THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EVERYDAY PRACTICAL ELECTRONICS

MARCH 2000

INCORPORATING ELECTRONICS TODAY INTERNATIONAL £2.65

EPE ICEBREAKER
Real time PIC In-Circuit Emulator

AUTOMATIC TRAIN SIGNAL
Enhance your model layout

PARKING WARNING
Uses coded infra-red sensing

Series TECHNOLOGY TIMELINES 2
Fundamental electronics in the 20th century

PLUS EPE TEACH-IN 2000 PART 5 – Waveforms, Frequency and Time

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12v 18Ah SEALED LEAD ACID BATTERIES, new and boxed, unused pack of 4 £39.95 ref CYC7 or £15 each ref CYC6

AUTOMATIC CHARGER For the above batteries, charges 2 at once, charge level indicator circuitry, 6 hour charge. £10 ref CYC8

A new range of 12v to 240v INVERTERS IV400S (400 watt) £89, IV800S (800 watt) £159. IV1200S (1200 watt) £219

ECG MACHINES?/6v 10AH BATTS/24V 8A TX Ex government ECG machines! Measures 390X320X120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear including video out etc. On the front panel are two DIN sockets for connecting the body sensors to Sensors not included. Inside 2 x 6v 10AH lead acid batts (not in good condition), pcb's and a 8A? 24v torroidial transformer (mains in) sold as seen, may have one or two broken knobs etc due to poor storage £15 99 ref VP2

SODIUM LAMP SYSTEMS £75.70 Complete system with 250w or 400 watt SON-T Agro bulb, reflector with bulb holder and remote ballast and starter(uncased) all you need is wire. 250W system ref SLS1, 400W system SLS2.

PC SUPPORT HANDBOOK The ultimate technical guide to building and maintaining PC's. Over 460 A4 pages packed with technical data and diagrams just £10 ref PCBK. If you want 4 copies for £33 ref PCBK2. Also available is a CD packed with diagnostic programmes to use with the book £5 ref PCBK1

D SIZE NICADS Tagged, 1200mA, 1.2v pack of 4 for £6 ref CYC9 or as a pack of 24 for £22 ref CYC10

D SIZE SEALED LEAD ACID BATTERIES 2v 2.5ah rechargeable sealed lead acid battery made by Cyclon 60x45mm (standard D size) supplied as a pack of 12 or 20 giving you options for battery configerations eg 12v at 5ah, 24v at 2.5ah, 6v at 10ah. These batteries are particularly useful in that you can arrange them in your project to optimise space etc (eg boat ballast etc) Pack of 12 £10 ref CYC4, pack of 20 £16 ref CYC5

HYDROPONICS DO YOU GROW YOUR OWN? We have a full colour hydroponics catalogue available containing nutrients, pumps, fittings, enviromental control, light fittings, plants, test equipment etc Ring for your free copy.

PC COMBINED UPS AND PSU The unit has a total power of 292 watts. standard mother board connectors and 12 peripheral power leads for drives etc. Inside is 3 12v 7.2aH sealed lead acid batteries. Backup time is 8 mins at full load or 30 mins at half load. Made in the UK by Magnum, 110 or 240vac input, +5v at 35A, -5v at 5A, +12v at 9A, -12v at 5A outputs 170x260x220mm new and boxed £29.95 Ref PCUPS2

ALTERNATIVE ENERGY CD, PACKED WITH HUNDREDS OF ALTERNATIVE ENERGY RELATED ARTICLES, PLANS AND INFORMATION ETC £14.50 REF CD56

AERIAL PHOTOGRAPHY KIT This rocket comes with a built in camera! it flies up to 500 feet (150 m) turns over, and takes an aerial photograph of the ground below. The rocket then returns with its film via its paracute. Takes 110 film. Supplied complete with everything including a launch pad and 3 motors (no film) £29 98 ref astro

PROJECT BOXES Another bargain for you are these smart ABS project boxes, smart two piece screw together case measuring approx 6"x5"x2" complete with panel mounted LED. Inside you will find loads of free bits, tape heads, motors, chips resistors, transistors etc Pack of 20 £19 95 ref MD2

TELEPHONES Just in this week is a huge delivery of telephones all brand new and boxed. Two piece construction - Illuminated keypad, tone or pulse (switchable), recall, redial and pause, high/low and off ringer switch and quality construction. Off white colour and is supplied with a standard international lead (same as US or modems) if you wish to have a BT lead supplied to convert the phones these are £1.55 each ref BTLX. **Phones £4.99 each ref PH2 10 off £30 ref SS2**

3HP MAINS MOTORS Single phase 240v, brand new, 2 pole, 340x180mm, 2850 rpm, builtin automatice reset overload protector, keyed shaft (40x16mm) Made by Leeson £99 each ref LEE1

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

CHIEFTAN TANK DOUBLE LASERS 9 WATT+3 WATT+LASER OPTICS Could be adapted for laser listener, long range comms etc Double beam units designed to fit in the barrel of a tank, each unit has 2 semi conductor lasers and motor drive units for alignement. 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 freq. The units also contain a receiver to detect reflected signals from targets. £199 Ref LOT4

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 whats hidden in that magnetic strip on your card! just £9.95 ref BAR31

SOLAR POWER LAB SPECIAL 2x 6"x6" 6v 130mA cells, 4 LED's, wire, buzzer, switch + relay or motor **£7.99** REF SA27

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

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

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead and cigar plug. 12v 2w **£12.99** REF AUG10P3

STEPPER MOTORS Brand new stepper motors, 4mm fixing holes with 47.14mm fixing centres, 20mm shaft, 6.35mm diameter, 5v/phase, 0.7A/phase, 1.8 deg step (200 step) Body 56x36mm £14.99 ea ref STEP6, pack of 4 for £49.95 PIC based variable speedcontroller kit £15 ref STEP7

WAREHOUSE CLOSING SALE

Come and vist our Sussex warehouse, fill you car (or van) with loads of goodies at bargain prices. We must clear this warehouse regardless of cost, first come, first served, 10,000 square feet of bargains to browse. Call us for an appointment and directions. Appointments only.

Hydrogen fuel cells

Our new Hydrogen fuel cells are 1v at up tp 1A output, Hydrogen input, easily driven from a small electrolosis assembly or from a hydrogen source, our demo model uses a solar panel with the output leads in a glass of salt water to produce the hydrogen! Each cell is designed to be completely taken apart, put back together and expanded to what ever capacity you like, (up to 10watts and 12v per assembly. Cells cost £49 ref HFC11

PHILIPS VP406 LASER DISC PLAYERS, SCART OUTPUT, JUST PUT YOUR VIDEO DISK IN AND PRESS PLAY, STANDARD AUDIO AND VIDEO OUTPUTS, FULLY TESTED AND WORKING. £24.95 REF VP406

SMOKE ALARMS Mains powered, made by the famous Gent company, easy fit next to light fittings, power point. Pack of 5 £15 ref SS23, pack of 12 £24 ref SS24

4AH D SIZE NICADS pack of 4 £10 ref 4AHPK

SENDER KIT Contains all components to build a A/V transmitter complete with case £35 ref VSXX2

10 WATT SOLAR PANEL Amorphous silicon panel fitted in a anodized aluminium frame. Panel measures 3' by 1' with screw terminals for easy connection. **3' x 1' solar panel £55 ref MAG45 Unframed 4 pack (3'x1') £58.99 ref SOLX**

12V SOLAR POWERED WATER PUMP Perfect for many 12v DC uses, from solar fountains to hydroponics! Small and compact yet powerful works direct from our 10 watt solar panel in bright sun. Max hd 17 ft Max flow = 8 Lpm 1.5A Ref AC8 £18.99

SOLAR ENERGY BANK KIT 50x 6"x12" 6v solar panels(amorphous)+50 diodes £99 ref EF112

