bit	Function	25-Way D-Connector Pin Number
0	Strobe (inverted)	1
1	Auto Feed (inverted)	14
2	-Initialise	16
3	Select Out (inverted)	17
4	IRQ Enable	-
5	Data Direction	-
6	Unused	-
7	Unused	-

The second line sets the port to input mode, and the next line reads the port and prints the returned value on the screen. The program is repeatedly looped back to this line, so that a continuous stream of readings are taken and displayed.

If a series of 0s are printed down the screen the port is not working as an input type, and it is simply reading the value on the output latch. The port is almost certainly operating as an input type if a column of 255s is displayed. There are pull-up resistors on the inputs, and a value of 255 is returned unless one or more of the inputs are taken low.

To make sure that the port is operating as an input type, try connecting one of the data lines to ground via a resistor of about 330 ohms in value. This should pull the input low, and produce a different reading on the screen (254 if D0 is taken low for example).

### All In

Whether or not a printer port is bi-directional, there are five handshake inputs available. As we have seen in previous *Interface* articles, these can be used to read in bytes of data, albeit in two four-bit nibbles. Table 2 provides details of the handshake inputs.

The intended functions of these lines are of no importance when they are used for general interfacing, and they can be used for any functions you see fit. Note that bit 7 (Busy) is obtained via a built-in inverter.

You may occasionally come across references to the handshake lines having bi-directional capabilities, but this is not strictly true. As far as I am aware, the handshake *inputs* can only operate as such, and have no output capability.

The handshake *outputs* are different propositions, and do have some input capability, but only with some ifs, buts, and maybes. It is possible to read the states of the outputs, and this capability is included so that the state of one line can be altered without changing any of the others. On the face of it, this does not enable the lines to operate as inputs, because it would not be safe to use brute force to drive outputs as inputs.

In practice it is sometimes possible to use the handshake outputs as inputs, due to the use of simple *npn* switching transistors at the outputs. Setting an output high switches off the switching transistor, so that the collector load resistor then pulls the output high. The output can then be safely controlled via a standard logic

Remember that three of the handshake outputs are inverted, and that 0s must be written to these lines in order to set them high. These outputs would also seem to be read back via inverters.

The following simple test program will show whether or not the handshake outputs can be used as inputs. Where appropriate, remember to change the address to suit the port you are using.

```
10 OUT &H27A,4
20 PRINT INP(&H27A)
30 GOTO 20
```

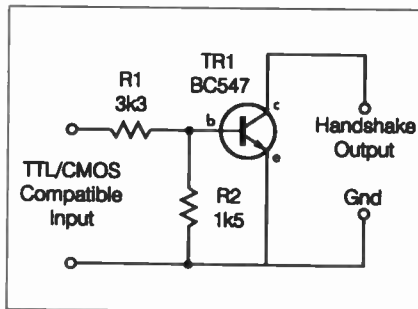
If the lines are acting as inputs this will provide a column of 4s down the screen. Connecting one of the inputs to ground via a 330 ohm resistor will pull it low, and should result in the displayed value changing. With bi-directional ports that also support this input mode it is possible to have some 17 inputs and no outputs!

Bear in mind though, that one handshake output plus a small amount of hardware can effectively double the number of data and (or) handshake

**Table 2: Handshake Inputs (Address &H279, &H379, or &H3BD)**

Bit	Function	Connector Pin No.
0	Unused	-
1	Unused	-
2	Unused	-
3	-Error	15
4	-Select In	13
5	Paper Empty	12
6	-Acknowledge	10
7	-Busy (inverted)	11

output, although it is safer to use an open collector driver such as the one shown in Fig.2. Note that this driver provides a signal inversion.



*Fig.2. A simple open collector driver stage. Note that this circuit provides an inversion.*

### On the Cards

This method did not work with any of the built-in printer ports that I tested. Presumably these ports do things in the obvious manner, and read back data from a data latch rather than from the output lines themselves.

However, it did work properly when tried with printer port cards both ancient and modern. They are probably designed to have full compatibility with the original IBM printer card, which apparently supported this mode of operation. The only way to ascertain whether or not a printer port card supports this method of working is to try it and see.

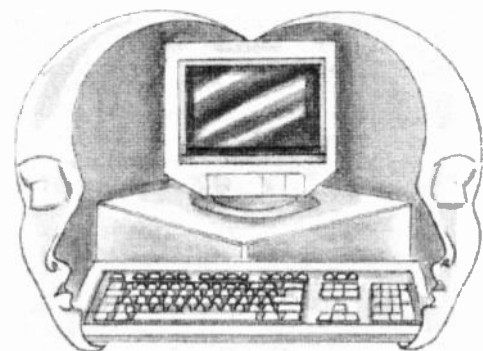
inputs. Reading data via the handshake outputs is something that might not be particularly useful in practice.

### Cheap Lines

If you have problems getting a built-in printer port to operate in bi-directional mode, or your computer simply does not have a suitable port, there is an easy solution. Just fit a modern add-on printer card.

I obtained a couple of these from my local PC World store for £10 each, and there were no problems in using them as bi-directional ports. They also enabled the handshake outputs to operate in the input mode.

With some 17 input/output lines for just £10 these cards truly represent real bargains.

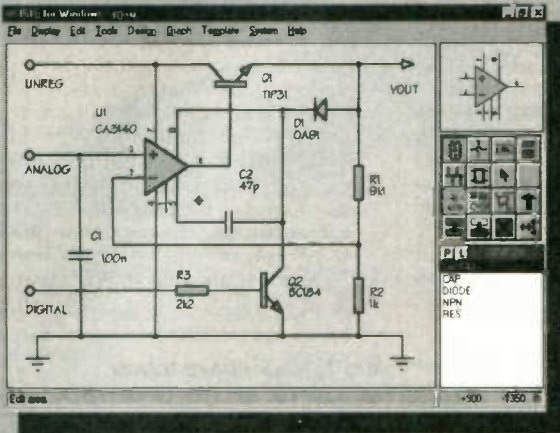




# PROTEUS

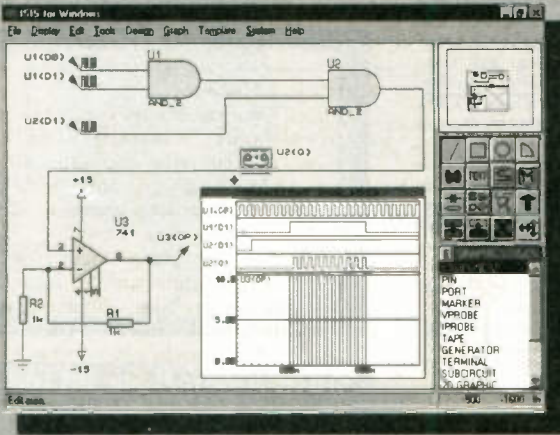
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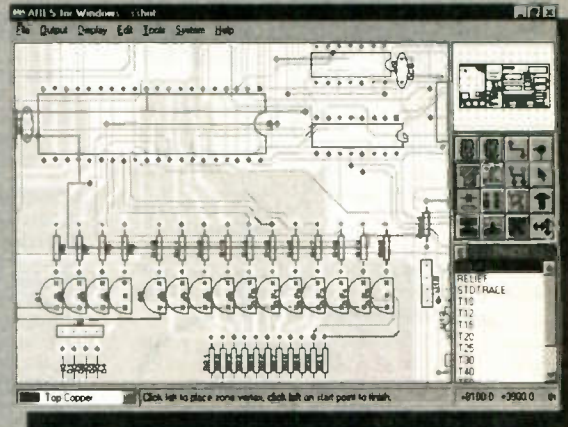
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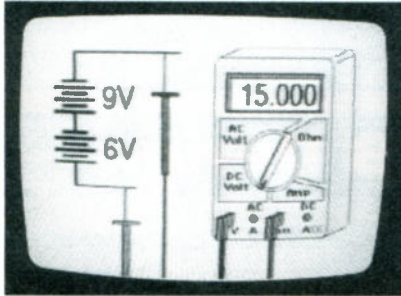
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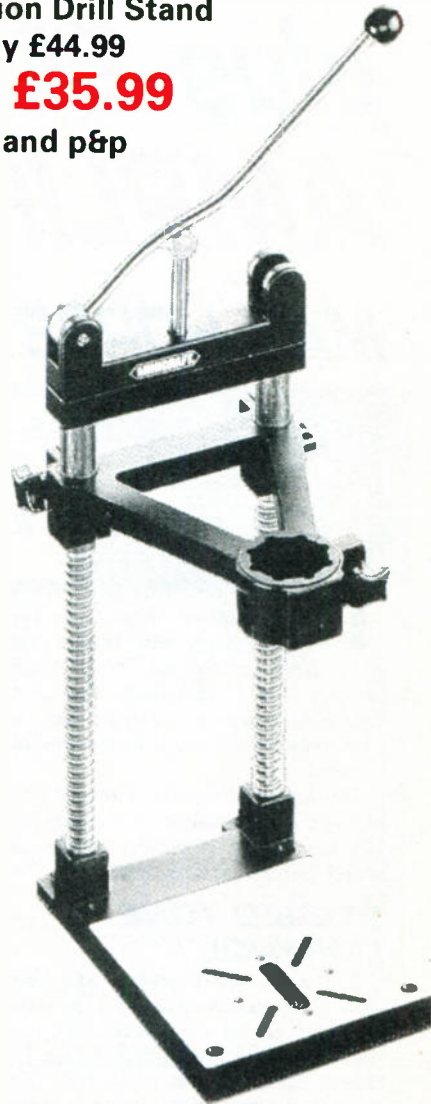


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# STEREO TONE CONTROL plus 20W STEREO AMPLIFIER



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**T**HIS article describes two projects, a general purpose Stereo Tone Control featuring Bass and Treble controls, complete with power supply. The prototype circuits were housed in a single case, but the tone control will work with any amplifier as required.

The amplifier described requires a 12V supply making it suitable for operation on a 12V car battery. However, a mains driven supply is included if required.

## STEREO TONE CONTROL

The tone control project was designed around a standard op.amp i.c. to avoid the problems caused when specialised i.c.s are suddenly withdrawn without notice. The i.c. chosen was the low noise NE5532; the single chip contains two op.amps making it ideal for stereo work.

## WORKING CIRCUIT

An advantage in using a general purpose op.amp circuit is that the features of the system can be changed as required. However, the calculations required to predict the frequency response of the circuit are quite complicated, and so owners of the software system *Electronics Workbench* can bypass the calculations and plot a frequency response curve (a Bode Plot) automatically.

A suitable test circuit is shown in Fig.1. The frequency control components are around the variable resistors (potentiometers) B – for Bass control, and T for Treble control. Select the i.c. type which allows the power supply pins to be connected, as the circuit is designed for use with a single rail power supply.

Notice how the Function Generator is connected both to the input of the circuit, and to the Bode Plotter. The output from the circuit is also connected to the Bode Plotter.

Double-click the Bode Plotter to display the results, and set the frequency range from 20Hz to 20kHz. Click "activate" to obtain an automatic bode plot.

You should find that setting the two controls to 50 per cent (i.e. midway) results in

a fairly straight line, showing that no frequency correction has been applied. However, changing the setting of either control will result in a bass or treble boost or cut. The component values around the Bass and Treble controls can be changed to provide different responses and hence create your own unique tone control system!

## CIRCUIT DESCRIPTION

Those without the benefit of *Workbench* are advised to use the component values suggested the Stereo Tone Control circuit design shown in Fig. 2. This shows the complete tone control circuit for both channels. We only describe the left-hand channel since the right-hand one is identical.

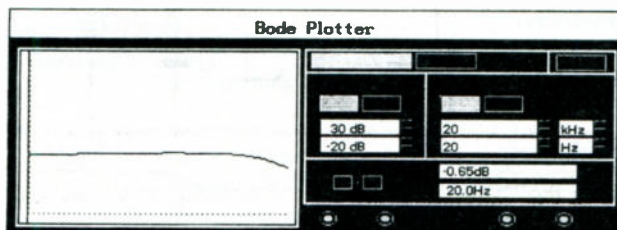
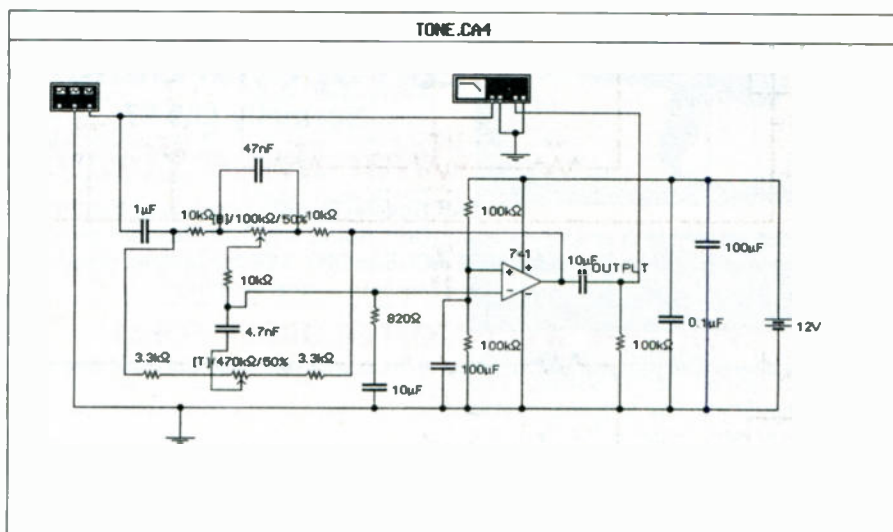


Fig.1. Test circuit diagram and Bode plot printout, produced using the Electronics Workbench software.

Since the circuit is required to operate on a single rail power supply, the average d.c. level must be held at half the supply voltage. Hence the a.c. signal (i.e. the sound signal) moves above and below 0V at the left-hand side of C1, but above and below 6V at the right-hand side of C1.

Resistors R7 and R8 maintain the non-inverting input (pin 3) of IC1a at 6V. This causes the inverting input (pin 2) and the output (pin 1) of IC1a to also reside at an average of 6V.

Capacitor C1 is therefore required to block the d.c. which would otherwise flow from the 6V side of the circuit towards the input. However, C1 allows the a.c. sound signal to flow from the input to the tone control network.

The output from pin 1 is fed back to the inverting input (pin 2) via the network of resistors and capacitors around potentiometers VR1 and VR2. This is known as *negative feedback*, and the capacitors cause the frequency response to be controlled in the required manner.

The principle is that capacitors block d.c., and are resistant to the flow of low frequency a.c. As the frequency increases the degree of flow through the capacitor increases. Large capacitor values pass lower frequencies more readily than smaller capacitors.

The following is a simplified non-mathematical account of how the tone control network works, based on extremes of frequency where "low frequencies" will not pass through the capacitors C3 and C2 but "high frequencies" will.

## BASS CONTROL

Ignoring the effect of resistor R2, if the Bass control is set with the wiper (moving contact) nearer R3 (a setting of 0% on *Workbench*) then the low frequency gain is determined by the ratio of  $R3/R1 + VR1$ , i.e.  $10k/110k$ , hence a cut of roughly a factor of ten. This assumes that the frequency is so low that capacitor C2 is virtually an open circuit.

As the frequency increases C2 conducts an increasing amount of signal until it virtually becomes transparent. The resistance of VR1 is now short circuited and so the high frequency gain is given by the ratio of  $R3/R1$  i.e.  $10k/10k$ , or unity.

When the wiper of VR1 is moved nearer R1 (100% on *Workbench*) the gain at the highest frequencies will still be unity, but the gain at low frequencies (when C2 is effectively an open circuit) will be given by the ratio of  $R3 + VR1/R1$  i.e.  $110k/10k$ , i.e. a gain of about 11.

## TREBLE CONTROL

The effect of capacitor C3 is to prevent low frequencies effecting operation of the Treble control circuit. When the wiper of

VR2 is nearer resistor R5 (a setting of 0% on *Workbench* assuming that the wiper arrow is pointing up as shown in Fig 1) the possible gain at high frequencies is given by  $R5/R4 + VR2$  i.e.  $3k3/473k$ .

When the wiper is nearer R4 (100% on *Workbench*) the possible gain is given by  $VR2 + R5/R4$  i.e.  $473k/3k3$ . The actual gain will be determined by the effect of the Bass control circuit and resistor R2, though the setting of VR1 is irrelevant.

A Bode plot produced by *Workbench* when the Bass and Treble controls are set at 100% is shown in Fig.3. Note that at centre frequencies (around 630Hz) there is little cut or gain, but at low frequencies of around 20Hz the gain can be cut or boosted by around 7 to 8 times. Similarly the treble frequencies of around 20kHz can be cut or boosted by the same.

The effect of resistor R6 and capacitor C4 is to reduce the gain at very high frequencies which might affect stability. The output from pin 1 of IC1a is at a d.c. average of 6V and capacitor C6 reduces the average to zero, so allowing the a.c. sound output signal to oscillate above and below 0V ready for the next stage of the system.

Fig.3. Bode plot produced by *Workbench* when Bass and Treble controls are set at 100 per cent.

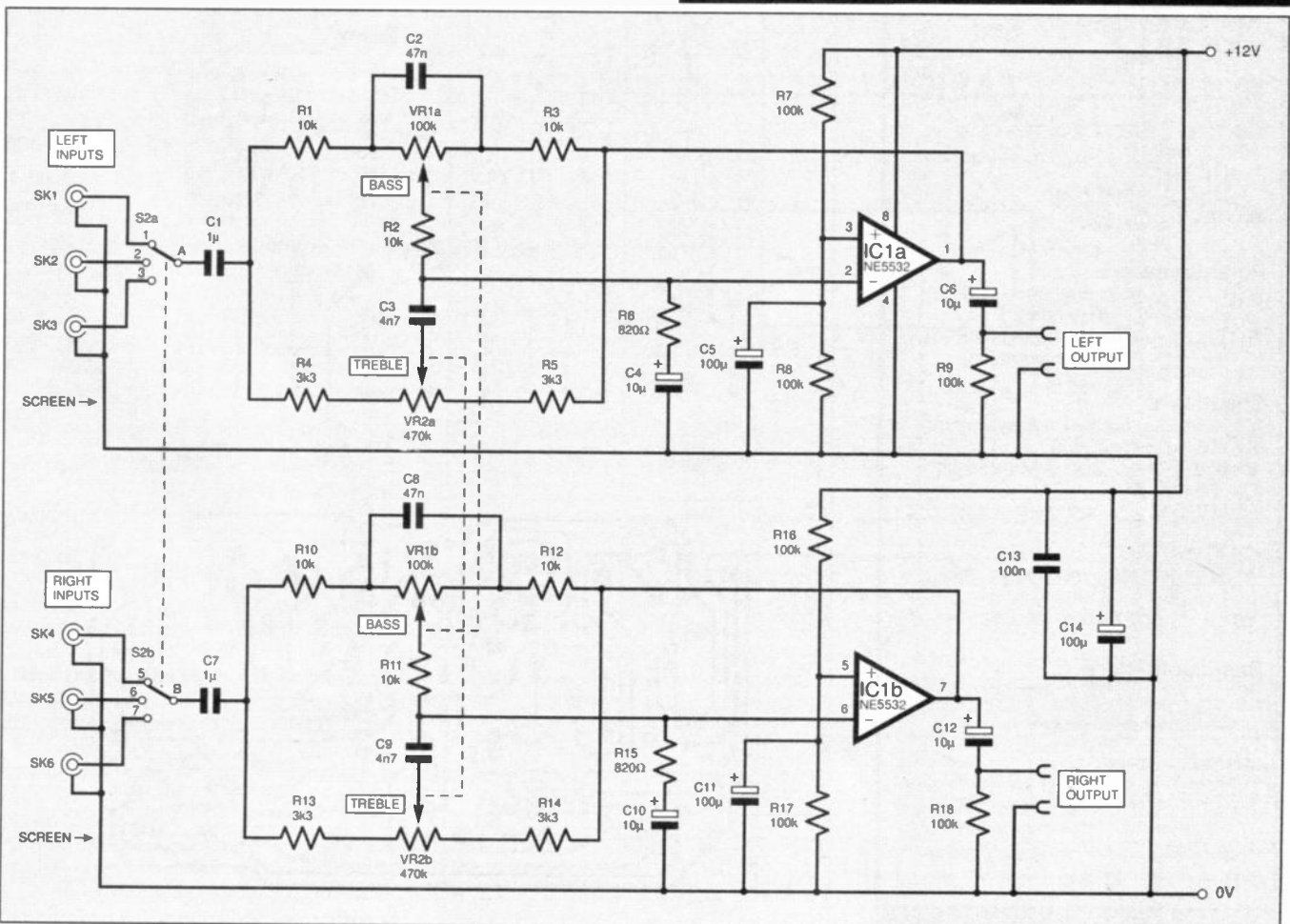
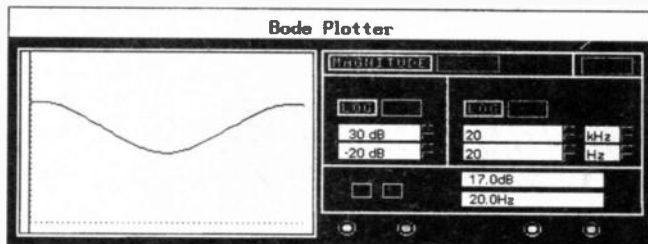


Fig.2. Full circuit diagram for the Stereo Tone Control. If installing in an existing system, the input selector switch and phono sockets can be discarded.

Resistor R9 provides a dummy load to ensure that the negative side of C6 is at 0V. Capacitors C13 and C14 provide decoupling for the circuit ensuring a smooth power supply.

## CONSTRUCTION

Apart from the tone control potentiometers, all components for the Stereo Tone Control are contained on a single-sided printed circuit board (p.c.b.). The topside component layout and full size underside copper foil master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 190.