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/vcr connnectors £49.95 ref CC6J

SOLAR MOTORS Tiny motors which run quite happily on voltages from3-12vdc. Works on our 6v amorphous 6" panels and you can run them from the sun! 32mm dia 20mm thick £1.50 each

WALKIE TALKIES 1 MILE RANGE £37/PAIR REF MAG30

LIQUID CRYSTAL DISPLAYS Bargain prices, 16 character 4 line, 62x25mm £5.99 ref SMC1640A 40 character 1 line 154x16mm £6.00 ref SMC4011A

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

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MINATURE TOGGLE SWITCHES These top quality Japanese panel mount toggle switches measure 35x13x12mm, are 2 pole changeover and will switch 1A at 250vac, or 3 A at 125vac. Complete with mounting washers and nuts. Supplied as a box of 100 switches for £29.95 ref SWT35 or a bag of 15 for £4.99 ref SWT34

VOICE CHANGERS Hold one of these units over your phone mouth piece an you can adjust your voice using the controls on the unit! Battery operated £15 ref CC3

BULL ELECTRICAL

250 PORTLAND ROAD, HOVE, SUSSEX. BN3 5QT. (ESTABLISHED 50 YEARS).

MAIL ORDER TERMS: CASH, PO OR CHEQUE WITH ORDER PLUS £4.00 P&P PLUS VAT.

24 HOUR SERVICE £6.50 PLUS VAT.

OVERSEAS ORDERS AT COST PLUS £3.50

(ACCESS, VISA, SWITCH, AMERICAN EXPRESS)

'phone orders : 01273 203500

FAX 01273 323077

Sales@bull-electrical.com

30 WATTS OF SOLAR POWER for just £69, 4 panels each one 3'x1' and producing 8w, 13v. PACK OF FOUR £69 ref SOLX

200 WATT INVERTERS plugs straight into your car cigarette lighter socket and is fitted with a 13A socket so you can run your mains operated devices from your car battery £49.95 ref SS66

THE TRUTH MACHINE Tells if someone is lying by micro tremors in their voice, battery operated, works in general conversation and on the 'phone and TV as well! £42.49 ref TD3

INFRA RED FILM 6" square piece of flexible infra red film that will only allow IR light through. Perfect for converting ordinary torches, lights, headlights etc to infra red output only using standard light bulbs Easily cut to shape. 6" square £15 ref IRF2

33 KILO LIFT MAGNET Neodynium, 32mm diameter with a fixing bolt on the back for easy mounting. Each magnet will lift 33 kilos, 4 magnets bolted to a plate will lift an incredible 132 kilos! £15 ref MAG33 Pack of 4 just £39 reg MAG33AA

HYDROGEN FUEL CELL PLANS Loads of information on hydrogen storage and production. Practical plans to build a Hydrogen fuel cell (good workshop facilities required) £8 set ref FCP1

STIRLING ENGINE PLANS Interesting information pack covering all aspects of Stirling engines, pictures of home made engines made from an aerosol can running on a candle! £12 ref STIR2

ENERGY SAVER PLUGS Saves up to 15% electricity when used with fridges, motors up to 2A, light bulbs, soldering irons etc £9 ea ref LOT71 10 pack £69 ref LOT72

12V OPERATED SMOKE BOMBS Type 3 is a 12v trigger and 3 smoke cannisters, each cannister will fill a room in a very short space of time! £14.99 ref SB3. Type 2 is 20 smaller cannisters (suitable for mock equipment fires etc) and 1 trigger module for £29 ref SB2 Type 1 is a 12v trigger and 20 large cannisters £49 ref SB1

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

NEW LASER POINTERS 4.5mw, 75 metre range, hand held unit runs on two AA batteries (supplied) 670nm £29 ref DEC49J

HOW TO PRODUCE 35 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. £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

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

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

SUPER WIDEBAND RADAR DETECTOR Detects both radar and laser, X K and KA bands, speed cameras, and all known speed detection systems. 360 degree coverage, front&r earwaveguides, 1.1"x2.7"x4.6" fits on visor or dash £149

LOPTX Made by Samsung for colour TV £3 each ref SS52

LAPTOP LCD SCREENS 240x175mm, £12 ref SS51

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. £22 ref MOT4

Online web catalogue bull-electrical.com

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 MOT5A

INFRA RED REMOTE CONTROLS made for TV's but may have other uses pack of 100 £39 ref IREM

RCB UNITS Inline IEC lead with fitted RC breaker. Installed in seconds. Pack of 3 £9.98 ref LOT5A

On our web sites you can

1. Order online.
2. Check your premium bonds.
3. Enter our auction or build your own.
4. Add E-commerce to your own site.
5. Discover our software site, optical site, hydroponics site, holiday home exchange site, inkjet site, hotels site.
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COMMENTS ... POPULAR FEATURES ...

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EVERYDAY PRACTICAL ELECTRONICS

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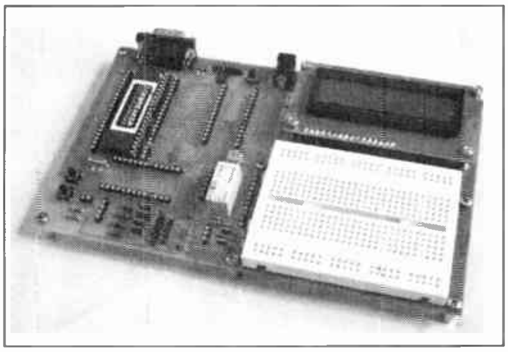
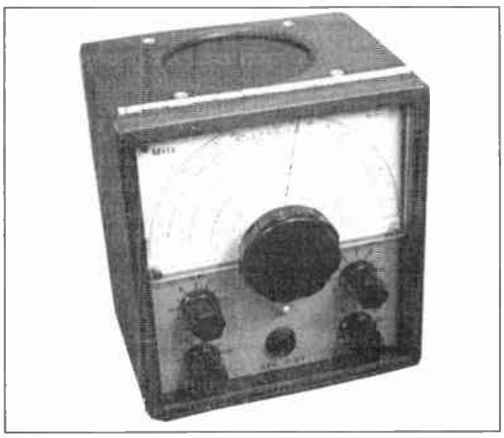
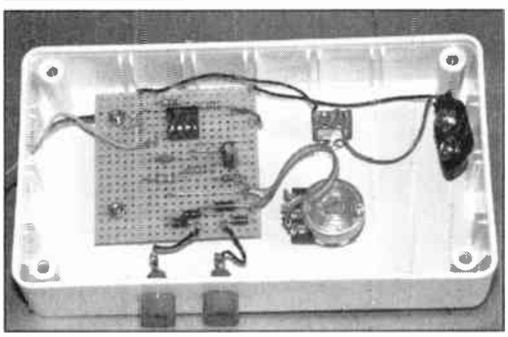
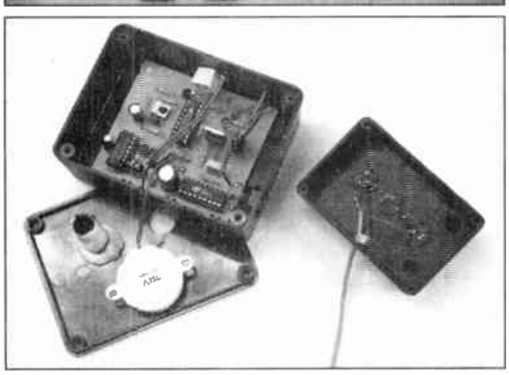








Our March 2000 issue will be published on Friday, 3 April 2000. See page 155 for details

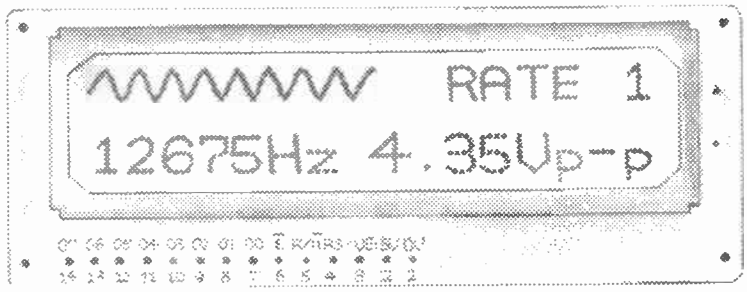
Projects and Circuits

Series and Features

Regulars and Services

NEXT MONTH

MICRO-PICSCOPE



It's astonishing what opportunities are continuing to be revealed for the recently introduced PIC16F87x series of microcontrollers. The Micro-PICscope is a prime example of a design idea whose implementation was greatly simplified by using one of these devices.