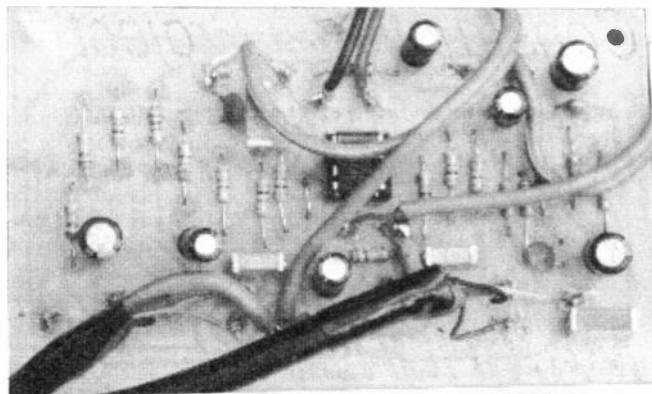
As mentioned at the beginning, the options for the Stereo Tone Control are two-fold in that it can be built as an entirely stand-alone unit, for inclusion in existing amplifiers, or it can be incorporated into the following 20W Stereo Amplifier design. Details of wiring the Tone Control into the amplifier will be given at the end of the amplifier construction section.

The copper pads provided for the pots, are arranged to allow the use of presets if preferred. Begin construction by soldering in the i.c. socket and the wire link and resistors. The smaller capacitors may be connected either way round, but insert the larger electrolytic capacitors with care ensuring correct polarity.

If the distance between the pots and the p.c.b., within the case, is very small, ordinary wires may be employed to link the two. However, if screened cable is used the risk of interference being induced from other parts of the circuit is greatly minimised.

This is particularly important if the Tone control is housed near to the power amplifier and power supply circuits. Multi-core screened wire was used in the prototype, but any screened cable will do, assuming that the screen (the outer layer) is connected to 0V at one end.

Finally, insert the i.c. into its socket, and apply a 12V supply. Testing is best achieved with a signal generator and oscilloscope, but if these are not available, try connecting a tape recorder or CD player to the inputs of the circuit and listen with a pair of headphones to the output.



Components mounted on the printed circuit board. Use multi-core screened cable for the potentiometer leads.

## HUM

The Stereo Tone Control circuit should be free of hum assuming that a battery or well smoothed power supply is used. However, hum can be induced by an "earth loop".

For example, if two circuits are powered from a single supply and the outer screen of an audio connection is connected to the 0V side of both circuits, then current may flow through the screen, inducing hum. If in doubt, disconnect the outer screen at one end of a link, and see if hum is reduced.

## COMPONENTS

### STONE CONTROL

#### Resistors

- R1, R2, R3, R10, R11, R12 10k (6 off)
  - R4, R5, R13 R14 3k3 (4 off)
  - R6, R15 820Ω (2 off)
  - R7, R8, R9 R16, R17, R18 100k (6 off)
- All 0.6W 1% metal film

See  
**SHOP  
TALK**  
Page

#### Potentiometers

- VR1 100k dual-gang (stereo) rotary carbon. lin.
- VR2 470k dual-gang (stereo) rotary carbon. lin.

#### Capacitors

- C1, C7 1μ polyester layer (2 off)
- C2, C8 47n (2 off)
- C3, C9 4n7 disc ceramic (2 off)
- C4, C6, C10, C12 10μ radial elect. 63V (4 off)
- C5, C11, C14 100μ radial elect. 25V (3 off)
- C13 0.1μ disc ceramic

#### Semiconductors

- IC1 NE5532 dual low-noise op.amp

#### Miscellaneous

Printed circuit board available from the *EPE PCB Service*, code 190; 8-pin d.i.l. socket; multi-core screened cable; single-sided solder pins; self-adhesive nylon stand-off pillar, 2 off; solder etc.

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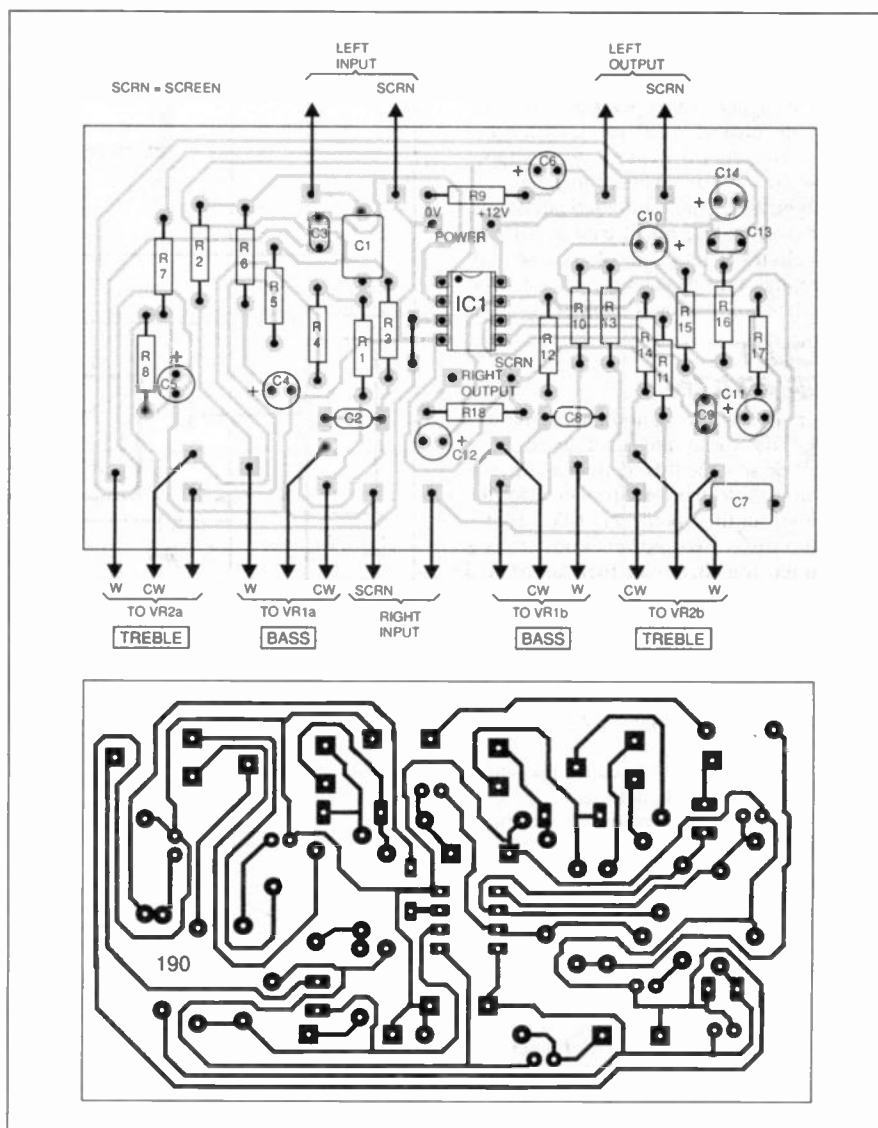
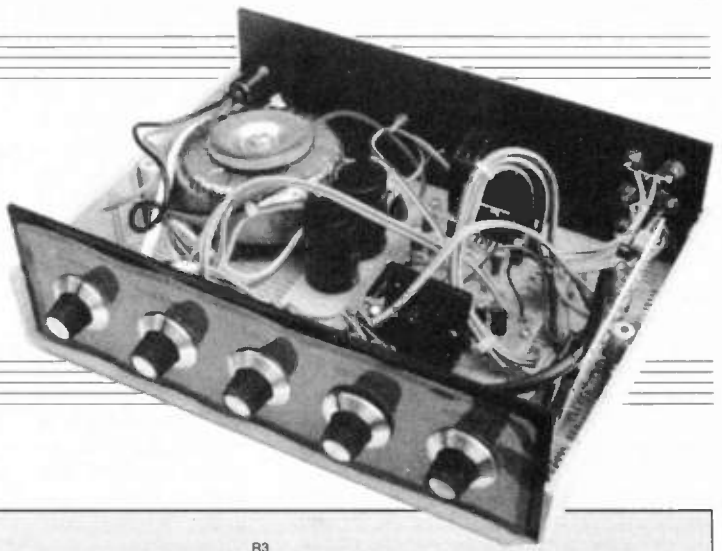


Fig.4. Stereo Tone Control printed circuit board component layout and full size copper master.

# Constructional Project

# 20W STEREO AMPLIFIER

MAX HORSEY



Two-chip, low voltage power amplifier.

**T**HE FIRST point to consider when building an amplifier, is the type of power supply to be employed. If an amplifier is to supply a total of 40 watts (r.m.s.), then the power supply must be capable of delivering more than this.

A normal battery would be exhausted within a few minutes, and the types of power supplies which are built into mains plugs will not deliver the power required. So remember to allow for the size and cost of the power supply before building the amplifier!

The i.c. employed for the 20W Stereo Amplifier is type TDA2004 or TDA2005. This is designed for operation on 12V making the project ideal for use in cars, caravans etc. A car battery will supply sufficient current for several hours.

This type of i.c. will automatically shut-down if overloaded, but it cannot tolerate an open circuit at its output. It is essential, therefore, that the speakers are *always* connected whenever power is applied.

## CIRCUIT OPERATION

The i.c. houses two amplifiers in the one package, and these are configured in a "bridge" arrangement to deliver the maximum voltage into the loudspeaker from the rather low starting point of 12V. Hence for stereo use, two power booster i.c.s are required together with their associated components.

The full circuit diagram for the low voltage 20W Stereo Amplifier is shown in Fig.5, together with a suitable mains power supply. The following description applies to the left-hand channel, the right-hand channel being identical.

The input signal is delivered into potentiometer VR1a, which acts as a Volume control, and then via capacitor C1 into pin 1 of the power amplifier IC1.

The loudspeaker LS1 is driven from the two outputs of IC1 so that if the voltage at the output from one amplifier is high, the other output will be low, and vice versa. This arrangement enables IC1 to deliver up to 20 watts, assuming a speaker impedance of two ohms ( $2\Omega$ ).

Most speakers will have a higher impedance, and the power will be reduced a little. However, the amplifier is capable of quite a "beefy" performance, particularly if efficient speakers are employed. Capacitors C3, C8 and C11 provide local decoupling.

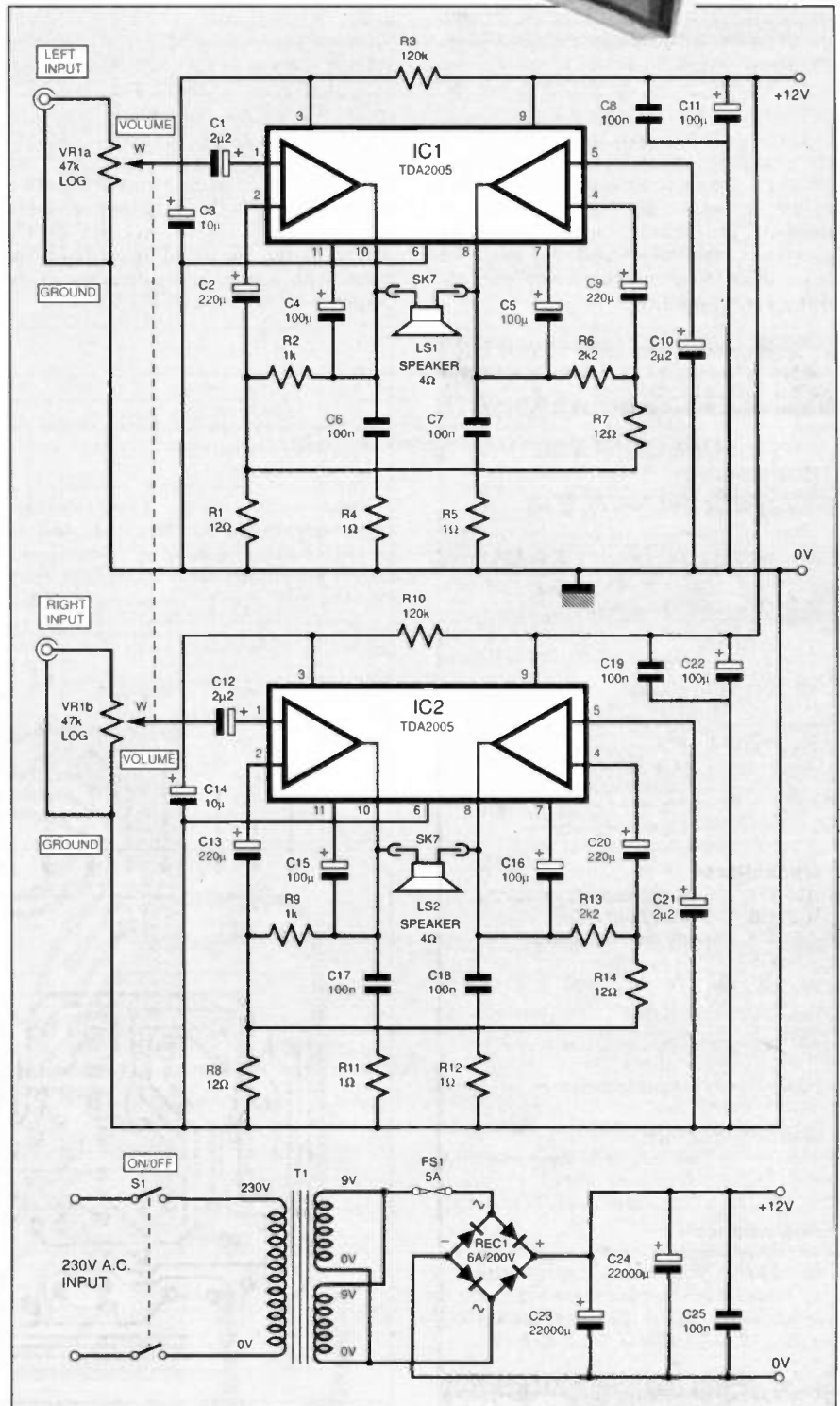


Fig.5. Full circuit diagram and system power supply for the 20W Stereo Amplifier.

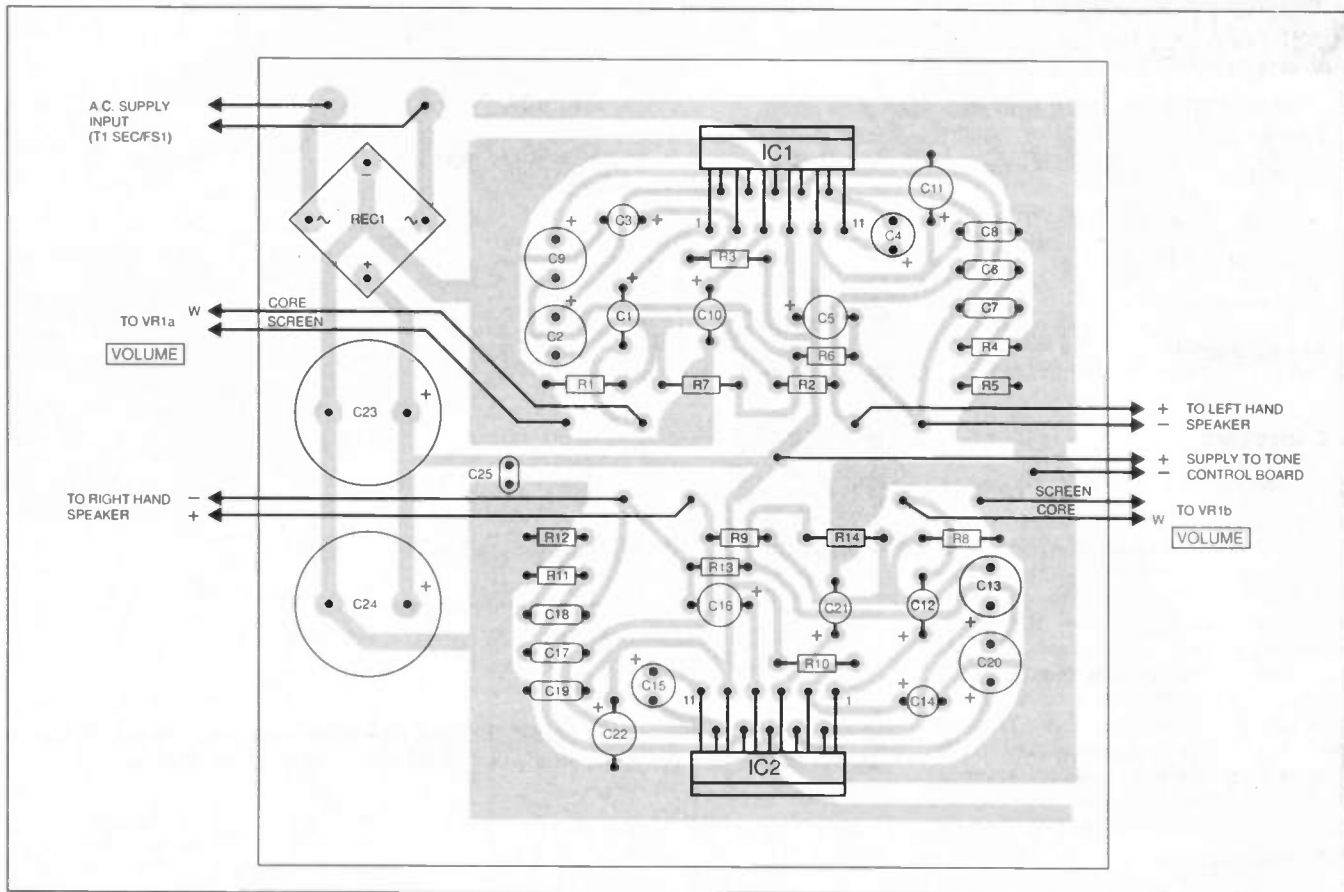


Fig. 6. Printed circuit board component layout for the 20W Stereo Amplifier. The full size underside copper foil master pattern is shown below.

## POWER SUPPLY

The amplifier may be powered directly from a 12V car battery via a suitable fuse, and the i.c.s will tolerate up to 16V which may result from the engine being revved. However, a suitable mains power supply is shown in Fig. 5, and has been included on the p.c.b.

The mains transformer T1 should be chosen to provide an output of 9V a.c. When this a.c. voltage is changed to d.c. by the bridge rectifier REC1, and smoothed by capacitors C23 and C24, the supply will become about 12V d.c.

This apparent increase in voltage will be compensated by an equivalent decrease in the available current. Hence the output current provided by the transformer must be about 1.4 times greater than the current required by the amplifier.

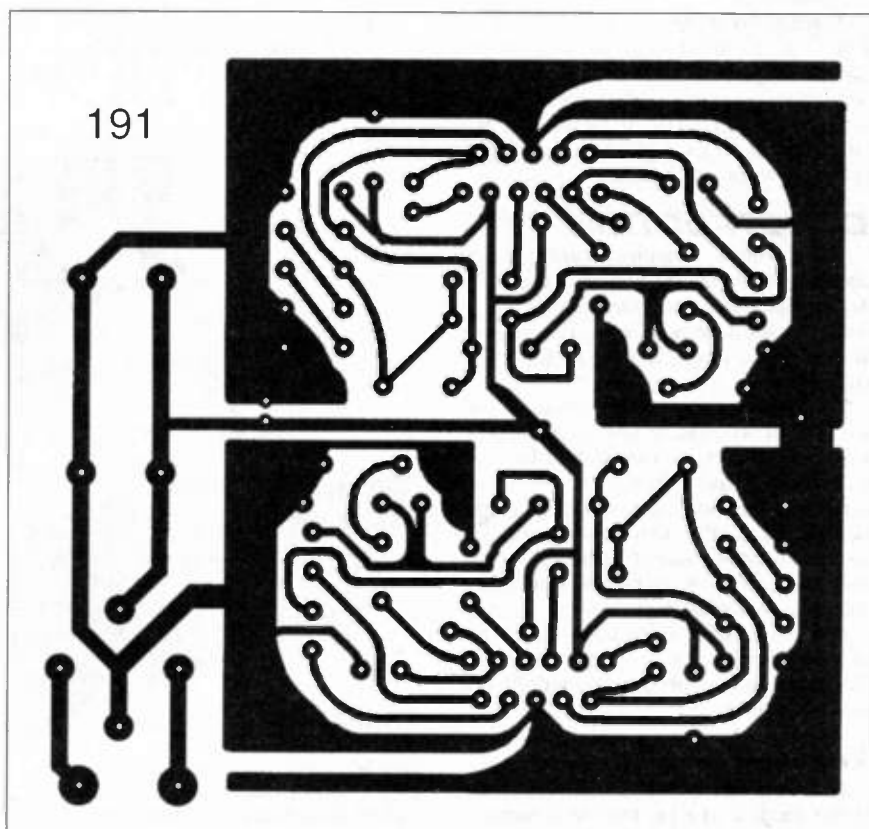
The suggested transformer is a 50VA type with an output of 9V. For example, an inexpensive standard transformer could be employed. The primary coils must be connected in series assuming the UK supply of 230V is employed.

If there are two secondary coils which are both rated at 9V, then they must be connected in parallel as shown in Fig. 7. The parallel arrangement will leave the output at 9V, but will double the current available from a single coil.

A more expensive toroidal transformer may be preferred. These are popular in amplifiers as very little magnetism is radiated, which might otherwise cause interference. In the author's experience the difference is marginal, though a toroidal type was used in the prototype to conform with the current fashion!

Unfortunately, there is no standard colour system regarding the leads, and the supplier's catalogue must be followed with care. If the primary coils are rated at 120V a.c. then they must be connected in series, alternatively the transformer may contain a single 230V/240V winding.

The two 9V secondary windings must be connected in parallel; for example, if the catalogue states that the secondary colours are Red/Yellow, and Blue/Grey, then the red and blue wires must be connected together, and the yellow and grey connected together.





# COMPONENTS

## 20W STEREO AMPLIFIER

### Resistors

R1, R7  
R8, R14 12 $\Omega$  (4 off)  
R2, R9 1k (2 off)  
R3, R10 120k (2 off)  
R4, R5,  
R11, R12 1 $\Omega$  (4 off)  
R6, R13 2k2 (2 off)  
All 0.6W 1% metal film

See  
**SHOP  
TALK**  
Page

### Potentiometer

VR1 47k dual-gang (stereo)  
rotary carbon, log.

### Capacitors

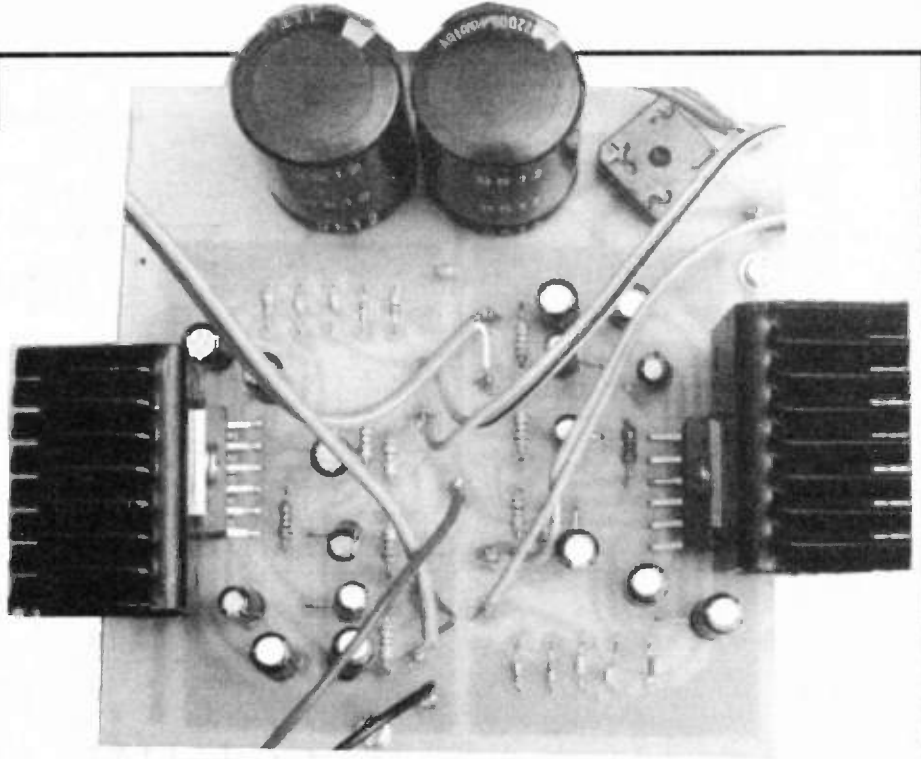
C1, C10,  
C12, C21 2 $\mu$ 2 radial elect. 63V  
(4 off)  
C2, C9,  
C13, C20 220 $\mu$  radial elect. 16V  
(4 off)  
C3, C14 10 $\mu$  radial elect. 63V  
(2 off)  
C4, C5, C11,  
C15, C16,  
C22 100 $\mu$  radial elect. 25V  
(6 off)  
C6 to C8,  
C17 to  
C19 100n disc ceramic  
C23, C24 22,000 $\mu$  radial elect. 16V  
(2 off)  
C25 100n disc ceramic

### Semiconductors

REC1 6A 200V bridge rectifier  
IC1, IC2 TDA2005 or TDA2004  
power amp.

### Miscellaneous

LS1, LS2 4 ohms or more  
loudspeaker (2 off)  
T1 50VA or 60VA, chassis  
mounting or toroidal,  
mains transformer with  
9V secondary windings  
– see text



Completed amplifier circuit board showing the finned heatsinks bolted on the power amp chips. Note, the heatsinks **must not** touch any other component.

S1	d.p.d.t. mains rated rotary switch	SK7	4-way, spring-loaded speaker terminal
S2	3-pole 4-way min. rotary switch (optional input switch – see text)	Printed circuit board available from the <i>EPE PCB Service</i> , code 191; plastic two-piece case, size 257mm x 190mm x 85mm; plastic knob (5 off); finned heatsink (2 off); insulated twin core screened cable; strain-relief grommet; stand-off p.c.b. pillar (2 off); solder pins, solder etc.	
FS1	5A 20mm quick-blow fuse, with panel mounting fuseholder and protective insulating boot		
FS2	3A 25mm mains cartridge fuse to fit mains plug socket, for switched input option (6 off)		
SK1 to SK6	chassis mounting phono socket, for switched input option (6 off)		

**Approx Cost  
Guidance Only**

**£47**

There is no doubt that a toroidal transformer is more difficult to wire than a standard type, and it may be necessary to contact the supplier if in doubt about the colours. It may be wise to check the output voltage with an a.c. voltmeter before connecting it to the amplifier!

## CONSTRUCTION

The printed circuit board (p.c.b.) component layout and full size copper foil master pattern for the 20W Stereo Amplifier are shown in Fig.6. This board is also available from the *EPE PCB Service*, code 191.

Since the operating voltage is quite low, the current required by the circuit will be several amps, and so care should be taken to achieve sound solder joints. The most awkward component is the i.c., and it may be wise to fit this first, so that any extra drilling which may be necessary to allow the i.c. leads to be pushed through the p.c.b. can be undertaken.

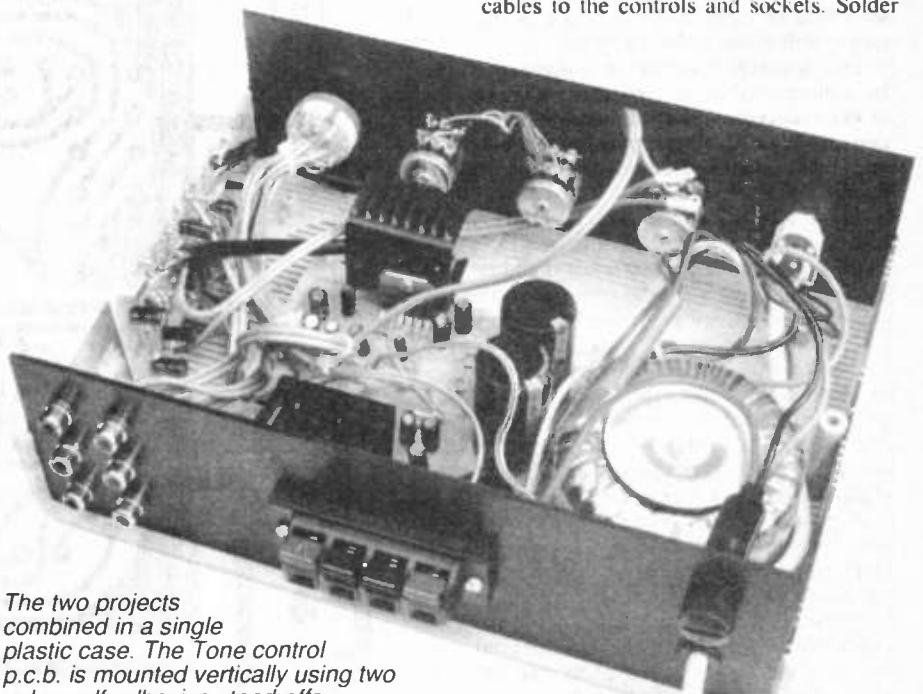
Solder in the resistors as indicated, and fit the capacitors, taking great care that the electrolytic capacitors are inserted the correct way round.

## WIRING

Note that the potentiometer VR1 is a stereo gang type i.e. two pots. mounted

on the same shaft. Ensure that log. types are used, so that the sound level rises at an even rate as the control knob is advanced.

Good quality cables should be employed for the speaker connections and power supply connections, and *screened* audio cable should be used for wiring signal cables to the controls and sockets. Solder



The two projects combined in a single plastic case. The Tone control p.c.b. is mounted vertically using two nylon self-adhesive stand-offs.

terminal pins are strongly recommended for all wire connections to the p.c.b. A full interwiring diagram, including the Tone Control board and optional input selector rotary switch, is given in Fig.8.

The amplifier i.c.s require heatsinks when used at full power. These should be bolted firmly to the metal tabs of the i.c.s ensuring that they do not make contact with anything else. The case should be well ventilated.

## TESTING

Ensure that a speaker is plugged into *each* channel *before* connecting the circuit to a power supply, since this type of amplifier tends to assume a "short circuit" mode if the speaker is disconnected.

Apply a signal to the input (touching the input with your fingers will generally induce some hum, which shows that the amplifier is working).

Failure of the circuit to work will generally be caused by a dry joint i.e. a poor solder joint, or a bridged solder joint. Capacitors not fitted the correct way round, and wrong resistor values may also present a problem.

A common problem when testing the stereo system is to connect a speaker to

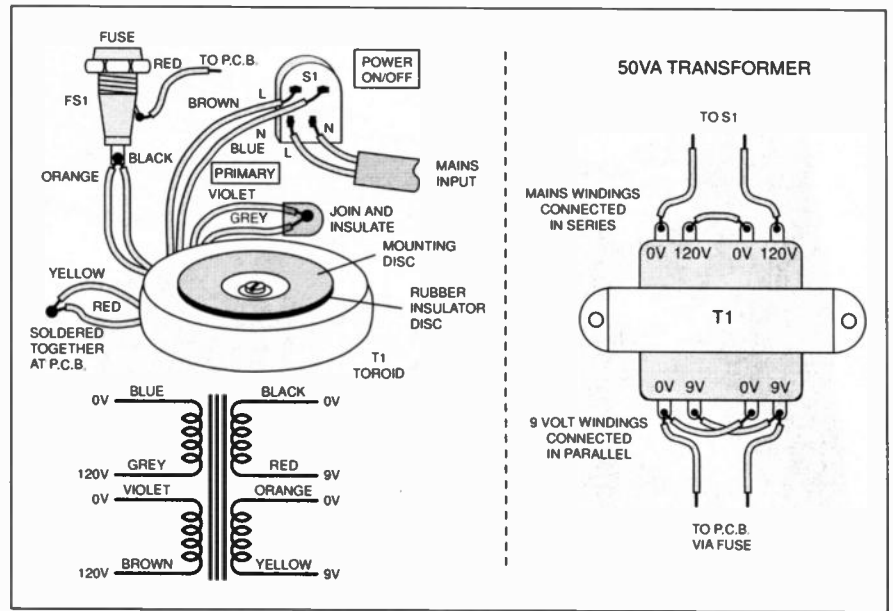


Fig.7. Power supply wiring to the toroidal transformer, used in the model, and "parallel" (sec.) and series (primary) connection details for chassis type.

only one output, leaving the second output open circuit. The second i.c. will then cause a short circuit, pulling down the

power supply voltage, and preventing the first i.c. working! **Speakers must be connected to both outputs.**

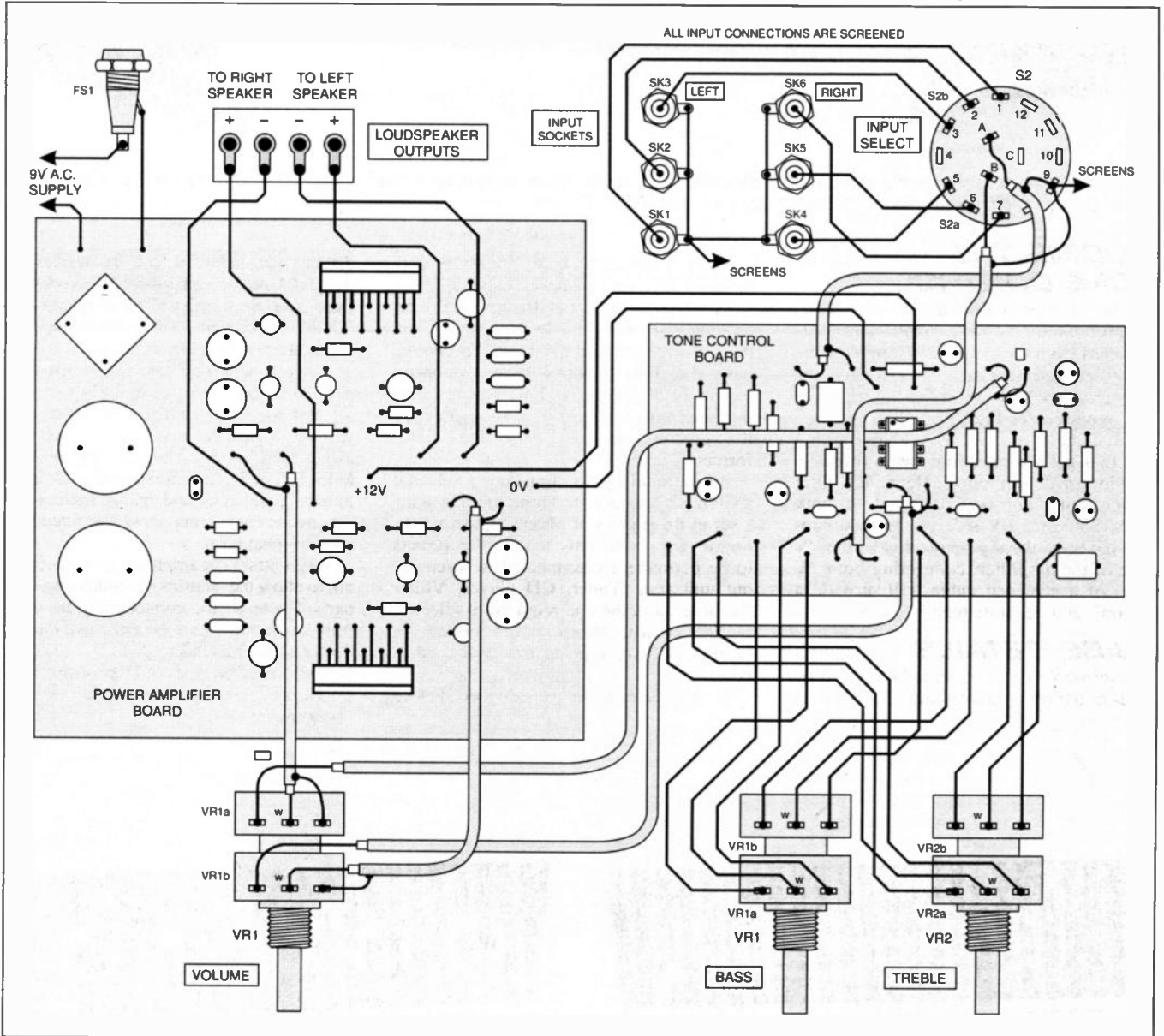
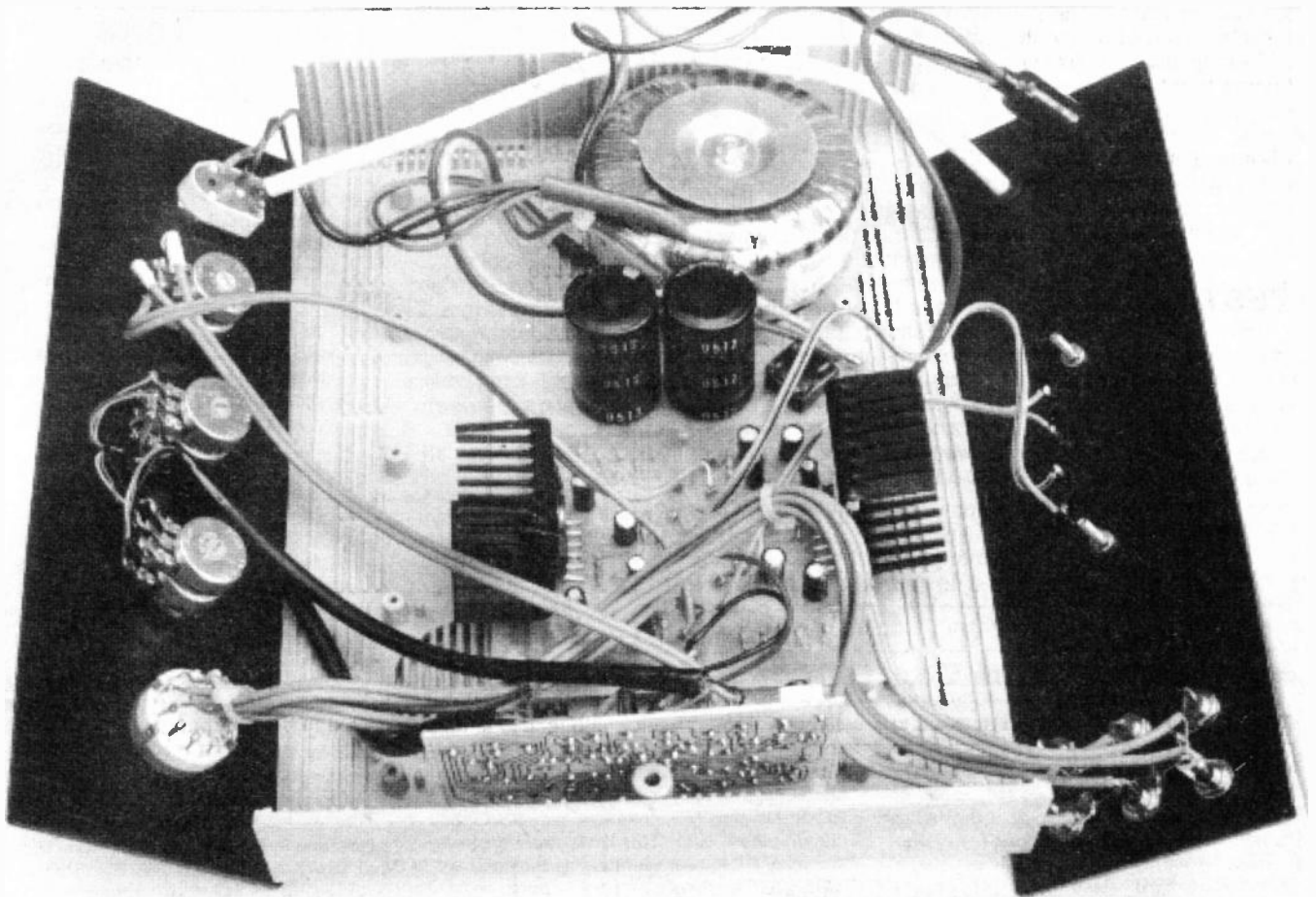


Fig.8. Interwiring details between the amplifier and tone p.c.b.s and off-board components.



Front and rear panels removed from the combined set-up to show component positioning. Note the mains transformer and Tone Control p.c.b. should be kept as far apart as possible.

## ADDING THE TONE CONTROL

The current required by the Tone Control circuit is very small, and it is powered from the same 12V supply as the amplifier. Use screened cable to link the outputs of the tone control to the inputs of the amplifier, see Fig.8.

Note that the screened cables linking the two p.c.b.s must not be allowed to provide an "earth loop". Hence the outer screen must *not* be connected at *both* ends. Since the 0V side of the tone control p.c.b. is already connected to the 0V side of the amplifier, connecting both 0V ends of a screened cable will provide a "loop" and generate hum.

## CASE DETAILS

Internal views of the case layout can be seen in the photographs and the specified

case is almost made to measure and includes a generous supply of ventilation slots. The mains transformer may be mounted at one side, leaving space for the power amplifier p.c.b. in the centre, with the Tone Control board mounted vertically at the right. This ensures that the most sensitive part of the project is at the greatest distance from the transformer.

An optional signal input rotary selector switch S2 connects the tone module with a set of three pairs of phono input sockets on the rear panel. This enables the system to be permanently connected to three input units e.g. Tuner, CD player, Video Recorder, and the one required is selected by the switch. Mains on/off switch S1 is also a rotary type to match the other controls.

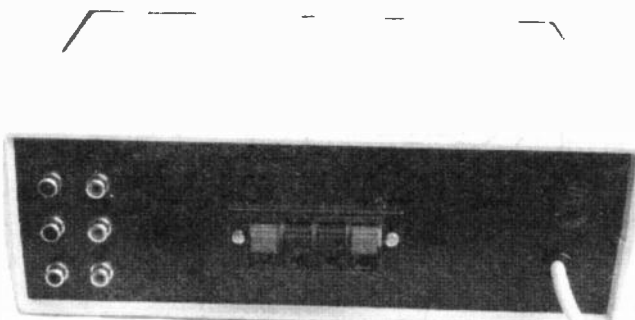
If the front panel is designed before

drilling the holes, it can be used as a template to ensure alignment. The prototype front panel was designed on computer, and printed on coloured card. Book covering material provides a glossy finish.

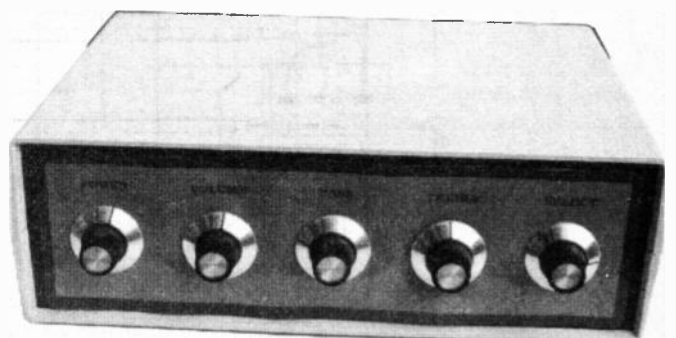
The recommended case allows the front and rear panels to be completely removed, which helps when drilling. The front panel requires a hole for each control including switches S1 and S2. The rear panel requires holes for the input sockets, loudspeaker terminals, fuseholder and mains cable entry. The mains cable entry should be fitted with a strain-relief bush.

When fitting the amplifier p.c.b. take care not to allow the heatsinks to touch *any* other parts. Route all the connecting leads carefully and neatly, again ensuring that they do not touch the heatsinks.

The amplifier should perform well providing loudspeakers are always connected to it.

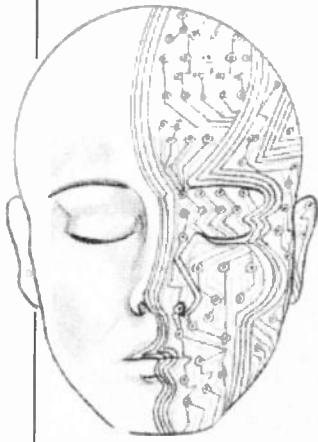


Rear view showing phono input sockets and spring-loaded speaker terminals.