The Micro-PICscope is a handy little item of test gear and of benefit to anyone's workshop. Using an alphanumeric liquid crystal display, it is basically a signal tracer, but one with the great advantage that it shows a representation of the signal waveform being traced. This is shown across eight of the l.c.d. character cells and is a real-time trace of the monitored waveform.

Not only that, the display also shows the frequency of the signal being monitored, and its peak-to-peak voltage. The frequency range covered is basically for audio, but frequencies well to either side of this range can be traced.

Several ranges of control are offered by push-button selection, covering the sampling rate, and synchronisation on/off for the 'scope display. The signal input is switchable to provide different maximum peak voltage monitoring ranges. Selection of a.c. or d.c. input is provided.

The entire design requires only two i.c.s, a PIC microcontroller and an op.amp, plus a 2-line by 16-character intelligent l.c.d. Probably the simplest and cheapest 'scope ever.

Starter Project

FLASH SLAVE

Cameras have undoubtedly increased in sophistication over the last ten years or so, with features such as auto-focus and built-in flashguns now being commonplace. On the other hand, a few "standard" features seem to have become rarities that are featured on little more than a few up-market cameras. The humble flash socket certainly falls into this category.

For most users, this lack of an external flash connector is probably of little consequence, but it is a major drawback for anyone wishing to go beyond simple "point and shoot" flash photography. This easy-to-build, inexpensive little unit will fire a secondary flash without any connections to the camera, thus overcoming the problem.

GARAGE LINK

This circuit helps to prevent the garage door (or either door in the case of a double garage having twin doors) being left open all night. It works by establishing a radio link between the garage and some point inside the house. The unit indoors then provides an audible warning in the form of a short bleep every 45 seconds. It could also be used to monitor a range of other things around the home.

TECHNOLOGY TIMELINES – 3
Communications

TEACH-IN 2000 PART 6

PLUS: ALL THE REGULAR FEATURES

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DON'T MISS AN ISSUE – PLACE YOUR ORDER NOW!
Demand is bound to be high

APRIL ISSUE ON SALE FRIDAY, MARCH 4

£1 BARGAIN PACKS – List No. 7

RELAY, Omron, 3 sets changeover contacts, coil voltage 50V AC, 4 for £1. Order Ref: GR10R.
RELAY, MAT42, 4 sets changeover contacts, size 1in. x ¾in. x 1½in. high, coil voltage 50V AC, 4 for £1. Order Ref: GR11.
12V RELAY, 3-pole changeover, miniature, clear plastic, enclosed. Order Ref: GR30.
OPEN TYPE RELAY, 3 sets 8A changeover contacts, 115V coil, 2 for £1. Order Ref: 6R7.
REED RELAY 6V changeover contacts, embedded in plastic case for p.c.b. mounting. Order Ref: 22R11.
PO TYPE RELAY, almost collectors' item, 12V, 3 sets of contacts. Order Ref: 22R14.
5K POT, standard size with DP switch, good length ¼in. spindle, 2 for £1. Order Ref: 11R24.
STEREO POT, miniature, both sections 50k, ¼in. spindle, single hole fixing with hex nut, 2 for £1. Order Ref: 16R6.
DITTO but 200k, 2 for £1. Order Ref: 11R28.
13A PLUG, fully legal with insulated legs, 3 for £1. Order Ref: GR19.
16A ROCKER SWITCH, changeover or simple on/off, 2 for £1. Order Ref: GR37.
OPTO SWITCH on p.c.b., size 2in. x 1in., 2 for £1. Order Ref: GR21.
22µF ELECTROLYTIC, 25V working, 5 for £1. Order Ref: GR22.
MINIATURE EARPIECE, good length lead terminating in 3·5mm jack plug, 2 for £1. Order Ref: GR33.
3¼in. LOUDSPEAKER, 4 ohm, 2 for £1. Order Ref: 10R17.
SCREW DOWN TERMINAL, mounts through metal panel with own insulators, 2 hefty nuts for securing cable, 3 for £1. Order Ref: GR42.
ROTARY SWITCH WAFER, one pole 12-way break-before-make, 4 for £1. Order Ref: 11R18.
SUPERIOR IN-LINE SWITCHES, ideal for controlling electric blankets, etc., slide switch illuminated when on, blue or white, 2 for £1. Order Ref: 21R4.
LARGE TYPE MICROSWITCH with 2in.. lever, changeover contacts rated 15A at 250V, 2 for £1. Order Ref: 21R7.
DOUBLE-POLE TOGGLE SWITCH, Arrow, 10A 250V, hex fixing nuts, 2 for £1. Order Ref: 22R8.
SPRING-LOADED TOGGLE SWITCH, quite small, push down for on, automatically springs back to off, 5A 250V, 4 for £1. Order Ref: 22R9.
TOGGLE SWITCH, standard size, centre off, push down for on but automatically springs up, push up for permanently on, mains 3A, 2 for £1. Order Ref: 24R13.
DOUBLE-POLE TOGGLE SWITCH, standard size, little storage soiled, 4 for £1. Order Ref: 24R23.
SCALE TO GO UNDER CONTROL KNOB, size 2in. diameter, engraved 1 to 10 on white base, 2 for £1. Order Ref: 5R10.
QUARTZ HEATER BULB, Thorn Ref R16-221, 180W 75V. Order Ref: 5R1.
TV REMOTE CONTROLS, cases are ideal for new projects, 2 for £1. Order Ref: 1068.
HEATER CONTROLLER, 2 separate rocker switches, neon light between. Left-hand switch engraved on/off, right-hand boost, chrome plated frame. Order Ref: 7RC14.
SWITCH, 3 rockers but 2 and 3 can only come on if one is on, 2 for £1. Order Ref: 7RC22.
JAP MADE ADAPTOR, mains in 6V at 350mA DC out, cased and boxed, Crown AD81. Order Ref: 6R1.
INTERSTAGE TRANSFORMER for transistor circuits, quite small, 1in. wide, 1in. high, 2 for £1. Order Ref: 7RC12.
SPECIAL FERRITE ROD AERIAL, 8in. long, 5/16in. diameter rod with long and medium wave coils, solder tags and mounting clips. Order Ref: 7RC18.
PHILIPS CAPACITOR, 470µF 25V, axial ended, 5 for £1. Order Ref: 7RC25.
FOLD-OVER AERIAL, extends from 4in. to 2ft., plugs into a 4mm socket. Order Ref: 21R2.
SOCKET FOR BT FLAT PLUG, p.c.b. mounted, 2 for £1. Order Ref: 7RC24.
COMPONENT MOUNTING PANEL, heavy Paxolin 10in. x 2in., 32 pairs of brass pillars for soldering binding components. Order Ref: 7RC26.
RESETTABLE 3-DIGIT COUNTER, operated by 1in. diameter wheel, groove for belt, 2 for £1. Order Ref: 10R8.
MINI RADIO CASE, 70mm x 60mm x 30mm deep, gold embellished front cover over cream loudspeaker grille, 2 for £1. Order Ref: 16R1.
FLEX PROTECTORS, rubber, 30mm long, 8mm diameter with 12mm shoulder, 5 for £1. Order Ref: 21R10.
PEA LAMPS, only 4mm but 14V at 0·04A, wire-ended, 4 for £1. Order Ref: 7RC28.
WIRE-ENDED LAMPHOLDERS, MES, take screw-in Christmas lights, 10 for £1. Order Ref: 24R3.
SCREW-IN BULBS for the above lampholders, in different colours, 4 for £1. Order Ref: 24R4.
HIGH AMP THYRISTOR, normal 2 contacts from top, heavy threaded fixing underneath, think amperage to be at least 25A, 2 for £1. Order Ref: 7RC43.
TV AERIAL SOCKET, brown surface mounting plastic plate. Order Ref: 11R14.
LONG REACH KNOB, black body, silver metal inset, diameter approx. 17mm, push on to ¼in. flatted spindle, 10 for £1. Order Ref: 16R22.
PUSH ON KNOB, 1in. diameter metal face, 4 for £1. Order Ref: 16R36.
ANOTHER KNOB, long shafted push-on knob for flatted ¼in. spindle, face size approx. 18mm, 10 for £1. Order Reef: 16R39.
OVENSTAT, Satchwell, single hole fixing by hex nut. Order Ref: 16R38.
TELEPHONE EXTENSION CABLE, proper BT colours and tough white outer, ideal permanent extension. Order Ref: 1067.
BRIDGE RECTIFIER, ideal for 12V to 24V charger at 5A, 2 for £1. Order Ref: 1070.
3½in. 8 OHM SPEAKER, quite powerful 11W and waterproof. Order Ref: 1073.
TELEPHONE FLEX LEAD, 2m with flat plug one end and flat socket other end, ideal to take phone into another room. Order Ref: 1033.