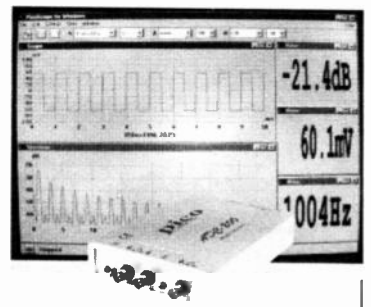
Front panel control layout and operating function lettering.

# INGENUITY UNLIMITED



Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas *must be the reader's own work and not have been submitted for publication elsewhere*. The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

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## Pneumatic Torque Controller - Talk is Cheap

**T**HE purpose of the circuit of Fig. 1 was to produce an electronic shut-off for an air tool within specified torque limits. Commercially built units are available but prices are extremely high whereas the circuit shown can be produced for approximately £20.

Input from a transducer (strain gauge) is taken to IC1 which is a 741 op.amp configured as a differential amplifier with adjustable gain (VR1). As the balanced output from the transducer changes, the signal is amplified and fed through the attenuator formed by R6 and VR2 to IC2. This is a standard LM3914 linear bargraph display which has ten comparators on board that switch at specific voltages, usually used to drive ten l.e.d.s at its output pins when the voltage on pin 5 increases. Two outputs are used to drive D1 and D2.

Potentiometer VR3 determines the current

level for the l.e.d.s and is also used to set the lower limit at which the first l.e.d. lights by varying the voltage reference at pin 4. When the voltage at pin 5 reaches a specified level, D1 lights and TR1 conducts, which triggers the thyristor CSR1. This latches and operates the relay RLA, also illuminating the indicator D3 (green) to signify a "pass" torque.

The normally-closed relay contacts operate a pneumatic solenoid valve coupled to the air tool air supply, turning the tool off at the desired torque. Should the signal level to pin 5 further rise above a specified limit, the l.e.d. on pin 10 lights, and in turn TR2 conducts triggering CSR2. This keeps the relay energised but extinguishes D3, current sinking via D4 and lighting D5 (red) to signify a "fail" or excessive torque.

Capacitor C4 and resistors R12 and R11 form a timing delay of less than one second.

This is required because I found when the air tool shuts off, there is a momentary over-load signal which would trigger the "fail" light even though the torque achieved was within the specified limits. Two push to break switches S1 and S2 act as reset controls by interrupting the thyristors' anode currents.

The air tool control has to be set up on calibration equipment to programme the high and low torque limits. The tool should be powered up to the "fail" torque level and VR2 adjusted until D2 just lights. With this now set, power the air tool until the lowest "pass" torque level is achieved and adjust VR3 until D1 lights. The unit is now ready. At switch on the "fail" light will glow due to C4 charging but can be extinguished by opening S2. On test the unit worked consistently within the pass band, trials being carried out on calibration equipment with torque outputs of 1,000 lbs/ft (69 bars).

**Brian Hiley,**  
Harby, Leicestershire.

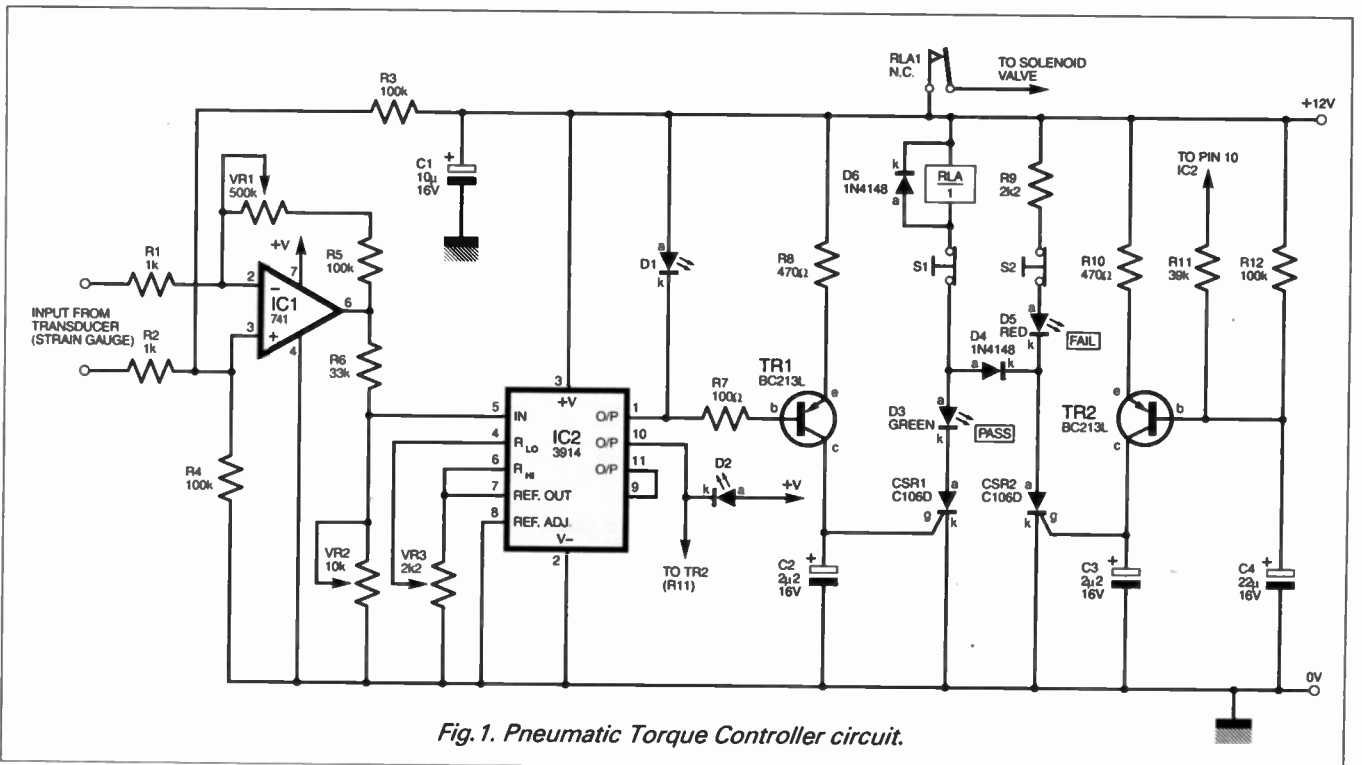


Fig. 1. Pneumatic Torque Controller circuit.

## Simple IR Remote Checker

THE simple circuits of Fig. 2 were conceived when a friend brought a couple of suspect remote control handsets in for repair. Infra-red light, being invisible to the human eye, cannot be readily detected and so this circuit was assembled to provide a simple Go/No-Go display of the remote hand-set's output without the need to resort to using an oscilloscope.

The circuit operates on the principle that the resistance of a light-dependent resistor will fall dramatically when exposed to IR light. In Fig. 2a, a passive solution was provided by using an l.d.r. mounted into one end of a black 3.5mm jack plug cover, and two lengths of hook-up wire were then taken to the inputs of a digital multimeter, set to a high resistance range. With a finger placed over the open end of the plastic housing, a reading of many megohms will be obtained. Aiming the l.d.r. at the infra-red emitter of the controller produced a resistance of about 500k with an intact controller. The l.d.r. used on the prototype was of unknown origin with a dark resistance of over 20megohms and 1kilohm when light.

In the second version of Fig. 2b, a 2N7000 "FETlington" (FET Darlington transistor) is wired as a switch, driving a standard 3mm l.e.d. D1. R1 biases the gate low and keeps the FET switched off until the resistance of the l.d.r. falls on receipt of infra-red pulses, when the l.e.d. will flash in sympathy with the infra-red signal received (if any). It is important to keep any daylight away from the light-dependent resistor, and a 10mm diameter tube can be placed over it to avoid stray light interfering with the circuit operation.

D. Allen,

Cheltenham, Gloucestershire.

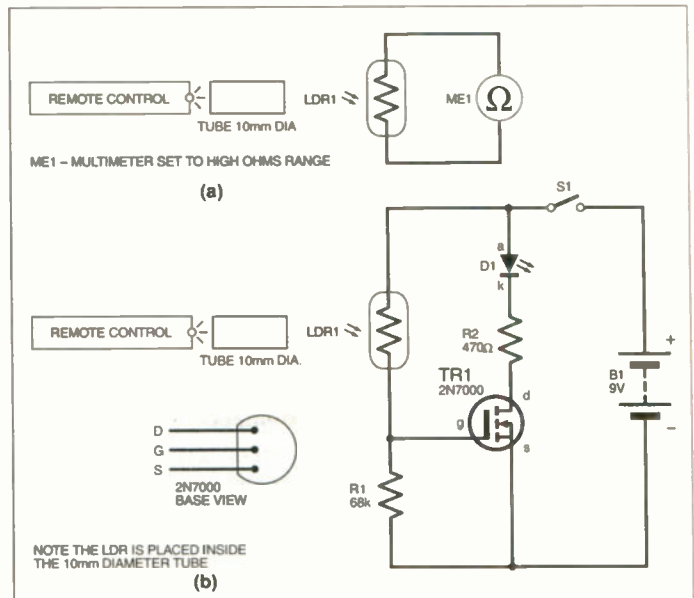


Fig. 2. Simple IR Remote Checker.

### PICO PRIZE WINNERS

It's twelve months since Pico Technology started to sponsor IU and it's time to award some more prizes. The various IUs published over the last six months (Dec '97 to May '98) were judged by Alan Winstanley and Mike Kenward on the following criteria: • Any "lateral thinking" or novelty in resolving a design objective • Technical merit, feasibility and practicality • The resourcefulness and originality of the idea • Appropriate and justifiable use of electronics • General presentation and completeness.

Our thanks to Pico for their on-going sponsorship

**FIRST prize** – a Pico ADC200-50 PC-based Digital Storage Oscilloscope, worth £399 + VAT

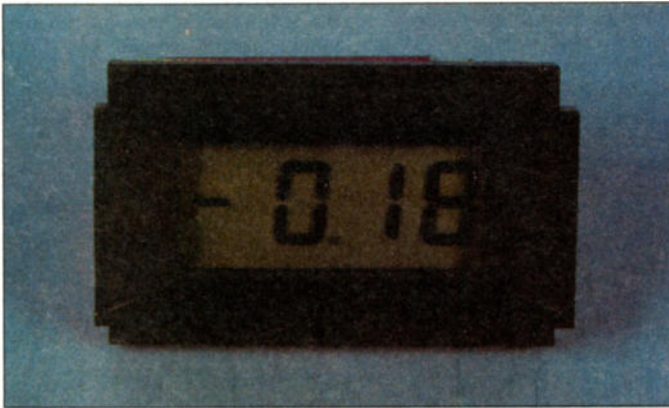
**Dec. 97** – Mechanical Vibration Sensor – D. Stringwell – an excellent example of ingenuity, designed to monitor the mechanical vibration in electric motors.

**RUNNERS-UP** – Pico ADC-40 single channel PC oscilloscopes worth £59 + VAT

**Apr. 98** – Traffic Light Simulator – Thomas and Nick Walton – A good example of how Boolean algebra helped out with a logic design problem.

**May 98** – Pneumatic Torque Controller – Brian Hiley – the ingenious use of electronics to control a mechanical application, with a substantial cost saving.

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## An Introduction to DIGITAL ELECTRONICS

Ian Bell, Rob Miles, Dr. Tony Wilkinson, Alan Winstanley

**T**EACH-IN is a series designed to support candidates following City and Guilds (C&G) 726 Information Technology, with reference to the following specific syllabuses: \*7261/301 Introductory Digital Electronics, \*726/321 Elementary Digital Electronics, \*726/341 Intermediate Digital Electronics.

Even if you are not undertaking the City and Guilds syllabus, there is much to be learned from *Teach-In*.

### Lab Work

Throughout *Teach-In*, attempts are made to involve the student with practical "Lab Work" experiments and demonstrations, and complex mathematics will be avoided unless really necessary – and even then, plenty of help is to hand! We make a point of identifying practical components in special sections of *Teach-In*, so that you will learn to recognise parts.

### Part Seven: MORE ON FLIP-FLOPS

**F**OLLOWING on from Part 6, we continue our look at flip-flops and progress to storing and moving bytes and words around rather than bits of data. We also look at the clock signals which provide the "heartbeat" of many digital systems.

#### Flip-Flops Re-visited

A flip-flop is a circuit which can be placed in one of two states (we could call them *flip* or *flop*). When you "trigger" the flip-flop it decides which state to move into based on one or more inputs.

The flip-flop is the basis of very many digital components. In Part 6 we looked at two different types of flip-flop, the Data Latch and the SR (Set Reset) flip-flop.

A data latch stores the status of a single bit. We have considered two flavours of latch, *transparent* or *edge triggered*. Both types have a "clock" input which is used to "enable" the latch. By *enable* we mean "the input is now important, so I want you to make a note of it".

One form is called transparent because it will pass through the state of the data input when it is enabled (i.e. if the input changes when the latch is enabled, the output will change instantly to reflect this – it then holds the input prevailing when the enable is removed).

#### On Edge

Sometimes we do not want a latch to be transparent, but instead to read the incoming data at a particular instant, which is where the edge triggered latch comes in. It will "sample" the state of the incoming data when the clock makes a transition from one state to another. Once the latch has been triggered in this way, the input signal can do what it likes, but the output will remain at the setting the latch "saw" when the trigger took place.

The Set Reset flip-flop does not use a clock to tell it when to store the data. Instead it has two data inputs, one of which sets the state of the flip-flop to high (Set),

the other to low (Reset). It does not therefore sample an input to decide which state to occupy, but instead is told by the application of the "set" level on one of the two inputs. (If both inputs are set we have a problem, and the state of the flip-flop may become indeterminate.)

There are many other kinds of flip-flops in use in digital circuits, for example there are versions of SR flip-flops which are clock controlled (more of this later). The art of digital design involves using flip-flops and combinational logic as building blocks which are used to construct our larger circuits.

As we go through the design process we are making life easier for ourselves. First we thought about individual switches, or transistors. Next we moved up to combine these into logic gates (the OR, AND and NOT for example).

Now we have combined the logic gates to take components into the next level up. Later we will look at how flip-flops are used, and combined to make even higher level "building blocks" such as counters and shift registers.

the output will stay 0 even if we try to load a data 1 with the clock.

#### Synchronous Circuits

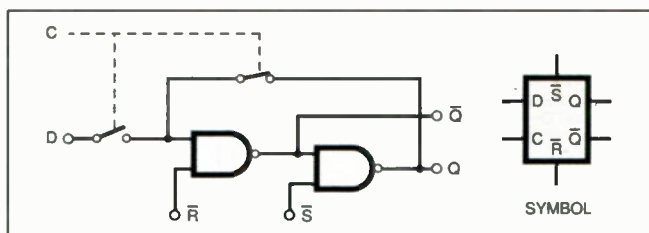
We describe the way that the set and reset act immediately without reference to the clock by saying the circuit is *asynchronous* in operation. The term asynchronous, when applied to digital circuits in general, means that not all changes take place under the direct control of the clock.

Circuits in which all flip-flops are clocked from a single clock signal are *synchronous*. As an analogy, consider a regiment of soldiers. If all the soldiers are simply walking together, their actions are asynchronous. If we add a drill sergeant who is barking "left right" (clock inputs), the soldiers can be made to march in a synchronised fashion.

#### Synchronous and Asynchronous Resets

We know that when you apply power to a circuit you do not know the state of each of the components in it. This

Fig. 7.1. D-type latch with Set and Reset.



#### Combination Flip-Flop

We can combine the "switch" and "gate" approaches we discussed for getting data into our "storage loop" in Part 6. This is shown in Fig. 7.1.

Data on the D input is stored when the clock changes from its transparent to store state as before. The set ( $\bar{S}$ ) and reset ( $\bar{R}$ ) inputs act immediately and take precedence over the data/clock. Thus, if we are holding the reset "on" (i.e. low)

means that you must apply a signal right at the start which forces everything into the reset state.

This signal is used once at power up, before the system starts to respond to clock pulses. We have already talked about Power On Resets, and how they are created. This reset signal does not have to be synchronised to the clock, and so is called an *asynchronous* reset.

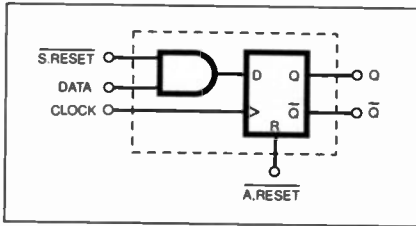
Once the circuit is in normal operation,

with clock pulses controlling when things happen, it is completely synchronous. We can therefore talk about synchronous circuits which have asynchronous reset signals.

Sometimes you will want to use a reset signal to set some components back to their reset position during normal synchronous, clock controlled, operation. This synchronous reset could occur at the beginning of a particular transaction.

To do this you would need to devise a flip-flop with a synchronous reset input. Fig.7.2 shows a D-type flip-flop (with an asynchronous reset) and an AND gate used to derive the synchronous reset. Both resets are active low.

If  $\overline{SRESET}$  in Fig.7.2 is low the flip-flop will load 0 when it is clocked whatever the state of the data. Whenever we want to reset the flip-flop we trigger the Clock with the  $\overline{SRESET}$  held low. This is a synchronous reset action. The original D flip-flops asynchronous reset (labelled  $\overline{ARESET}$ ) will reset the flip-flop irrespective of the signals on Clock, Data and  $\overline{SRESET}$  terminals.



A timing diagram for the flip-flop in circuit Fig.7.2 is shown in Fig.7.3. This illustrates the difference between synchronous and asynchronous operation. Note that the signal connected to the Data input is represented as a series of "boxes" in Fig.7.3. Each box could be either 1 or 0.

What the diagram is showing is that the system will work on an arbitrary stream of data. Each box is labelled with a name so that we can track the movement of particular bits of data on the timing diagram.

The Clock changes state between 0 and 1 in a regular way. When the clock changes from 0 to 1 this is called a *positive* edge. A change from 1 to 0 is described as a *negative* edge.

In Fig.7.3 the positive edge of the clock signal occurs in the middle of the data box

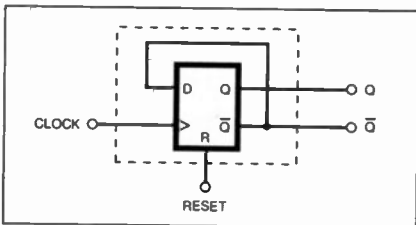


Fig.7.4. Toggle flip-flop.

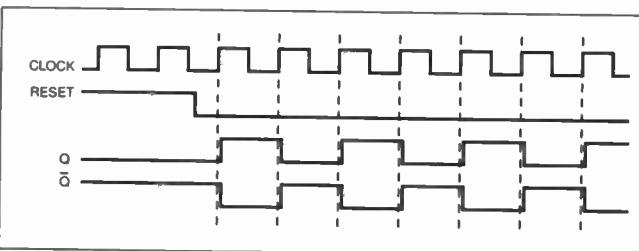


Fig.7.5. Toggle flip-flop timing diagram.

and the negative edge coincides with the data changes. This is an arbitrary choice but represents realistic signals for this type of circuit. If the data was changing at the same time as the positive (*active*) clock edge we would be in trouble as the flip-flops would probably not work properly due to timing problems.

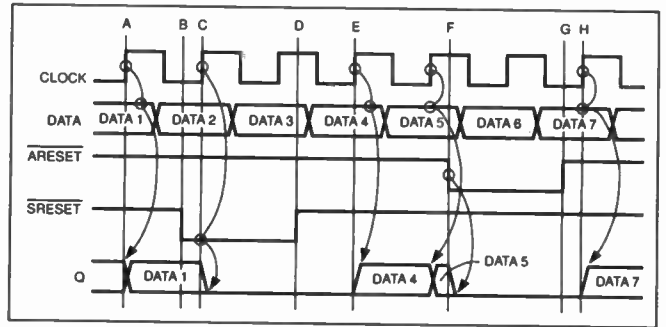
Lines and arrows are used to show the relationships between different parts of the timing diagram. Now we have set the scene for the timing diagram we can look at the operation of the circuit, depicted in Fig.7.2.

When neither reset is applied data is transferred to Q on the positive edges of the clock. For example, at time A on the diagram (Fig.7.3).

When  $\overline{SRESET}$  goes low, there is no immediate effect (time B) but on the next positive clock edge Q is reset (time C). When  $\overline{SRESET}$  returns high, again there is no immediate effect (time D) but on the next positive clock edge the current data is loaded (Data 4 at time E).

Fig.7.2 (left). D-type flip-flop with asynchronous and synchronous reset.

Fig.7.3 (right). Timing diagram for Fig.7.2 showing synchronous and asynchronous operation.



When  $\overline{ARESET}$  goes low, Q immediately (i.e. after a short propagation delay) goes low (time F). When  $\overline{ARESET}$  returns high (time G) data is loaded at the next positive clock edge (time H).

### Toggleing

Now consider Fig.7.4. What do you think happens when we clock the flip-flop? (By "clock" the flip-flop in this case we mean apply a positive edge to it). The answer is that it loads  $\overline{Q}$  - the *opposite* value to that which is currently stored. This is described as *toggleing*.

The timing diagram for Fig.7.4 is given in Fig.7.5. Notice that when the flip-flop

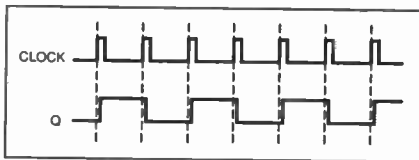


Fig.7.6. Toggle flip-flop output with short pulse clock.

is not being reset the output is a square wave at half the clock frequency. The output square wave will always be *symmetrical* (what we mean is that the signal will be at 0 for the same duration as it is at 1).

This is sometimes called having an "even mark-space ratio". We get the even mark-space ratio even if the clock is a series of short pulses (assuming the pulses are long enough to trigger the flip-flop). This is shown in Fig.7.6.

By connecting a number of these circuits together we can divide a high incoming frequency into a series of lower ones. Fig.7.7 shows a 3-stage circuit and Fig.7.8 its timing diagram. This trick is often used to get a low frequency timing signal from a high frequency clock.

The toggle function is obviously useful but sometimes we may want to control whether or not a flip-flop toggles at any given time. We could do this by switching off the clock, but this may not be straightforward or convenient.

An alternative is to provide a "hold" mode of operation in addition to the toggle mode. In hold mode the flip-flop loads its Q value rather than  $\overline{Q}$  so the output remains unchanged. A suitable circuit is shown in Fig.7.9. The toggle/hold control determines which action the flip-flop performs when the clock edge occurs. You might recognise the combinatorial circuit in Fig.7.9 as a 2 line to 1 line multiplexor (see Part 5). Fig.7.10 is the timing diagram for this circuit.

When toggle/hold is high the flip-flop changes state on each positive clock edge in the same manner as Fig.7.5. When toggle/hold is low the flip-flop's output does not change.

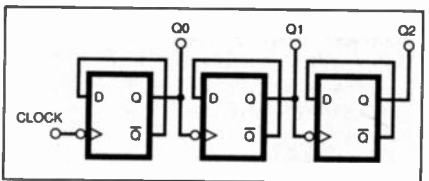


Fig.7.7. A simple 3-stage frequency divider set-up using toggle flip-flop.

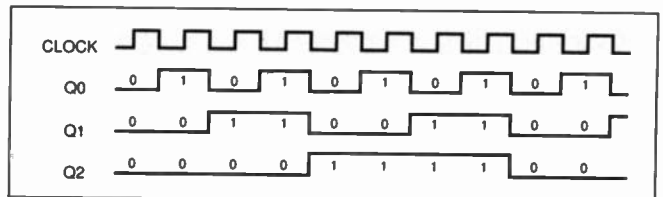


Fig.7.8. Simplified timing diagram for Fig.7.7.



## Counting and Bit Patterns

A careful study of the waveforms in Fig.7.8 will reveal that the circuit in Fig.7.7 also acts as a binary counter. If you look at the binary numbers represented by the patterns on lines Q0 to Q2 you will see the values counting up.

We will return to counter circuits later, meanwhile you may like to work out what happens if positive rather than negative edge triggered flip-flops are used in Fig.7.7. The timing diagram in Fig.7.8 has been simplified by excluding the propagation delays of the flip-flops. You may also wish to ponder what effect these have, we will return to this later.

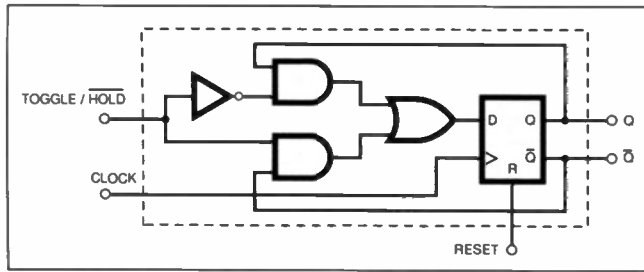


Fig.7.9. Circuit arrangement to produce a Toggle/Hold flip-flop.

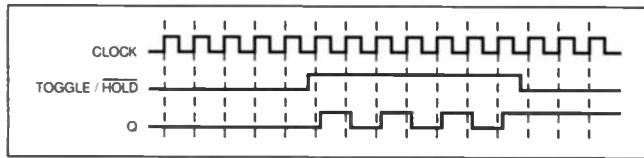


Fig.7.10. Timing diagram for the Toggle/Hold flip-flop.

## JK Flip-Flop

We have now encountered four clock-controlled flip-flop actions in addition to the basic loading of data. These are *hold*, *reset*, *set* and *toggle*.

The JK Flip-Flop provides a choice of the four actions by means of just two control inputs called J and K. The JK flip-flop symbol and a table summarising its operation are given in Fig. 7.11 and Table 7.1.

The JK flip-flop can also be configured for toggle/hold by making  $J=K$ , or for data loading applications by making  $J=\bar{K}$ . These circuits are shown in Fig. 7.12 and 7.13. You can confirm their operation by using Table 7.1.

A JK flip-flop built from a D-type flip-flop is shown in Fig.7.14. Have a go at designing the combinatorial logic for yourself. Start by writing out a Truth Table with J, K and CLOCK as the inputs, and the "next Q" ( $Q+$ ) as the output. Use a K-map to obtain the Boolean function. You should get:

$$Q+ = \bar{K}Q + J\bar{Q}$$

JK flip-flops are not necessarily built from D-types as shown in Fig.7.14. The classic JK flip-flop embeds the JK logic directly in a flip-flop similar to a two stage version of Fig.6.12 in Part 6. This circuit is shown in Fig.7.15 and is called a JK "master-slave" flip-flop. The first flip-flop is the master and the second the slave.

## Clocks and Computer Chips

A vital component in many digital systems is the clock generator, often this is provided by a very stable crystal

## TRI-STATE CALLOUT

The octal D-type latch 74HCT574 i.c., for example, has "Tri-State" outputs which allow the numerous signal sources to be connected to the same wire and yet still communicate.

It is worth considering how this is achieved. Fig.7.16 shows the circuit within the latch itself, with the output enable (OE) signal being used to cause the buffer to pass the signal at A onto the output Y.

The circuit shown in Fig.7.17 shows a wire being used to provide two paths of communication. In order for information to be passed

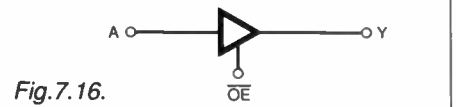


Fig.7.16.

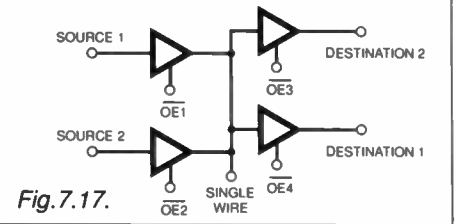


Fig.7.17.

between Source 1 and Destination 1,  $\overline{OE1}$  and  $\overline{OE4}$  must be activated at the same time. Similarly, to transfer information between Source 2 and Destination 2, OE2 and OE3 must be activated.

By activating different enable signals we can route the information between the appropriate Source and Destination. The only combination which is forbidden is the activation of OE1 and OE2. The activation of *both* source output enables at the *same time* causes the corruption of data and in the worst case the destruction of both output buffers due to uncontrolled current flow between them.

When no source output enables are enabled the wire is said to be in the *high impedance* state. This is the *third* state of our wire – high, low, or not driven at all.

There are no output transistors pulling the wire to either logic 0 or 1 and its voltage level is open to the influence of external electrical noise or interference. Wires that can potentially enter this state are generally "connected" to 5V or ground using resistors of around 10 kilohms to force them into a known stable state when not being driven.

oscillator. We even go as far as to use the rate at which the clock changes state to describe the speed of the computer. The unit of frequency is the *Hertz (Hz)* and a 200 Megahertz Pentium processor is so named because the main clock performs 200 million cycles in a second.

The faster the signal is switched on and

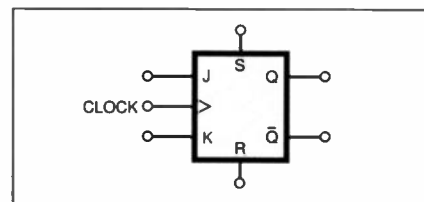


Fig.7.11. Symbol for positive edge triggered JK flip-flop with asynchronous Set and Reset.

Table 7.1: JK flip-flop behaviour.

J	K	VALUE OF Q AFTER CLOCK	ACTION PERFORMED
0	0	PREVIOUS Q	HOLD
0	1	0	RESET
1	0	1	SET
1	1	PREVIOUS $\bar{Q}$	TOGGLE

Fig.7.15. Schematic diagram for the classic JK "master-slave" flip-flop.

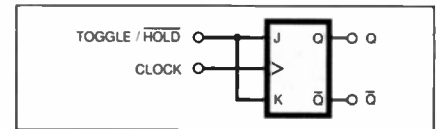
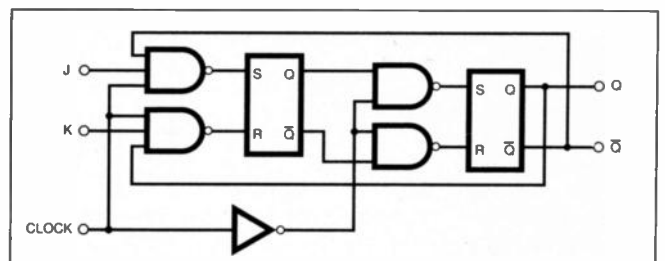


Fig.7.12. JK flip-flop used as a Toggle/Hold flip-flop.

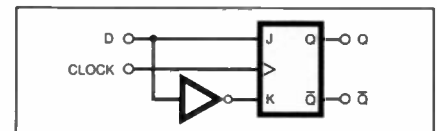


Fig.7.13. JK flip-flop used as a D-type flip-flop

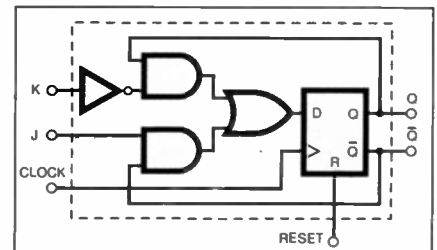


Fig.7.14. JK flip-flop built from a D-type.

off, the greater the power consumed by the circuit which is performing the switching. For this reason some complex digital chips, particularly those in portable computers, are able to "wind down" to a lower speed (or even stop the clock completely) when there is nothing for them to do.

An event such as a touch on a key is then used to "wake up" the clock signal and return to maximum speed to process the incoming data. Once the character has been displayed on the screen the computer can "go back to sleep" again.

### Complicated Clocks

We have shown a number of circuits with a clock signal and indeed most digital circuits have a clock. In its most basic form the clock is simply a continuous sequence of 1s and 0s, evenly spaced as in Fig.7.18a.

The Time duration of the repeated part of the waveform (called the *clock cycle*) is the *clock period*, this is labelled  $T$  in Fig.7.18a. The *frequency* ( $f$ ) of the clock is one divided by the period, i.e.  $f=1/T$ . So, a clock with period 5ns (five nano seconds) has a frequency of 200MHz (two hundred megahertz).

If the 1s and 0s are equal in length, the clock is described as having a *50 percent mark-space ratio*. The mark-space ratio need not be even, as in the waveform in Fig.7.18b, where the "mark" and "space" are labelled  $m$  and  $s$ .

This has the same period (and therefore the same frequency) as the waveform in Fig.7.18a but it has a different mark-space ratio. The mark-space ratio can be expressed in terms of the percentage of  $T$  which each part takes up, for example "a 60/40 mark-space ratio".

### Phase Relationship

It is possible for more than one signal to be required to clock a system, and in such cases it may be necessary to be able to describe the relationship between two or more clock waveforms. If we assume that the waveforms have the same frequency, then it is their *phase* relationship which we must define.

Phase is simply a way of expressing when a signal starts. Two signals can have exactly the same frequency but different phase, in that they do not track each other exactly because their cycles start at different instants.

We can divide the period of a waveform into 360 degrees, just as we divide a circle (note repeated waveforms are referred to as *cyclic*). Fig.7.19 shows four waveforms, W, X, Y and Z.

Here W and X are *in-phase* because their cycles start and finish at the same time. Waveform Y is said to have a 90 degree *phase shift* with respect to W and X because its cycle starts 90 degrees (a quarter cycle) later - it does not line up exactly with W and X. Because Y starts 90 degrees later than W and X, Y can be said to *lag* W and X by 90 degrees.

Waveform Z is in *antiphase* to waveform Y - it has 180 degrees phase shift. We can say Z lags W and X by 270 degrees, but since phase measurements are relative we could also say that Z *leads* W and X by 90 degrees.

Clocks with more than one signal are often referred to as *multi-phase* because these signals have the same frequency, and it is their phase relationships which are important.

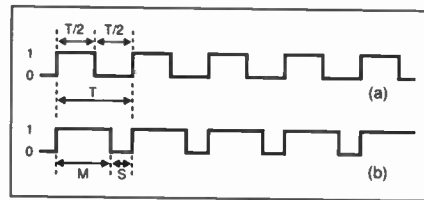


Fig.7.18. Clock period Mark/Space ratio.

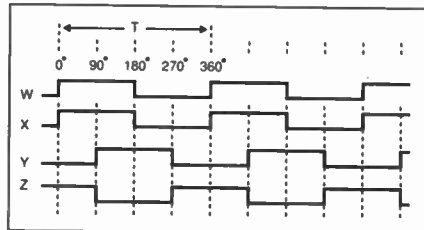


Fig.7.19. Clock phase relationship.

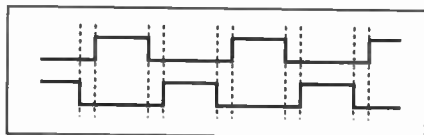


Fig.7.20. Two-phase non-overlapping clock.

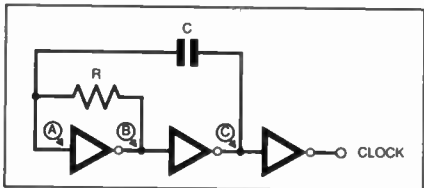


Fig.7.21. A simple clock generator.

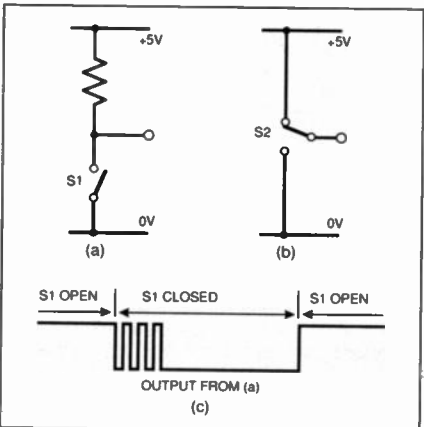


Fig.7.22. "Bouncing" switches which are not suitable for clocks.

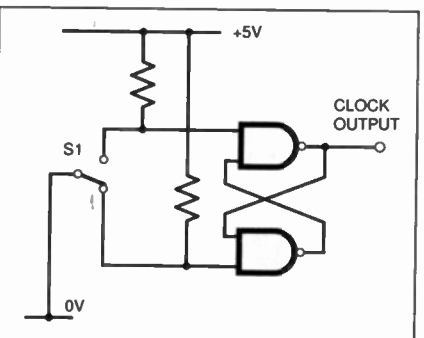


Fig.7.23. Manual clock debounce circuit diagram.

With antiphase signals such as Y and Z in Fig.7.19, and other situations where two clocks change "at the same time" we have to be careful about specifying their exact behaviour. In a real circuit two signals are unlikely to change at exactly the same time due to variation in propagation delays in different parts of the circuit.

We may need to check if it is important that the two signals must both be high together (*overlapping*) or if they must never be high together (*non-overlapping*). Fig.7.20 shows a two phase non-overlapping clock. This is two antiphase clocks which are never high at the same time. Careful design of the timing properties of complex clock signals can ensure that such conditions are met.

Within the processor chip we may have many signals which are based on the clock but have different phases, for example the signal which switches the memory chip on must appear slightly *before* the signal which latches the data from the chip. All these signals may have the same frequency; the rate at which the data is fetched and processed, but they will have different phases so that certain functions can be made to happen in the correct order.

### Clock Generators

To build a complete system with a clock you need a *Clock Generator*. These are quite often left out of schematics, but there are plenty of circuits you can use. A simple one is given in Fig.7.21 in which the frequency of the clock is determined by the values of R and C.

The circuit in Fig.7.21 operates as follows. We start with point C low.

1. If point C is low then point B must be high (because there is an inverter between points B and C). There will therefore be a voltage difference between C and B, which will charge up the capacitor C, through resistor R.

2. When the voltage at A reaches the logic threshold of the gate it will switch sending point B low and point C high.

3. Capacitor C will now discharge through resistor R until the voltage at point A crosses the logic threshold again and the current switches back to the starting point.

This switching process will occur indefinitely whilst power is supplied and is called *oscillation* (the circuit is an *oscillator*).

The circuit in Fig.7.21 depends on the values of resistor R and capacitor C to determine the frequency. The characteristics of the gates and the supply voltages also influence the clock speed. For a more accurate, highly stable clock frequency a crystal oscillator is used.

There are a few applications which require a manual clock, i.e. a clock which is generated by someone pressing a switch. This sounds straightforward enough - just connect the switch to the clock input, with a pull-up or pull-down resistor as required.

Unfortunately, this does not work because switches "bounce" so you get more than one pulse per switch press, and worse than that an unpredictable and variable number of them (see Fig.7.22). Fortunately, the RS flip-flop comes to the rescue.

# Check Out: Cables and Connectors

A glance through any electronics catalogue will reveal a bewildering array of wires and cables available. Let's start with basic interconnecting or "hook-up" wire: insulated wire may either be single core or multi-stranded. The latter is generally used for most types of wiring which is subject to bending or vibration. Solid core might be used in telecommunications (e.g. in telephone wiring) or where rigid looms of wires are to be produced. Multi-core cables contain several insulated copper cores, all bound into one cable which can therefore carry several signals at once.

The number of cores, plus their cross-sectional area (and prevailing temperature), determines the maximum current the cable can safely carry. The larger the CSA, then the lower the resistance of the wire, so the higher its current-carrying capacity will be.

Mains wire has extra insulation, though its current-carrying capacity is also determined by the surrounding temperature (which is why mains wire buried in a wall can carry less current than a similar one mounted on the surface).

For carrying, say, audio frequency (AF) or radio frequency (RF) transmissions, the cable is specially designed not to impede or degrade the signal at the likely frequency of operation, because the cable's capacitance can seriously affect the signal passing through. Co-axial cable is used, and it is imperative that the cable is screened to help prevent outside electrical and electromagnetic interference (e.g. from a high voltage source, or from the magnetic field surrounding a transformer) from impinging on the signals. The screen is formed of a surrounding copper braid of which ordinary TV antenna wire is a good example, and co-axial connectors are used which don't degrade the signal unduly.

## Making Clear Signals

If you have several signal connections to make along the same route, then instead of using individual wires, ribbon cable may be used. These are very common in personal computers, printers and digital equipment where they are used to carry data. Colourful ribbon cables may be terminated with multi-way soldered connectors such as the "D" type plug, or an insulation displacement connector (IDC) to match a receptacle on the printed circuit board.

These slice through the insulation to make contact with the wire strands carried within, and consequently IDCs require no soldering. They are usually very reliable but are best made with special tools which force the IDC components together, correctly aligned with the ribbon cable (see photos). One downside is that the signals they carry are susceptible to noise – caused by electrical interference generated by other parts of the equipment nearby.

For more specialist applications involving high speed data transfer over long distances, twisted pair cable will be used. Internally, the conductors resembles the double helix of a DNA molecule: the result of spiralling two conductors together is that it introduces a noise-cancelling capacitive effect with each complete turn of the wires. This cleverly filters out any noise introduced along the way.

## Make the Right Connection

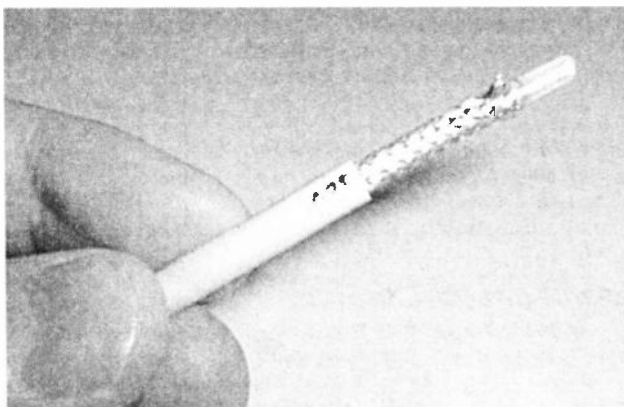
Let's take a brief look at some of the connectors associated with these cables. As a manufacturer or technician, which one is suitable for your application may depend not only on technical compatibility issues but also commercial ones – cost price (including bulk discounts and credit terms), availability and lead time (how long it will take for the parts to be delivered once you place an order). Even if you don't use all these connectors, at least you will now have heard of them. Manufacturers' and distributors' catalogues are a good place to find out more.

- Multi-pole connectors are manufactured in bucket-loads of different styles, for terminating (screened) multi-core or mains cables. The styles don't all fit each other.

- Co-axial connectors are associated with signal transmissions, e.g. TV aerial, video or satellite. A "phono" (RCA) connector is an unsophisticated co-axial connector seen in audio and video equipment. The "F" type co-axial connector is seen on domestic satellite receiver systems.

- BNC (a "bayonet" action connector, named after its American designers Neill and Concellman in the 1940s) is used with co-axial leads (e.g. oscilloscope test leads), having a co-axial cable connection plus the twist and lock security of a bayonet action. Also, TNC (Threaded Neill Concellman) a screw-on version.

- DIN connectors are associated with the audio sector, for stereo, audio, microphone and loudspeaker connections. They are a multi-pin standard which offers scope for incompatibility problems.



*Ethernet screened (coaxial) cable, showing braided screen.*

- Jack connectors include the famous 3.5mm plug, as seen on audio headphones, e.g. for a portable stereo. 2.5mm diameter and 6.35mm (1/4") are common, too.

- "D" connectors are universally seen in the computer industry (on PC cards or output ports, for example), but also on test and measurement equipment having a data output. They have 9, 15, 25, 37 or 50 pins. Some expertise and a steady hand is needed to solder them!