ARE YOU A BIG BUYER?

We have to clear one of our stores and if you buy big, then you can have our already low-priced stock at half price, even less if you can come and collect because we will then give you an additional 10 per cent discount. If you can't collect, however, we will have to add the cost of carriage. Also these very low prices will not include VAT, except for the samples which will include VAT and carriage if order over £25.

LIGHT ALARM
Originally made by a large company to sell at around £10, this unit is in a very neat plastic case. Was intended for fixing inside a cupboard to ring a bell should the cupboard be opened, ideally to prevent children or others getting at medicines, etc. If you can buy 100 of these, then the price is £150, 50 for £85 or a sample for £3. Order Ref: BB1.

WATER LEVEL ALARM
Neatly cased, this was intended for fixing above the bath. You pull out the sensor to the level you want the water to rise and when the water reaches the sensor a bell rings. Again 100 for £150, 50 for £85 or a sample for £3. Order Ref: BB2.

CASED BURGLAR ALARM
Originally intended to be sold at around £50. This is an ultrasonic detector, battery operated, with its own internal bell. It also has an output connector for external speaker or light. 100 for £450, 50 for £250 or a sample for £10. Order Ref: BB3.

3 OCTAVE KEYBOARD
Has a 3 octave board with piano size keys. Originally intended to be sold for just under £20. 100 for £450, 50 for £250 or a sample for £10. Order Ref: BB4.

BT TELEPHONE EXTENSION WIRE
This is a proper heavy-duty cable for running round skirting boards, etc., when you want to make a permanent extension. External PVC cover is white and its 4 cores are properly colour coded to the BT spec. In coils of 20m length, 100 for £150, 50 coils for £85. Order Ref: BB5.

12V 18AH SEALED LEAD ACID BATTERY
Similar batteries are sold at the regular price of around £40. If you can buy 100, you can have them for £1,000, 50 for £600 or a sample for £12.50. Order Ref: BB6.

ULTRAVIOLET VIEWING UNIT
For sorting out the dud bank notes, etc. Completely cased and with UV tube, mains operated, 100 for £600, 50 for £400 or a sample for £12. Order Ref: BB7.

SILICON DIODES
Spread over 20 different types, some on reels, some on boxes. 100,000 available in one lot, price £500. Order Ref: BB8.

BATTERY OPERATED MOTORS
Originally intended for model aircraft, these do not require a switch as they are spin-to-start. Buy 1,000 and you can have them for £100. Order Ref: BB9.

PRESSURE SWITCH
Intended for low pressures, different water levels for instance will operate this and it contains 3 switches, each of which is operated at different levels. Can be mouth operated, 10 for £50, 50 for £30, sample £1. Order Ref: BB10.

MAINS OPERATED SOLENOIDS
Complete with plunger, these are very powerful, 100 for £50, 50 for £30, sample for £1. Order Ref: BB11.

SMALL MAINS TRANSFORMER
In plastic case and potted, p.c.b. mounting, output 18V-0V-18V at 10VA. 100 for £50, 50 for £30, sample £1. Order Ref: BB12.
DITTO but 15V-9V-15V 10VA, 100 for £50, 50 for £30, sample £1. Order Ref: BB13.

TELEPHONE LEADS
2 metres long and with the normal BT flat pin plug one end. Ideal for phone extensions, etc. 200 for £50, 100 for £30, sample £1. Order Ref: BB14.

COOKER CLOCK
Mains operated with normal dial, this also has switch connections. 100 for £50, 50 for £30, sample £1. Order Ref: BB15.

12V 2A BATTERY CHARGER
This is made by Amstrad, they call it a power supply. It has an output of 13½V at 1·7A, but to a discharged 12V battery this will charge at around 3A, the charging rate gradually dropping off as the battery charges. In a neat plastic case with input and output leads of good length. 100 for £300, 50 for £175, sample £6. Order Ref: BB16.

SOLAR TOYS
All the parts to make a bi-plane whose propeller will rotate in sunlight or under a 100W bulb. 100 for £350, 50 for £200, sample £7. Order Ref: BB17.
SIMILAR KIT, but when made up this is an old-fashioned gramophone. 100 for £350, 50 for £200, sample £7. Order Ref: BB18.

12V BRUSHLESS FAN
Made by the Japanese Nipon company, approximately 93mm square. 100 for £200, 50 for £125, sample £4. Order Ref: BB19.

AM/FM RADIO
With l.c.d. display and switching for alarms, etc. 100 for £200., 50 for £125, sample £4. Order Ref: BB20.

PRECISION MAINS MOTOR
Made by famous Japanese company. This is 1500r.p.m. reversible, really beautifully made, originally intended for tape recorder. 100 for £200, 50 for £125, sample £4. Order Ref: BB21.

TERMS
Send cash, PO, cheque or quote credit card number – orders under £25 add £3.50 service charge.

J & N FACTORS

Pilgrim Works (Dept. E.E.)
Stairbridge Lane, Bolney, Sussex RH17 5PA
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The latest MAGENTA DESIGN – highly stable & sensitive – with I.C. control of all timing functions and advanced pulse separation techniques.

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

KIT 847.....................£63.95

PORTABLE ULTRASONIC PEsT SCARER

A powerful 23kHz ultrasound generator in a compact hand-held case. MOSFET output drives a special sealed transducer with intense pulses via a special tuned transformer. Sweeping frequency output is designed to give maximum output without any special setting up.

KIT 842.......................£22.56

MK. II ACOUSTIC PROBE

- NEW DESIGN
- HIGH SENSITIVITY & POWER

Picks up vibrations amplifies, and drives headphones. Sounds from engines, watches, pipes and speech through walls can be heard clearly. Useful for mechanics, instrument engineers and nosey parkers! Very effective device.

KIT 876.......................£29.95

DC Motor/Gearboxes

Our Popular and Versatile DC motor/Gearbox sets. Ideal for Models, Robots, Buggies etc. 1·5 to 4·5V Multi ratio gearbox gives wide range of speeds.