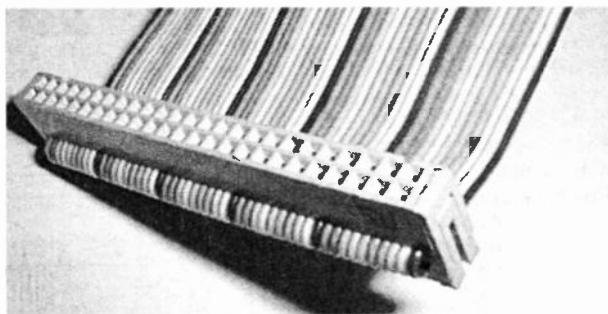
- Edge-connectors enable smaller circuit boards ("daughter boards") to be inserted into a larger "motherboard", with conductors on the daughter board being brought right to the edge, where they make contact with the edge connector. Thus, circuit boards can be connected together without the use of ribbon cables.

- PCB headers are soldered directly to printed circuit boards, and act as "plugs" which receive ribbon cable "sockets". They contain anything from 10 pins to 60 pins. Manufacturers each have their own style which may not be interchangeable with other brands of component.

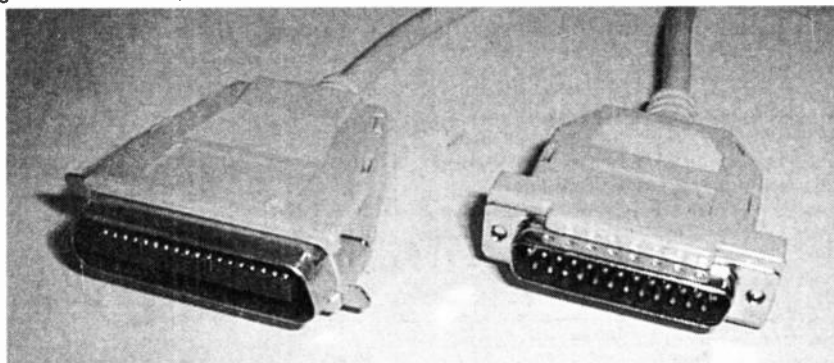
- DIL headers (dual-in-line) use the style of a dual-in-line integrated-circuit to produce a multi-way connector.

- IEEE 488 are also known as "Centronics-type" connectors, which you may have seen on one end of a parallel-type printer lead.

- DIN41612 connectors meet that (German) technical standard, and are a whole range of p.c.b. mounting male and female connectors. With differing body and contact styles, they are used on both signal and mains, or a mixture of both.



*50-way ribbon cable terminated with an IDC connector.*



*PC printer lead; (left) Centronics-type printer connector, (right) 25-way D-type connector.*

Remember that once the RS flip-flop has been reset further applications of the reset have no effect. The Set behaves in the same manner. Thus, if we connect our bouncing switch to an RS flip-flop we get a clean output with one pulse per switch press. Fig.7.23 shows how you wire it up.

## Parallel Data Transfer and Latches

So far we have looked mainly at single flip-flops which can only store one bit of data. To do useful things we often need many more data bits, often grouped as bytes or words.

To store a byte we simply need eight flip-flops and since all eight bits will be manipulated at the same time we can use common clock and reset signals. These data storage circuits are called *registers*. The 74HCT574 i.c. is an octal (eight-bit) D-type latch which can be used as a register, it has single clock and output enable signals.

To move data from one register to another, we can connect the outputs of

one register to the inputs of another and then enable the outputs of one and the inputs of the other. Of course, we must arrange that the enable signals are created at the appropriate time, this will require consideration of their relative timings.

To transfer data from one "sender" register to one of many "recipient" registers is quite easy. We simply have to make sure that only the inputs of the desired destination are enabled. All the other registers will ignore the data.

To allow more than one sender register to transfer data we must arrange that only one sender register has control at any instant. Note that this is a timing issue, and that we also need a way to electrically make sure that the outputs of the various registers do not interfere with each other. See the section on "Tri-State" signals for details of how this is achieved.

If we want a number of registers to be able to pass data to and from each other we group the appropriate connections together to form a *bus*. A bus will

also include signals which enable data transfer to and from the registers connected to it.

The word *bus* is often used to refer to the connection between the devices in a computer system, providing connection to the various memory and processor components.

## Next Time

In the next *Teach-In* we will consider how a bus is used to move information around, with the development of the "Faversham-Wills Household Command System". This innovation in home management will allow His Lordship to send requests to the various staff members around his mansion.

Now have a look at the *Lab Work* section and build up a JK Flip-Flop, with manual clock circuit and a T-type (Toggle) Latch demonstration circuit.

The *Teach-In* writers are delighted to receive your comments, feedback and queries. You can write to us at *Teach-In* c/o the Editorial address, or E-mail [Teach\\_In98@epemag.demon.co.uk](mailto:Teach_In98@epemag.demon.co.uk).

## SHOP TALK

with David Barrington

### Dice Lott

When buying the dual 7-segment displays for the *Dice Lott* project, two important factors must be checked out. It must be a common *cathode* type and the pinouts *must* run across the top and bottom of the device. The ones in the prototype came from Maplin, code BY68Y.

The mode switch is a miniature keyboard "click-effect" type and the round button version is listed by Rapid (☎ 01206 751166), code 78-0160 and a square button type by Maplin, code FF87U. The latter company also supplied the calculator style case, code YK24B.

A ready-programmed 16C71 microcontroller is available (*Mail Order Only*) from the Electronics Dept at Radley College for the sum of £8; add £1 for overseas orders. Payments should be made out to *Radley College* and addressed to: Mr Max Horsey, Radley College, Electronics Dept, Abingdon, Oxon, OX14 2HR.

If you wish to do your own programming, the software is available on a 3.5 inch PC-compatible disk from the Editorial Offices - see *PCB Service* page for details. If you are an Internet user, it is available *Free* from our FTP site: <ftp://ftp.epemag.wimborne.co.uk/pub/PICS/DiceLott>

The p.c.b. is obtainable from the *EPE PCB Service*, code 192.

### Security Auto-Light

Most of the components used for the *Security Auto-Light* should be freely available. However, we have encountered a problem with the p.c.b. mounting mains transformer. This transformer is an RS component, code 209-156, that has now been discontinued. Hopefully, some RS stockists may still carry stocks.

The alternative approach is to use an off-board chassis type and hard wire it to the p.c.b. A suitable alternative would be the Maplin sub-miniature wire-ended type, code WB00A.

The light dependent resistor (l.d.r.) also came from the above source, code AZ83E. The bridge rectifier was ordered from Electromail (☎ 01536 204555), code 183-4028 and the 12V 5A relay from Maplin, code JM18U.

The p.c.b. is available from the *EPE PCB Service*, code 189.

### Stereo Tone Control plus 20W Stereo Amplifier

One of the main causes of concern when gathering up the components needed to construct the *Stereo Tone Control plus 20W Stereo Amplifier* will be the selection of a suitable mains transformer. The toroidal transformer used in the model is a 60VA type, with two 9V secondary windings rated at 3-33A each, and was purchased from Rapid Electronics (☎ 01206 751166), code 88-1825. A suitable 50VA chassis mounting standard type transformer would be the Maplin DH30H.

The loudspeaker spring-loaded, lever action, 4-terminal strip (code BW71N), 3-pole 4-way rotary function select switch (code FF75S) and the on/off mains rotary switch (code FH57M) were supplied by Maplin. The two-piece case also came from the same source, code BZ77J.

The two printed circuit boards are available from the *EPE PCB Service*, codes 190 (Tone) and 191 (Amp), see page 388.

### Improved Infra-Red Remote Repeater

Collecting together the parts required to build up the *Improved Infra-Red Remote Repeater* should not be a problem and most advertisers should carry stocks or suitable alternative components.

The only exception could be the LD271 infra-red emitting diode. This was purchased from Maplin, code CY85G.

### PLEASE TAKE NOTE

#### EPE PIC Tutorial (March '98)

Add to components list:  
IC2 7805 5V 1A voltage regulator; C9 1µ radial elect., 16V

#### Software

Two extra files have been added to PIC TUTOR disk and *EPE* web site for users whose PC cannot be persuaded to use printer port register &H378. SEND2.EXE is for register &H278; SEND3.EXE is for &H3BC. Use in place of original SEND.EXE, calling SEND2 or SEND3, as appropriate.

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# LAB WORK

# 7

*Objectives: Demonstrate a JK flip-flop, then construct and observe a T-type and D-type flip-flop. Assemble a 2-bit asynchronous and synchronous counter and confirm their operation.*

**P**ART 7 of *Teach-In* main tutorial describes the flip-flop in more detail, specifically, the JK flip-flop and how it has four distinct actions (*Hold, Reset, Set* or *Toggle*), depending on how its J and K inputs are configured. In this section we will use such a flip-flop to demonstrate the differences to you. We think that actually seeing the flip-flop in operation is a great way of realising what they're all about.

For this part we'll continue to give you full circuit diagrams as before, but soon we hope you will be able to translate circuit schematics into actual prototype circuits for yourself. There will undoubtedly come a point where you will start to design your own circuits, and it will become vital that you gain experience in realising the circuit in its physical form for yourself, using data sheets, books and more besides in order to gather the data you need. More on this in the next *Lab Work*.

Meantime, don't forget to ensure that any *unused* inputs *anywhere* on a CMOS chip are not allowed to "float", but are best safely pulled up to the positive supply line with a resistor. One pull-up resistor can be shared amongst several inputs. You

should also note that the power supply connections for the i.c.s. are not necessarily the same for each chip used, so watch the pin-outs carefully or you may damage the device.

The following *Labs* look complicated, but they are constructed by making progressive modifications to one initial circuit and then observing the results. Work methodically and you'll be fine.

When we tested the circuits on a breadboard, they took roughly one hour to construct successfully (in spite of an odd wiring mistake or two along the way!).

### Lab 7.1 - JK Flip-Flop

The demonstration *JK Flip-Flop* circuit for Lab 7.1 forms the basis for all the experiments in this *Lab Work*. In order to create a "clock" signal for our experiments, two NAND gates (we used a 74HCT00 i.c.) are used to create an RS flip-flop, see Fig. 7.24. This was described in the previous part of *Teach-In* (Fig. 6.11).

A flying lead is adequate to "toggle" (change over) this flip-flop by connecting either input to 0V temporarily, so that its output (at pin 3) flips either high or

low, as appropriate. The result is used as a manually-generated clock signal to "clock" a JK flip-flop. Importantly, the SR flip-flop introduces an "anti-bounce" measure, because once you set or reset this flip-flop with the flying lead, it won't change state again even if you "bounce" the flying lead several times.

We used a 74HCT73 i.c., a dual JK flip-flop with reset for IC2. This contains two such flip-flops, of which only one is used initially. Each one has J, K and Reset inputs, plus complementary outputs; see pinout panel.

The small circle on the clock (CLK) input signifies that the JK flip-flop will clock on a *negative-going* edge (one which goes from positive to negative). It is important you remember this!

As in previous Labs, outputs are monitored by light emitting diodes (D1 to D3), driven by inverting buffers (74HCT04, for example), IC3a to IC3c. An illuminated i.e.d. signifies that the corresponding output (IC1a/IC2a) is high.

Remember that the buffers *invert* a logic high signal – so the inverter's output goes low, which means that the i.e.d. sinks current into it to ground. This illuminates the i.e.d. So the i.e.d.s tell you what the states of the clock and two complementary outputs are.

Construct this circuit on your solderless breadboard, and use in conjunction with your 5V power supply. The pinouts for the three integrated circuits are given in the separate panel. Follow the pin numbers for the chips and complete the interwiring as usual, observing power supply connections carefully.

Two flying leads can be used for the J and K inputs, connecting to either +5V or 0V line as necessary. Note the three 100k (kilohms) pull-up resistors (R3 to R5) on the J, K and Reset inputs to prevent them floating. All unused input pins on all three i.c.s can be commoned together and "pulled up" by resistor R9.

## You Will Need

### Resistors

- 330 ohm (3 off)
- 100k (6 off)
- All 0.25W 5% carbon film

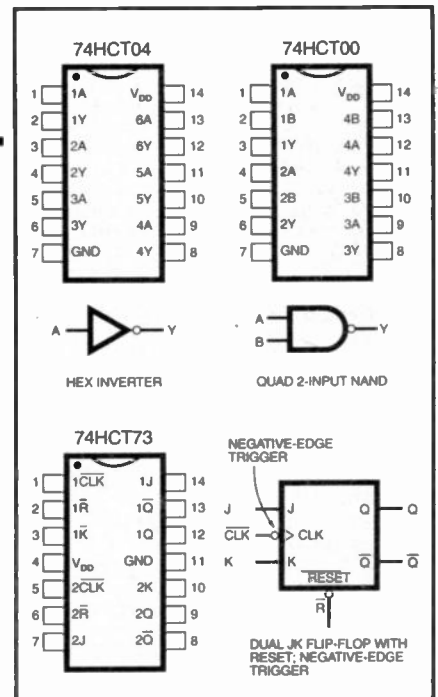
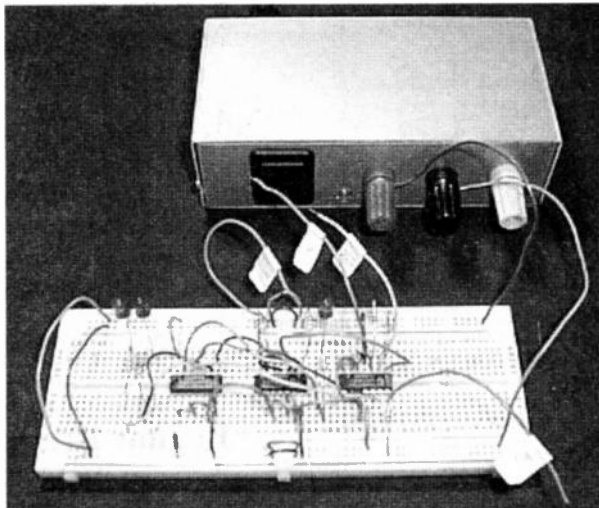
### Semiconductors

- 74HCT00
- 74HCT04
- 74HCT73

### Miscellaneous

- Red i.e.d. (3 off);
- solderless breadboard;
- 5V power supply;
- hook-up wire etc.

Powering the JK Flip-Flop from the 5V Add-on Regulator (see Lab Work 3).



Pinout details for the MOS logic i.c.s. used in lab Work 7.

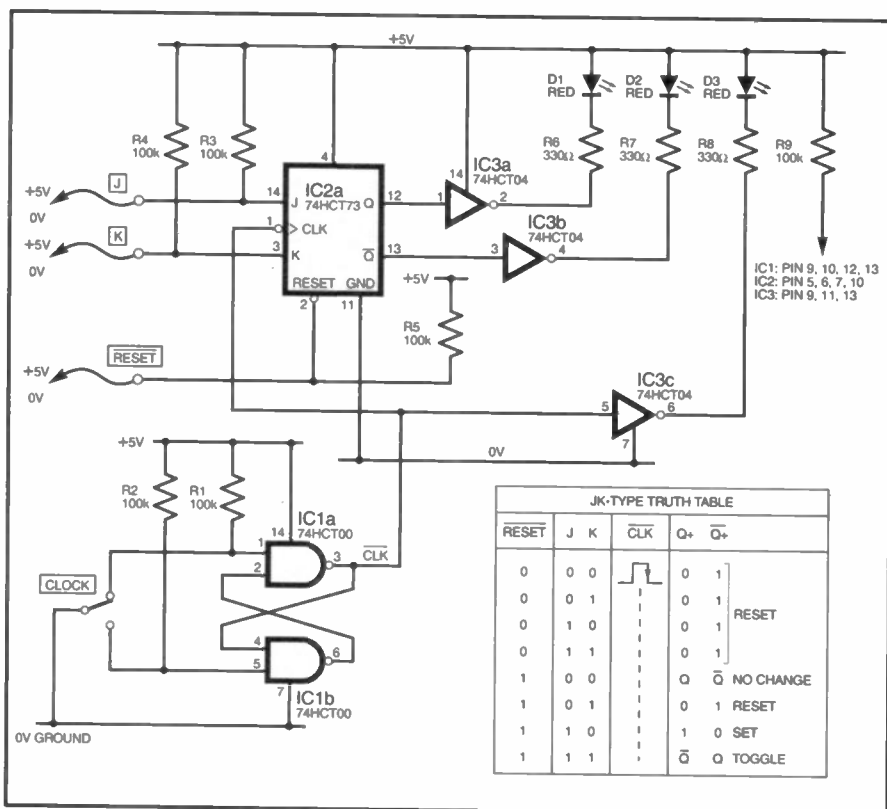


Fig.7.24. Circuit diagram to demonstrate the various properties of the JK flip-flop.

The object of this exercise is to demonstrate the action of the JK flip-flop. The Truth Table is given together with Fig.7.24. (Remember that "Q+" means the value of Q after the clock.)

Hook the three inputs high or low as necessary, clock the circuit manually and observe that the pattern of l.e.d.s confirms the Truth Table is correct. Notice how the flip-flop can be made to Set, Reset or even Toggle states. Being negative-edge triggered, something only happens to the JK flip-flop when the clock signal goes low.

### Lab 7.2 - T-type Latch

The next experiment is simple. Now change the input section to the J and K pins as shown in Fig. 7.25, retaining just one pull-up resistor (R3) for them both. Only one flying lead is now used for the input. This forms a T-type (Toggle) latch.

Click the circuit manually and confirm the Truth Table for the T-type latch. Notice how the two outputs change over or "toggle", but only when the flip-flop is not in a Reset state.

- The circuit behaves as a "divide by 2" circuit, because either output changes over at exactly half the frequency of the clock signal.

### Lab 7.3 - D-type Latch

For our next demonstration we need to modify the input section once again, as shown in Fig. 7.26. An inverter (IC3d) is inserted between the J and K inputs as shown, and again a pull-up resistor is a wise precaution.

You should clock the circuit manually and observe the circuit setting or resetting. This is a Data, or D-type latch.

A Data latch is useful for passing a data signal through to the output of the flip-flop, whenever a suitable clock signal is received. Whenever the circuit is clocked, the data on the "D" input is latched at the Q output.

- An alternative way of constructing a T-type toggle is to use a D-type latch, and feed its Data (D) input back from the Q output.

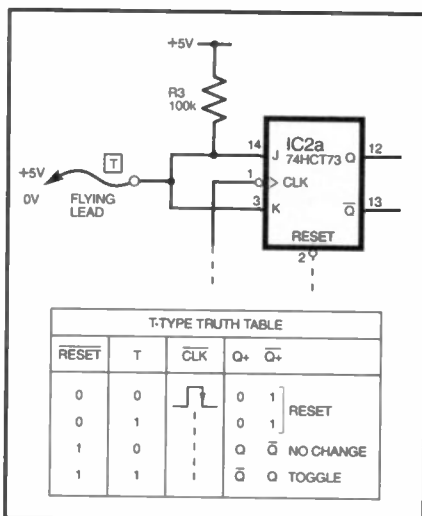
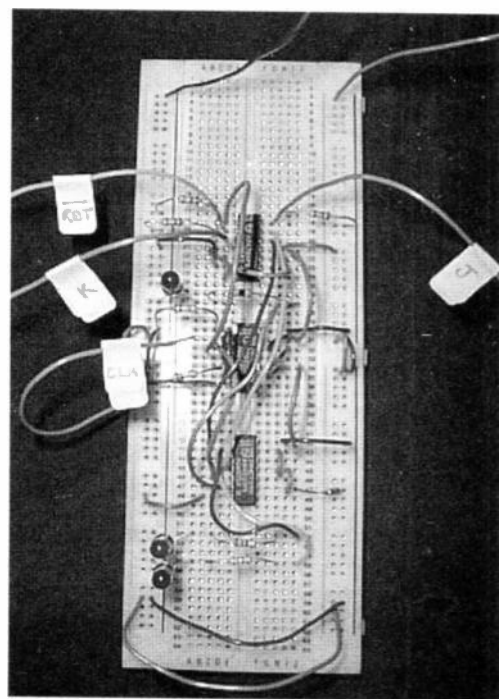


Fig.7.25. This is a T-type (Toggle) flip-flop. Modify the input of the previous experiment as shown.



Breadboard component layout for the JK Flip-Flop, with manual clock circuit.

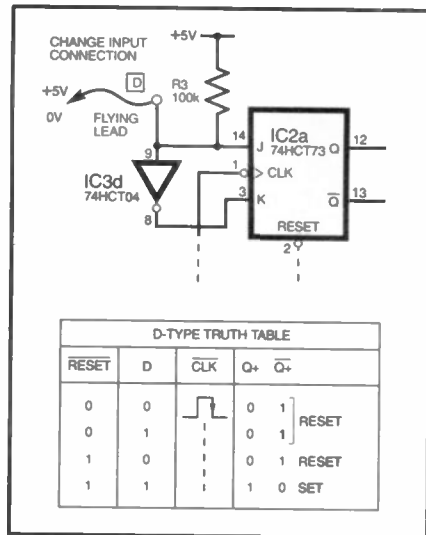
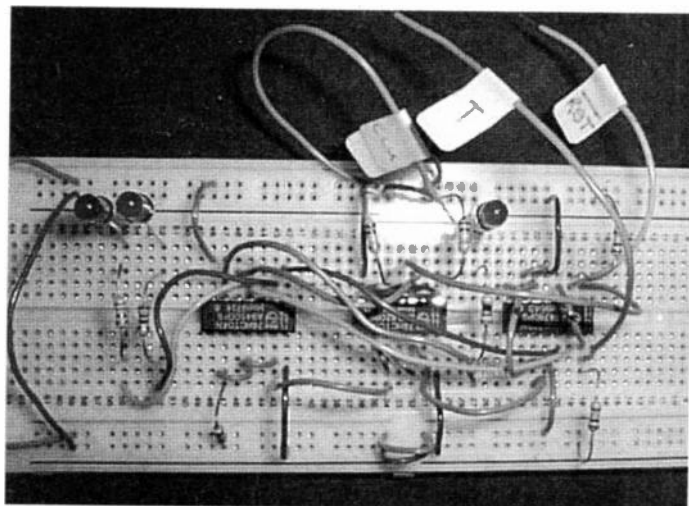


Fig.7.26. Add an inverter between the J and K inputs to create a Data type flip-flop. Pin 9 of IC3 is now pulled up by resistor R3, instead of by R9 as before.



Demonstration breadboard layout for the T-type (Toggle) latch circuit.

## Lab 7.4 - Asynchronous 2-bit Counter

For our next "practical" undertaking, we have modified the circuit of Fig.7.24 somewhat by adding the second JK flip-flop included in the 74HCT73 i.c. Also, the inverter we added in Lab 7.3, is removed again. The resulting circuit diagram is shown in Fig.7.27.

The clock signal for the second flip-flop (IC2b) is derived from the Q output of the first flip-flop. The J and K inputs are both taken high, and the Reset inputs are pulled high through resistor R5.

This means that T-type flip-flops are formed. Each flip-flop's complementary outputs will toggle states when a negative-going clock edge is received. Only the Q outputs are used, their complements are ignored.

This circuit will actually count two binary digits - it is a 2-bit counter with output 1Q being the least significant bit (the "b" of a 2-bit binary number *ab*) and 2Q the most significant bit (the "a"). Two light emitting diodes are used as usual, this time to indicate the binary number produced over the two outputs. In effect, a binary number sequence of 00, 01, 10, 11 will be seen.

• Because the clocks of the flip-flops are not clocked at the same time, this is an asynchronous 2-bit counter. Check out the function of this circuit and compare the two outputs against the clock input, as per the timing diagram.

## Lab 7.5 - Synchronous 2-bit Counter

For the final Lab, Fig. 7.28 shows a 2-bit Counter circuit as before, but with a difference: the clocks (CLK) of both flip-flops are driven simultaneously by the clock generator. Modify the previous Lab accordingly to build this synchronous 2-bit counter.

The only difference between this and the asynchronous counter is that each flip-flop of the synchronous counter is driven from the same clock, so all its outputs change state at the same time. An asynchronous counter has a "ripple through" effect.

In Lab Work 8: We will add a simple detector to both counters, and then you will see the difference yourself.

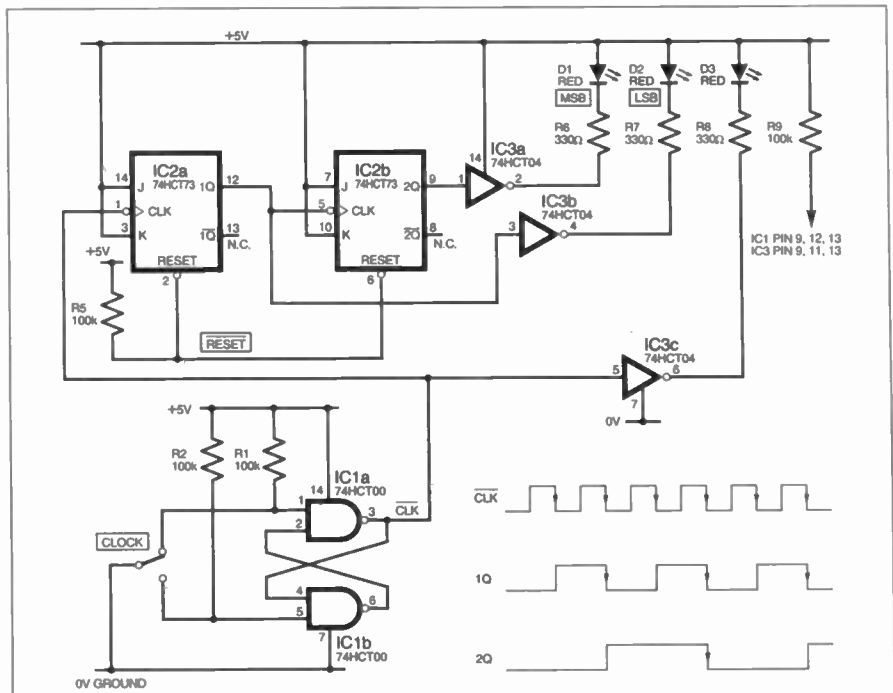


Fig.7.27. Demonstration circuit diagram for an asynchronous 2-bit counter.

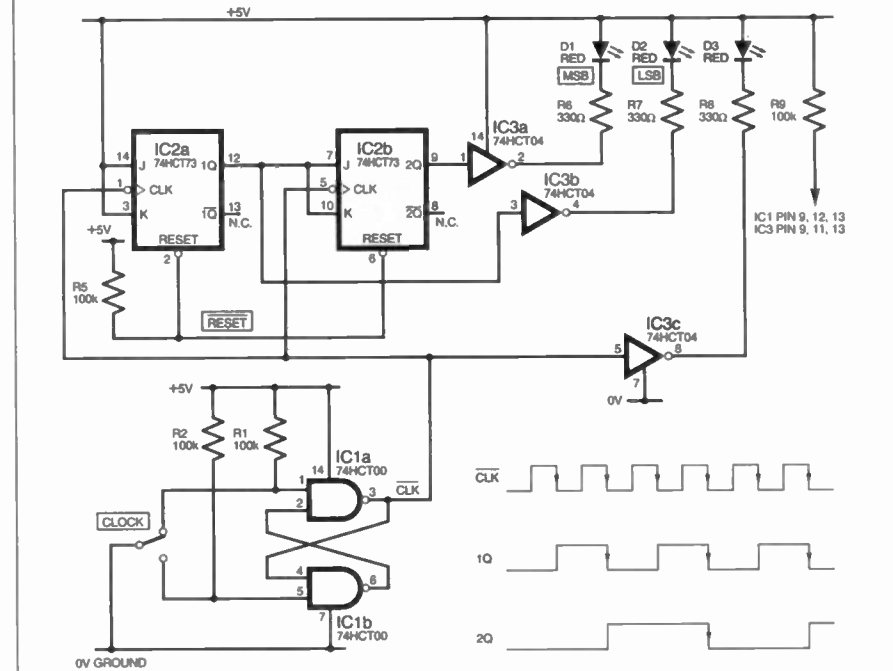


Fig.7.28. Demonstration circuit for a synchronous 2-bit counter.

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# IMPROVED INFRA-RED REMOTE REPEATER

ROBERT PENFOLD

*Control your video or satellite tuner from the bedroom when it's in the lounge!*

A PREVIOUS article in *EPE* featured a project for a device that enabled an infra-red remote control unit to be used via a connecting cable (*Infra-red Remote Control Repeater*, July 1997 issue). Although this might seem to be a retrograde step, adding a cable into the system means that it is no longer limited to "line-of-sight" operation. The operating range can also be extended.

No doubt there are other applications for a system of this type, but the most common use is to provide remote control of a VCR or satellite receiver from another room. If you have a television receiver in (say) a bedroom and it is fed from a VCR or satellite receiver in the lounge via a coax cable, you only have limited control over what you see. There is no way of setting the VCR to fast-forward or changing the channel of the satellite receiver, because the infra-red remote control handsets will not work through walls, ceilings, or anything opaque. Their maximum operating range is also very limited.

## LONG-RANGE

With a hard wired relay unit such as the unit featured here it is possible to use an infra-red control system over a range of at least 20 metres, and it will operate from one room to another. The general idea is to fit a thin screened audio cable alongside the coax cable that connects the signal source to the television set. This second cable carries a signal in the opposite direction, and provides the necessary control of the receiver or VCR.

A simple receiver unit picks up the infra-red pulses from the remote control handset and sends them down the cable. A transmitter unit at the other end of the cable transmits infra-red pulses that control the VCR or satellite receiver.

The design featured previously had a reasonable range at the transmitting end of the system, and the transmitter only needed to be within a few metres of the unit being controlled. Due to its extreme simplicity, the range obtained at the receiver end of the system was strictly limited. In fact, the remote control handset had to be held within about 0.5 metres of the receiver or the system failed to work at all.

Such limited range is usable, but is not very convenient. The improved system featured here is still quite simple, but it offers an operating range of several metres at the receiving end of the system. This means that in most cases the receiver can be tucked away in one corner of the room, and the system will then function well with the remote control handset anywhere in the room.

## SYSTEM OPERATION

The block diagram of Fig.1 helps to explain the basic function of the Improved Infra-Red Remote Repeater. The infra-red pulses from the IR Handset are received by a photo-diode where they produce corresponding electrical pulses.

These pulses are likely to be extremely weak, and will often be only a fraction of a millivolt "peak-to-peak". A

large amount of amplification is therefore needed in order to raise the signal level to one that can operate the output stages of the unit.

A low-noise preamplifier stage is followed by two further stages of amplification. This produces an output level of a few volts peak-to-peak from the final amplifier, and this is more than adequate to drive the subsequent stages. In fact the final stage of the amplifier block will normally be driven into clipping.

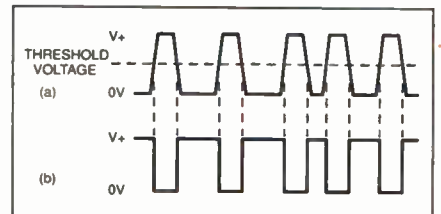


Fig.2. Example input (top) and output waveforms of the voltage comparator.

## IN COMPARISON

Although the infra-red diode and amplifier stages have fairly wide bandwidths, there is still some degradation of the waveform, especially when a weak signal is received. This results in reduced rise and fall times, giving a waveform of the type shown in Fig.2 (top).

The methods of pulse coding used in infra-red remote control systems are reasonably tolerant of waveform distortion, but any distortion must still be kept to a minimum in order to ensure good results. A voltage comparator is therefore used to

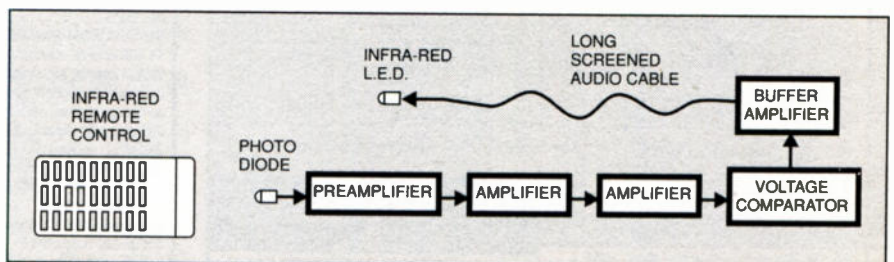


Fig.1. Block diagram for the Improved Infra-Red Remote Repeater



speed-up the waveform and minimise any distortion through the circuit.

The amplified signal is compared with a reference voltage of about half the supply potential. The output of the voltage comparator goes high when the input voltage is below the mid-supply threshold level, and low when the input is above the threshold level.

The signal is therefore inverted through the comparator, but this simply cancels out an inversion through the amplifier stages. Because the output of the comparator can switch relatively quickly, the output signal has improved rise and fall times, as in the lower waveform of Fig.2.

The output from TR1 is fed to further common emitter amplifiers (TR2 and TR3) which operate at full gain and provide most of the circuit's voltage gain. It is important that the circuit has poor sensitivity at low frequencies so that problems with 100Hz pickup from mains powered lighting are avoided.

Coupling capacitors C2, C3, and C5 have been given quite low values so that they introduce highpass filtering that greatly reduces the sensitivity of the circuit at 100Hz. On the other hand, they give an adequate low frequency response for the brief input pulses which do not have a significant low frequency content.

## VOLTAGE COMPARATOR

An operational amplifier, IC1, is used here as the voltage comparator. The basic function of an op.amp is to amplify the voltage difference across its inputs. The output goes more positive if the non-inverting (+) input is at the higher voltage, or more negative if the inverting (-) input is at the higher voltage. The voltage gain is so high (about 100000 times), that even a minute voltage difference is sufficient to send the output fully positive or negative.

In this case the inverting input, at pin 2, is fed from the collector (c) terminal of

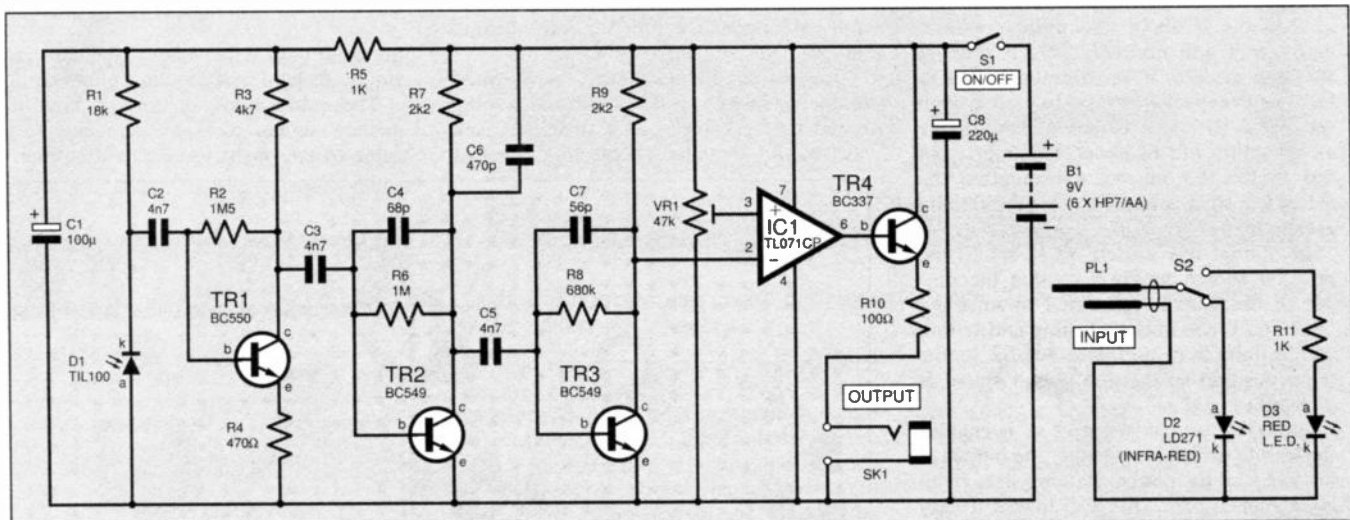


Fig.3. Full circuit diagram for the Improved Infra-Red Remote Repeater. The infra-red l.e.d. D2 (transmitter) is sited with the main household VCR/satellite receiver and linked to the "repeater" by screened cable at the second TV.

Returning to the block diagram of Fig.1, the final stage is a buffer amplifier. This enables the infra-red l.e.d. at the transmitter end of the relay link to be driven at a suitably high current. The transmitter unit is basically just an infra-red l.e.d., and it contains no active circuitry.

There is likely to be a substantial amount of capacitance in the long connecting cable, but due to the low output impedance of the circuit this will not produce a significant degradation of the output waveform. On the other hand, it does place an upper limit on the length of the connecting cable. The prototype has only been tried with cables of up to 20 metres in length, but the unit should function with cables somewhat longer than this.

## CIRCUIT OPERATION

The complete circuit diagram for the Improved Infra-Red Remote Repeater is shown in Fig.3. D1 is the infra-red diode, and this is used in the reverse biased mode.

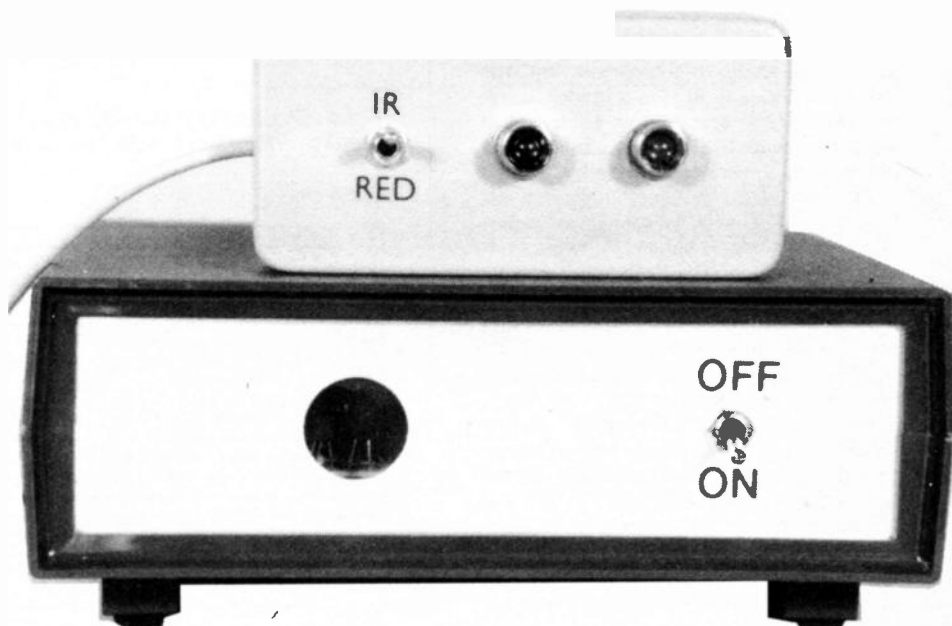
Under dark conditions D1 has the very low leakage level associated with normal silicon diodes, but the pulses of infra-red "light" from the infra-red keypad handset cause increased leakage, and generate small pulses at the cathode (k) terminal of D1. These pulses are coupled by way of capacitor C2 to the preamplifier, which is a common emitter stage based on transistor TR1. A common emitter amplifier normally has a high voltage gain, but in this case the voltage gain is only about 10 (20dB) due to the local negative feedback introduced by resistor R2.

The combined voltage gain of the three amplifier stages is very high indeed, and this can lead to problems with instability. Matters are made worse by the use of stripboard construction which tends to encourage stray feedback due to the capacitance between the copper strips.

In order to prevent instability the high frequency response of the circuit has to be rolled-off slightly, and this is the function of capacitors C4 and C7. These simply provide increased negative feedback over transistors TR2 and TR3 at high frequencies.

The non-inverting input, at pin 3, is fed with the reference voltage generated by preset potentiometer VR1. This reference potential can be varied from zero to the full supply voltage, and in practice it is set slightly lower than the voltage at the collector of TR3.

Under standby conditions the non-inverting input (pin 3) will be at a lower potential than the inverting input, and IC1's output will therefore go low. When a signal is received from the remote control handset, at the "window" of D1, a pulsed signal appears at the collector of TR3.



During negative half cycles the inverting input of IC1 will be taken below the reference voltage, sending the output of IC1 high. The relatively fast switching speed of IC1 results in a "clean" and fast version of the input signal appearing at its output.

A drive signal of only a few milliamps is available at the output of IC1 pin 6, and transistor TR4 is therefore needed to boost the output current to a level that will drive the infra-red l.e.d. D2 properly. Resistor R10 limits the l.e.d. current to about 70mA, but due to the pulsed and intermittent nature of the signal the average output current is far less than this.

The current consumption of the circuit as a whole is about five milliamps, and as the unit will normally be left running for long periods it is essential to use a fairly high capacity battery. In theory, each set of six HP7 size batteries should have an operating life of about 400 hours, but due to the low current consumption the actual life span is likely to be substantially greater than this.

In normal use switch S2 is set to the position shown in Fig.3 so that the output of the unit is connected to infra-red l.e.d. D2. When initially testing and setting up the unit it is useful to set S2 to the other position so that the output signal is directed to l.e.d. D3.

As D3 is a visible red l.e.d. it enables the user to determine whether the output of the unit is at the correct standby state (with D3 switched off). This also makes it easy to adjust preset VR1 to a suitable setting.

The red l.e.d. D3 will visibly flash when the unit receives a signal from the remote control handset, and this enables the user to determine whether or not the unit is operating correctly. Resistor R11 provides additional current limiting that protects D3 from excessive currents during the setting up process.

## CONSTRUCTION

The main circuit is constructed on a piece of stripboard which measures 37 holes by 17 copper strips using the component layout shown in Fig.4. The underside view of the board, giving details of breaks in copper tracks, is also provided. Construction of the board follows along the normal lines and should not provide any problems.

The TL071CP op.amp used for IC1 is not a static-sensitive component, but it is still a good idea to fit it in a holder. Infra-red diode D1 is specified as a TIL100 in the components list, but any similar component should work equally well.

In component catalogues diodes of this type are not necessarily sold under a particular type number, but are sometimes advertised as an infra-red diode for remote control applications. A Maplin "Infra-Red Diode" is used in the prototype, and Fig.4 is correct for this component. Other infra-red diodes might have different encapsulations or leadout configurations.

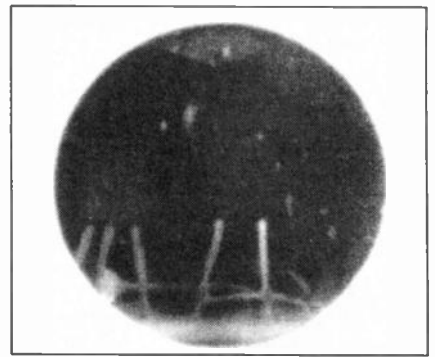
Mylar capacitors have long leadout wires that can be formed to accommodate a wide range of lead spacings, which makes them a good choice for C3, C5, and C7. It could be very difficult to fit other types of capacitor into this layout. Similarly, C4 and C7 should be miniature ceramic plate types, since other types are

not likely to fit properly into this component layout.

A medium size plastic box or instrument case will comfortably house everything. The only slight complication is that a window is required for the infra-red diode to "look" through. With the specified diode the large flat surface is the one that must be aimed towards the window.

It is best to cut a fairly large window of about 20mm to 25mm in diameter, and to position the circuit board so that D1 is quite close to the cut-out, see photographs. The unit will then have a wide angle of view instead of the "tunnel vision" that would be obtained if D1 is mounted well back from a small cut-out. A piece of transparent plastic is glued in place behind the cut-out.