LARGE TYPE – MGL £6.95
SMALL – MGS – £4.77

Stepping Motors

MD38...Mini 48 step...£8.65
MD35...Std 48 step...£9.99
MD200...200 step...£12.99
MD24...Large 200 step...£22.95

PIC PIPE DESCALER

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

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

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

MICRO PEsT SCARER

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

- **RANDOM PULSES**
- **HIGH POWER**
- **DUAL OPTION**

Plug-in power supply £4.99

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

WINDICATOR

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

KIT 856...£28.00

★ TENS UNIT ★

DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Set of 4 spare electrodes **£6.50**

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

KIT 866.... Full kit including four electrodes £32.90

1000V & 500V INSULATION TESTER

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

KIT 848...................£32.95

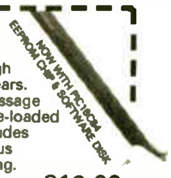
EPE TEACH-IN 2000

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

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

SPACEWRITER

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



KIT 849......................£16.99

12V EPROM ERASER

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

KIT 790...........................£29.90

SUPER BAT DETECTOR

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

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

KIT 861......................£24.99
ALSO AVAILABLE Built & Tested £39.99

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

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

Kit No. 845................£64.95

EPE PROJECT PICs

Programmed PICs for all* EPE Projects
16C84/16F84/16C71
All **£5.90 each**
PIC16F877 now in stock
£10 inc. VAT & postage
(*some projects are copyright)

ULTRASONIC PEsT SCARER

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

- KIT INCLUDES ALL COMPONENTS, PCB & CASE
- EFFICIENT 100V TRANSDUCER OUTPUT
- COMPLETELY INAUDIBLE TO HUMANS
- UP TO 4 METRES RANGE
- LOW CURRENT DRAIN

KIT 812...£15.00

SIMPLE PIC PROGRAMMER

INCREDIBLE LOW **PRICE!** Kit 857 **£12.99**

INCLUDES 1-PIC16F84 CHIP SOFTWARE DISK, LEAD CONNECTOR, PROFESSIONAL PC BOARD & INSTRUCTIONS

Power Supply £3.99

EXTRA CHIPS: PIC 16F84 £4.84

Based on February '96 *EPE*. Magenta designed PCB and kit. PCB with 'Reset' switch, Program switch, 5V regulator and test L.E.D.s, and connection points for access to all A and B port pins.

PIC16C84 LCD DISPLAY DRIVER

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

Kit 860 **£19.99**

Power Supply £3.99

FULL PROGRAM SOURCE CODE SUPPLIED – DEVELOP YOUR OWN APPLICATION!

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

PIC16F84 MAINS POWER 4-CHANNEL CONTROLLER & LIGHT CHASER

- WITH PROGRAMMED 16F84 AND DISK WITH SOURCE CODE IN MPASM
- ZERO VOLT SWITCHING MULTIPLE CHASE PATTERNS
- OPTO ISOLATED 5 AMP OUTPUTS
- 12 KEYPAD CONTROL
- SPEED/DIMMING POT.
- HARD FIRED TRIACS

Now features full 4-channel chaser software on DISK and pre-programmed PIC16F84 chip. Easily re-programmed for your own applications. Software source code is fully 'commented' so that it can be followed easily.

Kit 855 **£39.95**

LOTS OF OTHER APPLICATIONS

PIC TOOLKIT V1

- PROGRAMS PIC16C84 and 16F84 • ACCEPTS TASM AND MPASM CODE

Full kit includes PIC16F84 chip, top quality p.c.b. printed with component layout, turned pin PIC socket, all components and software*
*Needs QBASIC or QUICKBASIC

KIT 871 . . . **£13.99.** Built and tested **£21.99**

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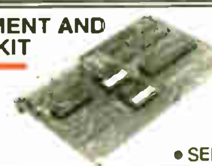
ALL PARTS FOR SERIES INCLUDING PCBs, PROGRAMMED CHIP, CD-ROM AND DISPLAYS

MAIN BOARD – FULL KIT	**£131.95**	BUILT	**£149.95**
I/O PORT KIT	**£16.99**	BUILT	**£24.99**
L.C.D.	**£12.49**	POWER SUPPLY	**£3.99**
8-BIT SWITCH/LATCH	**£7.95**	INT. MODULE	**£10.45**

68000 DEVELOPMENT AND TRAINING KIT

KIT 621 **£99.95**

- NEW PCB DESIGN
- 8 MHz 68000 16-BIT BUS
- MANUAL AND SOFTWARE
- 2 SERIAL PORTS
- PIT AND I/O PORT OPTIONS
- I2C PORT OPTIONS



- ON BOARD 5V REGULATOR
- PSU £6.99
- SERIAL LEAD £3.99

Mini-Lab & Micro Lab Electronics Teach-In 7

As featured in *EPE* and now published as Teach-In 7. All parts are supplied by Magenta. *Teach-In 7* is £3.95 from us or *EPE*

Full Mini Lab Kit – £119.95 –
Power supply extra – £22.55
Full Micro Lab Kit – £155.95
Built Micro Lab – £189.95

EPE PIC Tutorial

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

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

PIC TUTOR BOARD KIT

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

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

Optional: **Power Supply – £3.99, ZIF Socket – £9.99**
LCD Display ....£7.99   LED Display £6.99

Reprints Mar/Apr/May 98 – **£3.00 set 3**

PIC TOOLKIT V2

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

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

SUPER PIC PROGRAMMER

- READS PROGRAMS AND VERIFIES
- WINDOWS™ SOFTWARE
- PIC16C6X, 7X, AND 8X
- USES ANY PC PARALLEL PORT
- USES STANDARD MICROCHIP • HEX FILES
- OPTIONAL DISASSEMBLER SOFTWARE (EXTRA)
- PCB, LEAD, ALL COMPONENTS, TURNED PIN SOCKETS FOR 18, 28, AND 40 PIN ICs.

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

Kit 862 **£29.99**

Power Supply £3.99

DISASSEMBLER SOFTWARE £11.75

PIC STEPPING MOTOR DRIVER

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

Kit 863 **£18.99**

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

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

8-CHANNEL DATA LOGGER

NEW!

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

KIT 877 £49.95 inc. 8 x 256K EEPROMS

MAGENTA

All pricesinclude VAT. Add £3.00 p&p. Next Day £6.99

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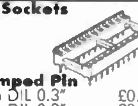
All Major Credit cards Accepted SWITCH SOLO

Prices Exclude Vat @17½%. Add £1.25 carriage & Vat to all orders. Cheques / Postal orders payable to ESR Electronic Components.

See Next / Last Months Ad. for COMPONENT ACCESSORIES

DIL Sockets



Stamped Pin
6 Pin DIL 0.3" £0.06
8 Pin DIL 0.3" £0.06
14 Pin DIL 0.3" £0.11
16 Pin DIL 0.3" £0.11
18 Pin DIL 0.3" £0.12
20 Pin DIL 0.3" £0.12
24 Pin DIL 0.6" £0.12
28 Pin DIL 0.6" £0.13
40 Pin DIL 0.6" £0.19

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14 Pin DIL 0.3" £0.20
16 Pin DIL 0.3" £0.23
18 Pin DIL 0.3" £0.25
20 Pin DIL 0.3" £0.28
24 Pin DIL 0.6" £0.35
28 Pin DIL 0.6" £0.39
40 Pin DIL 0.6" £0.64

ZIF Sockets
Universal ZIF DIL Sockets
24 Way 0.3-0.6" £5.78
28 Way 0.3-0.6" £6.75
32 Way 0.3-0.6" £7.47
40 Way 0.3-0.6" £8.93