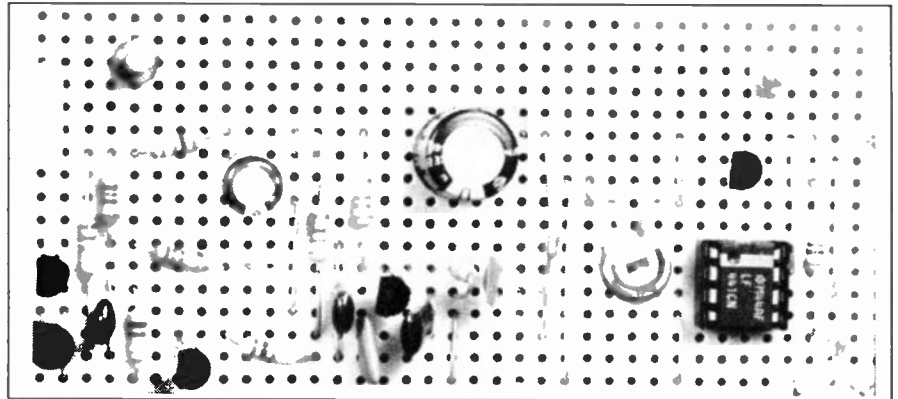
The screened connecting cable is fitted to the main unit via a 3.5mm jack plug wired to the cable, and a matching jack socket SK1 mounted on the rear panel of



Site the photodiode close behind the "window" to avoid any "tunnel vision" effect.

the main unit. Alternatively, the cable can simply be hard wired to the circuit board.

The cable does not carry a high frequency signal, and any screened audio cable of reasonable quality will suffice. It



Completed stripboard component layout.

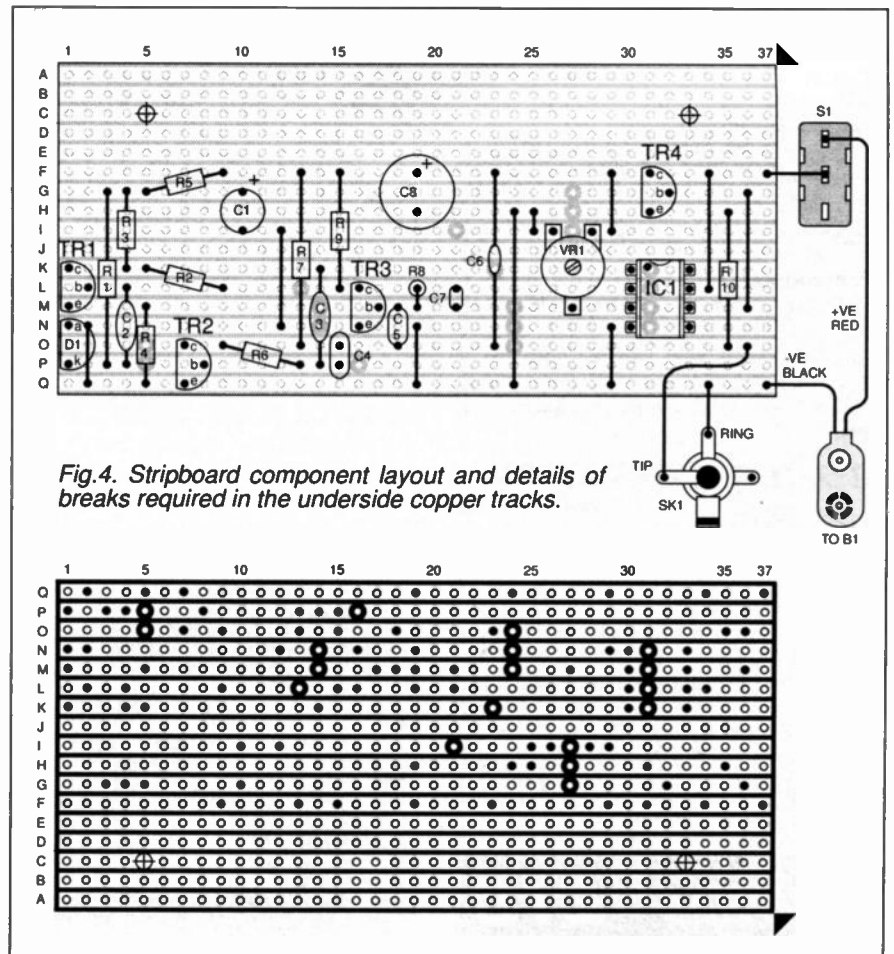
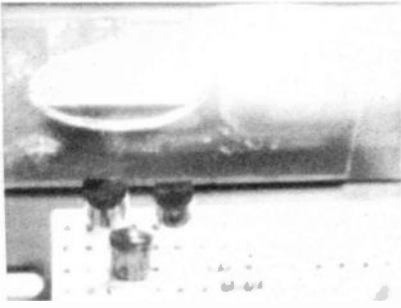


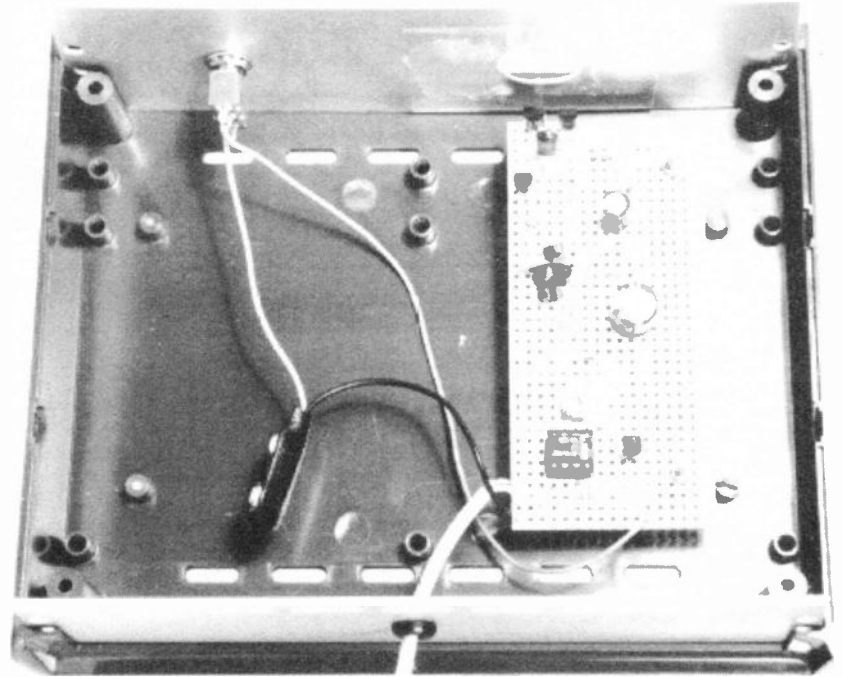
Fig.4. Stripboard component layout and details of breaks required in the underside copper tracks.



Protect the "viewing window" by glueing a strip of transparent material across the cutout.

must be a screened type though, with the screen carrying the earth connection so that there is no significant radiation of radio frequency interference.

Virtually any small plastic box should accommodate the transmitter components.



Layout of components inside the Repeater case. The space on the left is for the 6-cell battery pack.

With so few components there is no need for a circuit board, and it is just a matter of hard wiring the components together as is shown in Fig.5. The polarity of the l.e.d.s is indicated by having the cathode (k) leads slightly shorter than the anode (a) leads. Also, there is usually a "flat" on the cathode side of the body.

### TESTING AND USE

Start testing the unit with preset VR1 at a roughly central setting and S2 set to switch the red l.e.d. (D3) into circuit. At switch-on D3 will probably fail to light up, but adjusting VR1 in a counter-clockwise direction will result in D3 switching on.

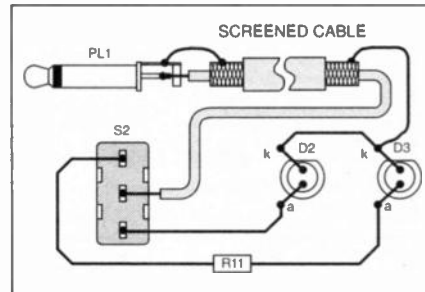


Fig.5. Wiring to the remote infra-red l.e.d. transmitter box.

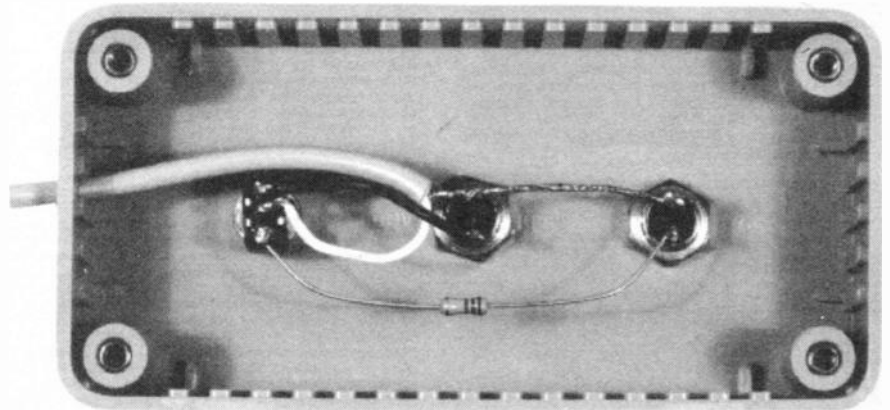
The unit should work well with VR1 backed off slightly from this setting so that the l.e.d. is normally switched off. It is advisable to back-off VR1 several degrees further so that any slight drift in the circuit's voltages will not result in the l.e.d. switching on and blocking proper operation of the system. Also, if the l.e.d. switches on under standby conditions the battery will have a fairly short operating life.

Aim the remote control handset at photo-diode D1 and press a few of the control buttons. If all is well this should result in some flashing from D3.

If preset VR1 does not seem to be having the desired effect, or using the remote control unit does not provoke any response from D3, switch off and recheck all the wiring.

Otherwise, switch over to the infra-red l.e.d. (D2) using switch S2, and try out the system. It should work well with the remote control handset up to about five metres away from the receiving end of the system.

The transmitter box can be up to about three metres away from the VCR or satellite receiver. Note that the system is unlikely to work at all with D3 rather than D2 switched into circuit. □



## COMPONENTS

### Resistors

R1	18k
R2	1M5
R3	4k7
R4	470Ω
R5, R11	1k (2 off)
R6	1M
R7, R9	2k2 (2 off)
R8	680k
R10	100Ω

All 0.25W 5% carbon film

See  
SHOP  
TALK  
Page

### Potentiometer

VR1	47k min. carbon preset, horizontal
-----	------------------------------------

### Capacitors

C1	100μ radial elect. 10V
C2, C3, C5	4n7 Mylar film (3 off)
C4	68p ceramic plate
C6	470p ceramic plate or polystyrene
C7	56p ceramic plate
C8	220μ radial elect. 10V

### Semiconductors

D1	TIL100 infra-red diode (or similar)
D2	LD271 infra-red l.e.d. (or similar), 5mm
D3	red l.e.d., 5mm
IC1	TL071CP bifet op.amp
TR1	BC550 npn transistor
TR2, TR3	BC549 npn transistor (2 off)
TR4	BC337 npn transistor

### Miscellaneous

SK1/PL1	3.5mm mono jack socket and matching plug
S1	s.p.s.t. min. toggle switch
S2	s.p.d.t. min. toggle switch
B1	9V battery pack (6 - HP7/AA size cells in holder), with clips (PP3)

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Guidance Only  
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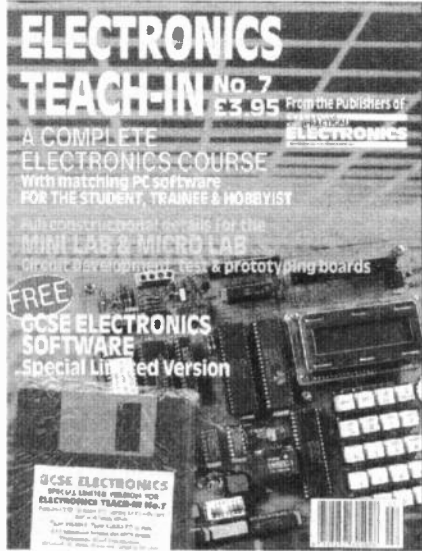
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## EPE SOFTWARE

Software programs for EPE projects are available on 3.5 inch PC-compatible disks or via our Internet site. Those marked with a single asterisk \* are all on one disk, order code PIC-DISK1, this disk also contains the *Simple PIC16C84 Programmer* (Feb '96). The *EPE PIC Tutorial* (\*\*) files are on their own disk, order code PIC-TUTOR. The disks are obtainable from the *EPE PCB Service* at £2.75 each (UK) to cover our admin costs (the software itself is free). Overseas (each): £3.35 surface mail, £4.35 airmail. All files can be downloaded free from our Internet FTP site: <ftp://ftp.epemag.wimborne.co.uk>.

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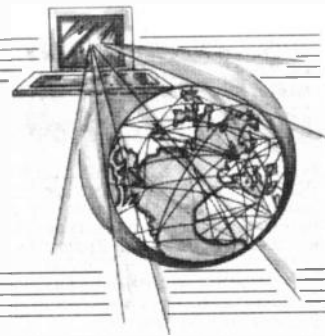
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# SURFING THE INTERNET

# NET WORK

ALAN WINSTANLEY



**N**ET WORK is our monthly Internet column specially written with the electronics enthusiast in mind. If you are a new reader or subscriber to *EPE*, don't forget that we have a web site at <http://www.epemag.wimborne.co.uk>. For the benefit of newcomers, it's worth briefly reviewing the *EPE* web presence. From our Home Page you can click through to several areas of interest including the following:

**media.htm** is a brand new page containing on-line Media Pack with fill-out form, which will interest potential advertisers.

**issues.htm** displays information about the contents of the latest edition of *EPE*, with photos of some of the projects; also, information related to the latest two or three issues is also displayed there as a reminder, in case you missed something of interest. This is particularly welcomed by our overseas readers.

**subrates.htm** details our present subscription rates in Sterling, with US\$ equivalents given to help American readers. There is of course an on-line secure order form where you can safely subscribe on-line. This has recently been improved slightly, with an option to subscribe for more than one year at a guaranteed price now being included.

**solderfaq.htm** is my popular Basic Soldering Guide which describes soldering techniques step by step, with a colour photo gallery available as well. It's used by students and trainers around the world and is part of the Edinburgh Engineering Virtual Library, and is probably the most comprehensive FAQ of its type on the Internet. It also seems to have inspired a commercial multimedia version.

You can order Back Issues and p.c.b.s. too via the *EPE* secure order form. Also on the *EPE* web site, there's *Net Work* on the web, at **network.htm** which contains the links for the last twelve editions of *Net Work*: additionally almost all the URLs I have ever provided are incorporated into an alphabetical listing – the *Net Work A-Z Index* (**netwkaz.htm**). After a mammoth effort, the Index has been completely re-validated and refreshed, with invalid or outdated links removed.

This month's PIC project files are on the FTP site at <ftp://ftp.epemag.wimborne.co.uk/pub/PICS/DiceLott>.

## Off the Air

Funnily enough, when I was revalidating all those links, it was purely by chance that I decided to check those which lead to my own web pages. I was horrified to see that my UK site ([homepages.tcp.co.uk/~alanwin](http://homepages.tcp.co.uk/~alanwin)) had suddenly gone off the air! This was caused by a disk failure at my ISP several days earlier, and in spite of their valiant efforts to restore their clients' pages, it eventually necessitated everyone re-uploading their entire sites. I cannot really complain given that the site uses the "free" 5MB web space provided with one of my dial-up accounts. Therein lies the difference between free, unsupported space and a commercial presence which costs far more but is (hopefully) fully backed-up.

Many SoHo (Small Office, Home Office) or SME (Small-Medium Enterprise) users will consider utilising their "free" web space for either business or personal projects. Compared with a commercial web presence it's important to realise that you get what you pay for in terms of service, statistics, technical support and reliability. It is also worth pointing out that I had exactly the same experience when my CompuServe web pages fell off the Internet temporarily, a year or so ago.

Having said that, Demon Internet's dial-in service connectivity was crippled briefly at the end of February when it lost its connection between its NOC in Finchley, North London and London's Telehouse, a super-reinforced high security communications centre housing the London Internet Exchange, itself a major European exchange point. The reason for the failure was the oldest in the book, and featured a workman, a cable and a JCB digger. There are some things you just can't legislate for.

## Give the Web Browser Credit

I was pleased to see that Barclaycard had opened a web site of their own ([www.barclaycard.co.uk](http://www.barclaycard.co.uk)), enabling "wired" customers like myself to review their account or make a payment, via the Internet. After firing up the web browser, my joy was short-lived, because Barclaycard's "account services" section held on a secure server isn't compatible with any version of Explorer. This was the excuse I needed for me to fetch Version 4 of Netscape Communicator!

I was pleasantly surprised by the usability of Netscape Navigator 4, with drop-down toolbars which neatly flick away when not needed; the Netscape site supplements these with further toolbars when browsing their web site. Overall, I found this latest browser to be efficient and productive, and a worthwhile upgrade from both Explorer 3 and Navigator 3. I especially like the right mouse-clicks enabling me to move forward, backwards, reload or stop. And, it's free and it doesn't try to bully its way into your operating system.

Netscape Communications is going full-speed ahead to stop its browser from being devastated by the onslaught of Microsoft Internet Explorer. In last month's *Net Work*, I predicted that Netscape would push their products in the "own label" enterprise market, and sure enough, they are now actively encouraging ISPs and software providers to incorporate it into OE software products. Thanks to Netscape's sudden openness with its source codes and newly-launched developer kits, soon you will be able to incorporate your own logo into a Navigator browser and bundle it with your product. A new group called [mozilla.org](http://www.mozilla.org) has been formed within Netscape to provide a central point of contact and "community" for those interested in using or improving the source code, they say. More at [www.mozilla.org](http://www.mozilla.org).

Footnote: after all that, using my new Communicator 4 browser, my on-line Barclaycard registration process failed, so I'm no better off anyway. The cheque's in the post (sometime).

## Hot and Historical Links

Here's my selection of links to give you a starting place for your surfing. Back to Netscape. Remember "Mozilla", the original codename for Netscape Navigator, and then the name of its mascot? Fans of the plucky dinosaur should go to The Mozilla Museum at [www.snafu.de/~tilman/mozilla/index.html](http://www.snafu.de/~tilman/mozilla/index.html). On a completely separate note, PC graphics users of JASC Inc. Paint Shop Pro 4 – the poor man's Adobe Photoshop – will be interested to hear that Version 5 is now out in beta, try [www.jasc.com](http://www.jasc.com) for details and downloading. It features layers, multiple undo, and more goodies. (Also don't overlook Usenet, try [comp.graphics.apps.paint-shop-pro](http://comp.graphics.apps.paint-shop-pro) for the latest news and views.)

The history of mathematician George Boole – whose algebra featured heavily in *Teach-In 98* – is well documented on the web, and there are links to Boolean-related sites. Remembering that URLs are case-sensitive, two which I bookmarked are [www.digitalcentury.com/encyclo/update/boole.html](http://www.digitalcentury.com/encyclo/update/boole.html) and [www.vma.bme.hu/mathhist/Mathematicians/Boole.html](http://www.vma.bme.hu/mathhist/Mathematicians/Boole.html).

Still on an historical note, the creation of the transistor – with photographs – is documented on the web at [www.cs.colorado.edu/~lindsay/talk/transistor.html](http://www.cs.colorado.edu/~lindsay/talk/transistor.html). Texas Instruments lays claim to pioneering the first microchip, read all about the work of Jack Kilby at the TI web site, [www.ti.com/corp/docs/history/kilby.htm](http://www.ti.com/corp/docs/history/kilby.htm).

Meantime, the first microprocessor – the Intel 4004 – was created in 1971. Try [www.wap.org/ifaq/posters/intel4004.html](http://www.wap.org/ifaq/posters/intel4004.html).

Let me know any favourite web sites. Next month, I'll be describing the layout of our FTP site, and various ways you can take advantage of this service. My E-mail address is [alan@epemag.demon.co.uk](mailto:alan@epemag.demon.co.uk).

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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

Newsletters or Usenet users advice: usenet.txt

Ni-Cad discussion: nicadfaq.zip and nicad2.zip

UK Sources FAQ: uksource.zip

Writing for EPE advice: write4us.txt

Ensure you set your FTP software to ASCII transfer when fetching text files, or they may be unreadable.

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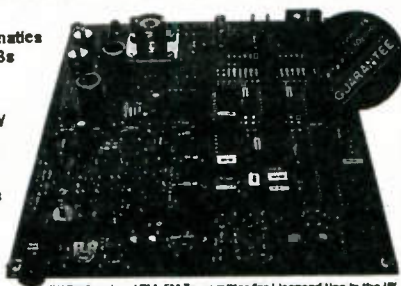
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
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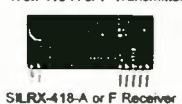
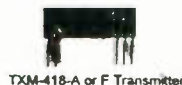
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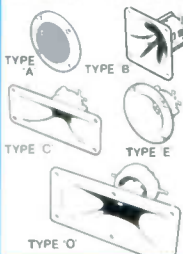


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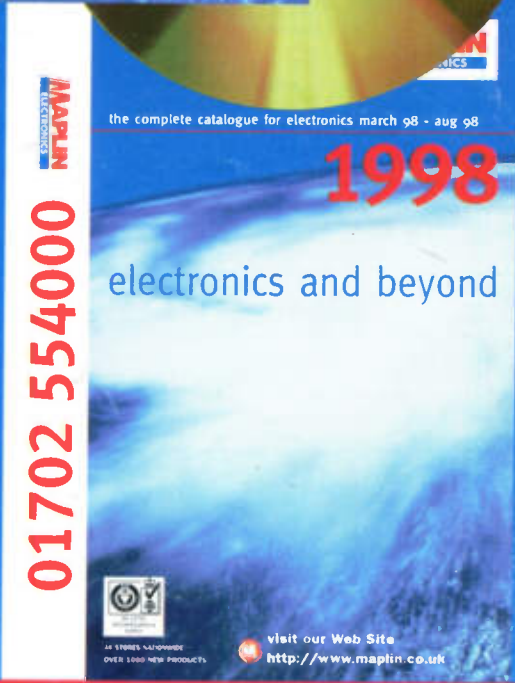
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