Transistor Sockets
T018-4 Base Socket £0.24
T05 Base Socket £0.24

IDC Cable Sockets

10 Way Socket £0.25
14 Way Socket £0.35
16 Way Socket £0.37
20 Way Socket £0.37
26 Way Socket £0.38
34 Way Socket £0.39
40 Way Socket £0.55
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IDC Cable Plugs *NEW*
10 Way Plug £0.58
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16 Way Plug £0.68
20 Way Plug £0.72
26 Way Plug £0.76
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40 Way Plug £1.00
50 Way Plug £1.22

PCB Box Headers

10 Way Straight £0.23
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26 Way Straight £0.55
34 Way Straight £0.68
40 Way Straight £0.75
50 Way Straight £1.03
10 Way 90° £0.32
14 Way 90° £0.44
16 Way 90° £0.42
20 Way 90° £0.63
26 Way 90° £0.82
34 Way 90° £0.81
40 Way 90° £1.17
50 Way 90° £1.14

PCB Latch Headers

10 Way Straight £0.41
14 Way Straight £0.45
16 Way Straight £0.51
20 Way Straight £0.55
26 Way Straight £0.73
34 Way Straight £0.88
40 Way Straight £0.92
50 Way Straight £1.27
10 Way 90° £0.46
14 Way 90° £0.48
16 Way 90° £0.54
20 Way 90° £0.59
26 Way 90° £0.81
34 Way 90° £1.03
40 Way 90° £1.23
50 Way 90° £1.41

DIL Headers

14 Way DIL £0.51
16 Way DIL £0.53
24 Way DIL £0.90
40 Way DIL £1.37

Transistion Headers
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14 Way Transistion £0.42
16 Way Transistion £0.48
20 Way Transistion £0.48
26 Way Transistion £0.52
34 Way Transistion £0.56
40 Way Transistion £0.63
50 Way Transistion £0.84

Large Range of Connectors available - contact our sales department for full details

D Type Connectors

Solder Bucket
9 Way Male Plug £0.24
9 Way Female Socket £0.24
15 Way Male Plug £0.36
15 Way Female Socket £0.39
15 Way H.D. Plug £0.48
15 Way H.D. Socket £0.64
23 Way Male Plug £0.44
23 Way Female Socket £0.50
25 Way Male Plug £0.36
25 Way Female Skt £0.37

IDC Ribbon Mounting
9 Way Male Plug £1.08
9 Way Female Socket £0.93
15 Way Male Plug £1.32
15 Way Female Socket £1.32
25 Way Male Plug £1.18
25 Way Female Socket £1.13

Right Angled PCB

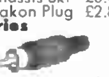
9 Way Mole Plug £0.33
9 Way Female Socket £0.33
15 Way Male Plug £0.39
15 Way Female Socket £0.39
15 Way H.D. Socket £0.58
25 Way Male Plug £0.52
25 Way Female Socket £0.51

Plastic D Covers
9 Way Cover - Grey £0.29
9 Way Cover - Black £0.30
15 Way Cover - Grey £0.32
23 Way Cover - Grey £0.38
23 Way Cover - Black £0.38
25 Way Cover - Grey £0.34
25 Way Cover - Black £0.37
9 to 9 Cover / Case £0.80
25 to 25 Cover / Case £0.84
9 to 25 Cover / Case £0.80

Audio Connectors

2.5mm Jack Plug £0.21
2.5mm Line Socket £0.16
2.5mm Chassis Socket £0.20
3.5mm Mono Plug £0.24
3.5mm Mono Line Skt £0.30
3.5mm Mono Chassis £0.14
3.5mm Stereo Plug £0.36
3.5mm Stereo Line Skt £0.37
3.5mm Stereo Chassis £0.34
¼" Mono Plug £0.34
¼" Mono Line Socket £0.35
¼" Mono Chassis Sk £0.35
¼" Stereo Plug £0.40
¼" Stereo Line Socket £0.38
¼" Stereo Chassis Skt £0.40
NEUTRIK Speakon Plug £2.81

Phono Series



Red Line Plug £0.20
Black Line Plug £0.20
Yellow Line Plug £0.20
White Line Plug £0.20
Red Line Socket £0.20
Black Line Socket £0.20
Yellow Line Socket £0.20
White Line Socket £0.20
Red Chassis Socket £0.20
Black Chassis Socket £0.20
Gold Plated Plug Red £0.66
Gold Plated Plug Black £0.66

XLR Series - metal

3 Pin Line Plug £1.46
3 Pin Line Socket £1.71
3 Pin Chassis Plug £1.50
3 Pin Chassis Socket £1.49
Neutrik Line Plug £1.68
Neutrik Line Socket £1.99
Neutrik Chassis Plug £2.13
Neutrik Chassis Socket £2.32

RF Connectors

BNC Plug 50Ω Solder £0.99
BNC Plug 50Ω Crimp £0.68
BNC Plug 75Ω Solder £0.95
BNC Plug 75Ω Crimp £0.68
BNC Chassis Socket £0.81
F Plug - Twist £0.24
F Plug - Crimp £0.26
TNC Plug 50Ω Solder £1.24
TNC Plug 50Ω Crimp £0.85
TNC Plug 75Ω Solder £1.40
TNC Plug 75Ω Crimp £1.16
UHF Plug 5mm Cable £0.63
UHF Plug 11mm Cable £0.75
UHF Chassis Skt- Sqr £0.50
UHF Chassis Skt- Rnd £0.73
Extensive range of RF connectors in stock, inc.FME, SMA, Mini UHF & N Type.

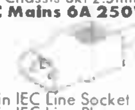
Terminals

Colours Red, Black, Green, Blue, White or Yellow
2mm Solder Plugs £0.18
2mm Chassis Sockets £0.26
4mm Solder Plugs £0.35
4mm Stackable Plugs £0.40
4mm Chassis Sockets £0.24
4mm Binding Posts £0.54
33mm Crocodile Clips £0.13

Power Connectors DC Low Voltage

DC Plug 0.7ID 2.35OD £0.47
DC Plug 1.3ID 3.4OD £0.32
DC Plug 1.7ID 4.0OD £0.47
DC Plug 1.7ID 4.75OD £0.47
DC Plug 2.1ID 5.0OD £0.25
DC Plug 2.5ID 5.0OD £0.24
DC Plug 3.1ID 6.3OD £0.46
DC Line Socket 2.1mm £0.57
DC Line Socket 2.5mm £0.56
DC Chassis Skt 2.1mm £0.40
DC Chassis Skt 2.5mm £0.41

IEC Mains 6A 250Vac

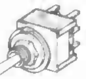


3 Pin IEC Line Socket £1.08
3 Pin IEC Line Plug £1.78
3 Pin Chassis Socket £0.55
3 Pin Chassis Plug £0.72

8 Way Bulgin

8 Pin Line Plug P551 £4.08
8 Pin Chassis Skt P552 £1.39

Toggle Switches

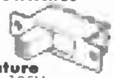


Sub-Miniature
3A 125V 1A 250V
5mm Ø Mounting Hole
SPST 5 x 10mm £0.58
SPDT 5 x 10mm £0.60
SPDT C/Off 5 x 10mm £0.81
DPDT 9.2 x 10mm £0.66

Miniature
6A 125V 3A 250V
6.2mm Ø Mounting Hole
SPST 8 x 13mm £0.65
SPDT 8 x 13mm £0.56
SPDT c/off 8 x 13mm £0.60
SPDT c/o Biased 2 way £0.97
SPDT c/o Biased 1 way £1.04
DPDT 12 x 13mm £0.72
DPDT c/off 12 x 13mm £0.80
DPDT c/o Biased 2 way £1.28
DPDT c/o Biased 1 way £1.28

Standard
10A 250V Push on terminals
12mm Ø Mounting Hole
SPST 18 x 30mm £1.28
SPDT 18 x 30mm £1.31
SPDT c/off 18 x 30mm £1.43
DPDT 21 x 30mm £1.65
DPDT c/off 21 x 30mm £1.68

Slide Switches



Miniature
300mA 125V
7 x 15mm Mounting Hole
DPDT 7 x 23mm £0.20

Standard
1A 125V
5.5 x 12mm Mounting Hole
DPDT 12 x 35mm £0.25
DPDT c/o 12 x 35mm £0.27

Rotary Switches

150mA 250V
Make before Break 22mm Ø
9.8mm Ø Mounting Hole
1 Pole 12 Way £0.84
2 Pole 6 Way £0.84
3 Pole 4 Way £0.84
4 Pole 3 Way £0.84

Push Switches

Miniature Round
250mA 125V 28 x 10mm
7mm Ø Mounting Hole
Non Latching Push to Make
Black PTM £0.23
Red PTM £0.23
Yellow PTM £0.23
Green PTM £0.23
Blue PTM £0.23
White PTM £0.23
Non Latching Push to Break
Black PTB £0.24

Standard Square

1A 250V
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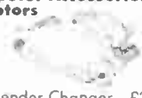

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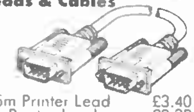

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BASH, WIND, WIRE

Occasionally a project comes along that makes you realise just how clever some of our modern i.c.s are. One such project is the *Micro-PICscope* to be featured next month (see page 155 for details). When I was an apprentice with the Ministry of Aviation (now MoD), back in the distant past, we built a *Wireless World* Oscilloscope – in those days *Wireless World* (now *Electronics World*) actually published constructional projects.

To build the 'scope you first spent a week "chassis bashing", we also had to weld up the sides of the aluminium chassis and if you have ever tried welding aluminium you will know that many of us had to start again when the prized chassis fell into holes under the welding torch! Then you fitted the transformers, valve bases – about six as I recall – switches, pots, tagstrips and the oscilloscope tube, inside its mu-metal screen; after which you could start wiring it all up. Oh, by the way, we also had to wind our own mains transformer and e.h.t. transformer before we started on the electronics.

By the time the unit was finished it weighed about 10kg and measured around 500mm × 300mm × 250mm, plus the performance was rather limited and it took five minutes to warm up. Now just 30 years on we can do roughly the same thing with two chips and an l.c.d., put it in your pocket, power it from a battery and build it for under £20. Accepted the performance is very limited and so, too, is the display, but it is a useful little tool for any hobbyist. We expect it to be very popular and there are a couple of other PIC-based items of test gear in the pipeline.

TERRY

We dedicate this issue to Terry Farmiloe, our Typesetting Manager, who died on Jan. 2nd, aged 61. Terry had a gruff exterior which hid a heart of gold, we miss him gently winding everyone up in the office. While his name will not be known to readers, he has been responsible for running our typesetting department, and thus the production of *EPE* and other publications, for the last 10 years.

Good luck on your onward journey. Terry, we miss you greatly. Our sympathy goes to your loving family.

Mike Kenward

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PARKING WARNING SYSTEM

TOM WEBB

How to avoid having an unwanted rear entrance to your garage!

THIS is a device to aid you in parking a car in a garage by providing a visual and audible warning. It is easily set up by mounting it onto the wall at the end of the garage.

The device produces a coded infra-red (IR) beam which detects the proximity of the vehicle by bouncing IR off it as it approaches, without being confused by other IR sources. When the vehicle is within the preset range, an audible warning is given and a group of light emitting diodes (l.e.d.s) are turned on.

The block diagram in Fig.1 shows how the circuit is split up into separate sections.

INFRA-RED CODING

A system based on a continuous IR signal would fail in this type of application, since the receiving circuit would be heavily influenced by stray background IR emission from lights etc. A coded IR signal is better since the receiver can be set up to only accept a specific code.

There are a number of encoding and decoding i.c.s available but two from Holtek are used for this circuit. The HT12B transmitter encodes the signal and adds a 38kHz carrier signal for greater reliability. A separate demodulating sensor detects the coded signal and provides a clean output waveform with the 38kHz carrier removed. An HT12D decoder then decodes the signal to give a steady output.

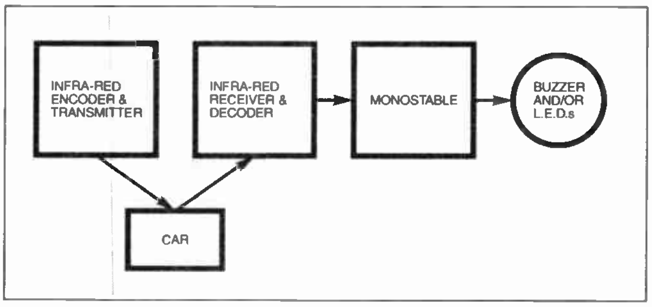
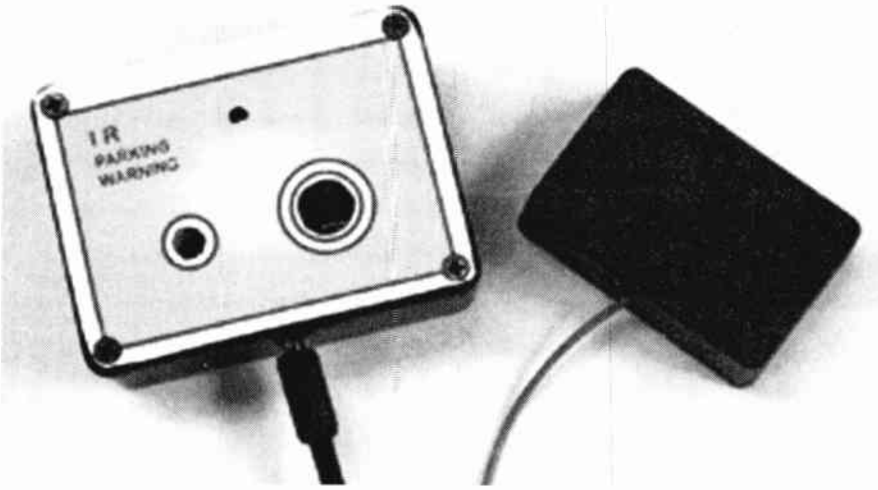


Fig.1. Parking Warning System block diagram.

CODED TRANSMITTER

Either the HT12A or HT12B transmitter devices may be used in the coded transmission circuit. They work in exactly the same way except the four data outputs of the HT12A are inverted as compared with the HT12B. However, since these outputs are not used in this circuit, this is of no importance.



Referring to the full circuit diagram in Fig.2, pins A0 to A7 of the transmitter IC2 set the coded signal for the IR transmission, which can only be accepted by a decoder chip (IC3 in Fig.2) with the same settings. The printed circuit board is designed so that pins A0 and A1 are connected to the 0V supply line, pins A2 to A7 being left unconnected.

Pin 9 of IC2 is connected to 0V and pin 18 connected to the positive supply, which should not exceed +5V. IC2 pins 11 to 14 are not used. The pins labelled X1 and X2 are the oscillator control pins, and require a 455kHz ceramic resonator (component X1) along with resistor R6 and two capacitors, C2 and C3.

The D_{OUT} pin provides a coded output superimposed on a carrier signal of 38kHz which, with the aid of Darlington transistor amplifier TR2, operates the IR light emitting diode D1.

Potentiometer VR1 allows the transmission power to be varied. Ballast resistor R8 prevents a power supply short circuit through D1 and TR2 when VR1 is set to minimum resistance.

IC2 pin 10 is connected to ground to hold the transmitter perpetually triggered.

INFRA-RED RECEIVER

The IR sensor/amplifier/demodulator, IC1, is housed in a package resembling a small power transistor. The receiver rejects all IR transmissions except the required 38kHz signal, and provides a clean output (easily viewed on an oscilloscope). There are three possible receivers that perform the functions required, but in tests the best performer for this circuit was the PIC26043S (*not* a PIC microcontroller!).

When the detector detects a signal having a frequency of 38kHz, its output goes high. Transistor TR1 inverts this level and supplies it to the decoder IC3 at D_{IN} (pin 14).

The code to which IC3 responds is set by its pins A0 to A7. Since pins A0 and A1 on

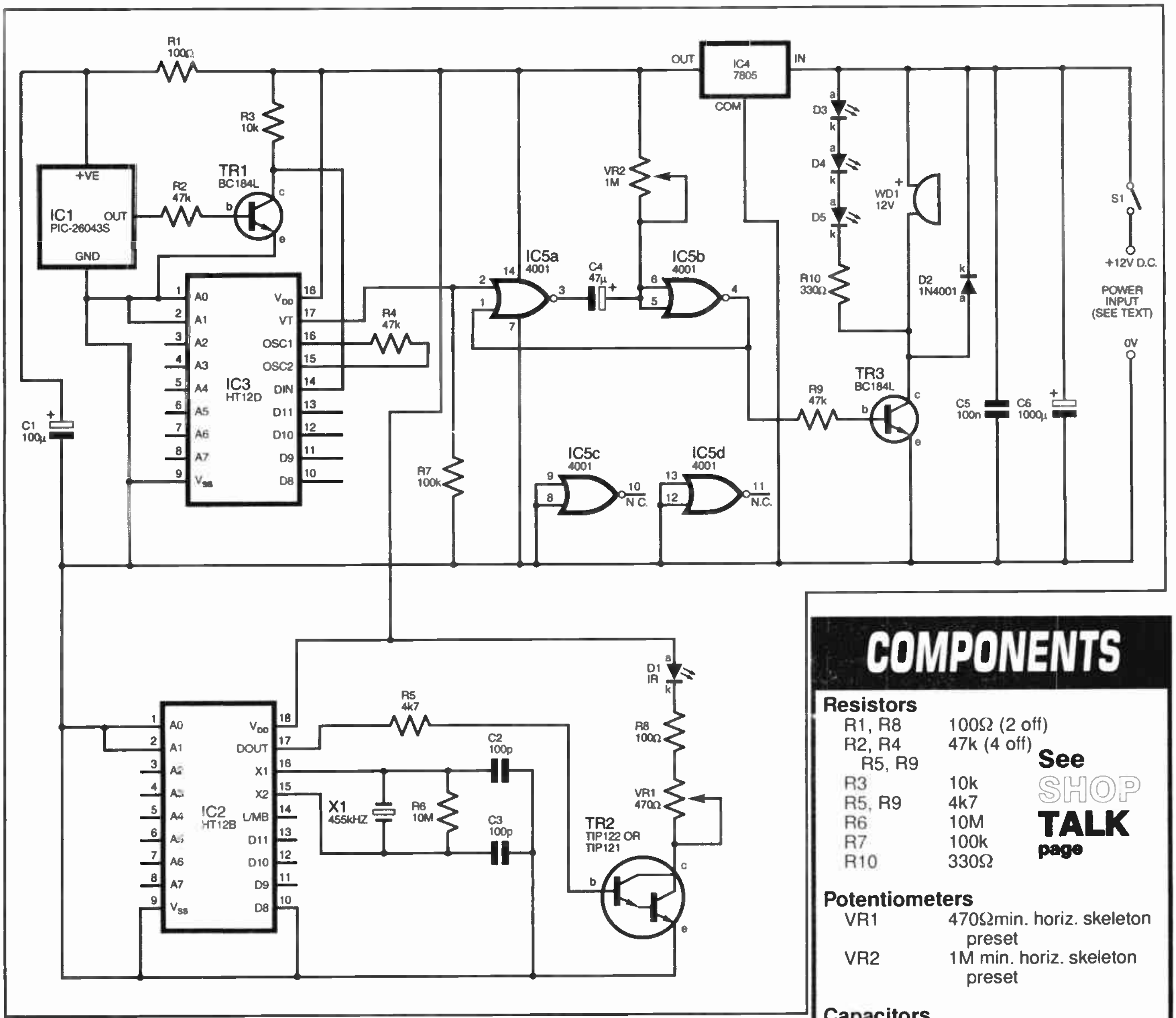


Fig.2. Complete circuit diagram for the Parking Warning System. The Transmitter is the lower section (IC2/TR2) of the circuit.

transmitter IC2 are connected to 0V, the same pins on IC3 are also connected to 0V.

Resistor R4 sets the oscillation frequency for IC3 to the required 150kHz. The value is chosen to suit a power supply of between 4·5V and 5V. When IC3 receives a correctly coded signal, its pin 17 (VT) goes high. This triggers the monostable formed by IC5a and IC5b. When the VT pin of IC3 is open circuit (no signal being received), resistor R7 draws the input pin of the monostable to 0V. Once triggered, the monostable's output remains high for a period set by the values of C4 and VR2.

The formula used to calculate this period is $T = 0{\cdot}7 \times R \times C$. With VR2 set to 100kΩ, the period will be $0{\cdot}7 \times 0{\cdot}1\text{M}\Omega \times 47\mu\text{F} = 3{\cdot}29$ seconds.

The output from the monostable, at IC5b pin 4, is fed to transistor TR3 via resistor R9. When the output level is high, TR3 is turned on and drives the warning buzzer WD1 and turns on l.e.d.s D3 to D5. Diode D2 prevents back e.m.f. from the buzzer which might otherwise damage the circuit. R10 is a ballast resistor to limit the current through the l.e.d.s.

POWER SUPPLY

Power to the circuit is intended to be from a 12V mains adaptor as the circuit will need to be left switched on for long periods of time. A supply of 12V is required in order to power the buzzer. The power supply is regulated down to 5V by IC4 to suit the rest of the circuit.

If a buzzer is not being used then diode D2 can be omitted and a supply of 5V (or 4·5V) could be used by inserting a wire link in the place of regulator IC4 (between its In and Out pins). However, in this case, the value of l.e.d. ballast resistor R10 should be reduced to about 180 ohms. This also means that batteries could be used as the standby current is less than 10mA.

Capacitors C5 and C6 decouple the power fed to IC4. Capacitor C1 and resistor R1 smooth out the voltage supplied to the receiver device, IC1.

CONSTRUCTION

Apart from the buzzer and l.e.d.s, all the components are contained on a single printed circuit board (p.c.b.). The topside component layout and full size underside

COMPONENTS

Resistors

R1, R8	100Ω (2 off)
R2, R4, R5, R9	47k (4 off)
R3	10k
R5, R9	4k7
R6	10M
R7	100k
R10	330Ω

See SHOP TALK page

Potentiometers

VR1	470Ωmin. horiz. skeleton preset
VR2	1M min. horiz. skeleton preset

Capacitors

C1	100µ elect. radial, 25V
C2, C3	100p (2 off)
C4	47µ elect. radial, 25V
C5	100n ceramic
C6	1000µ elect. radial, 25V

Semiconductors

D1	IR diode
D2	1N4001 rectifier diode
D3 to D5	red l.e.d. (3mm or 5mm)
TR1, TR3	BC184L *npn* transistor (2 off)
TR2	TIP122 (or TIP121) *npn* Darlington transistor
IC1	PIC26043S IR receiver
IC2	HT12B (or HT12A) encoder
IC3	HT12D decoder
IC4	78L05 +5V 100mA regulator
IC5	4001B quad NOR gate

Miscellaneous

S1	s.p.s.t. toggle switch (optional)
WD1	buzzer, 12V
X1	455kHz resonator

Printed circuit board, available from the *EPE PCB Service*, code 258; plastic case to suit (2 off, see text); 14-pin d.i.l. socket; 18-pin d.i.l. socket (2 off); connectors for power and l.e.d. cables (see text); p.c.b. pillars (4 off); connecting wire; solder, etc.

Approx. Cost Guidance Only £18

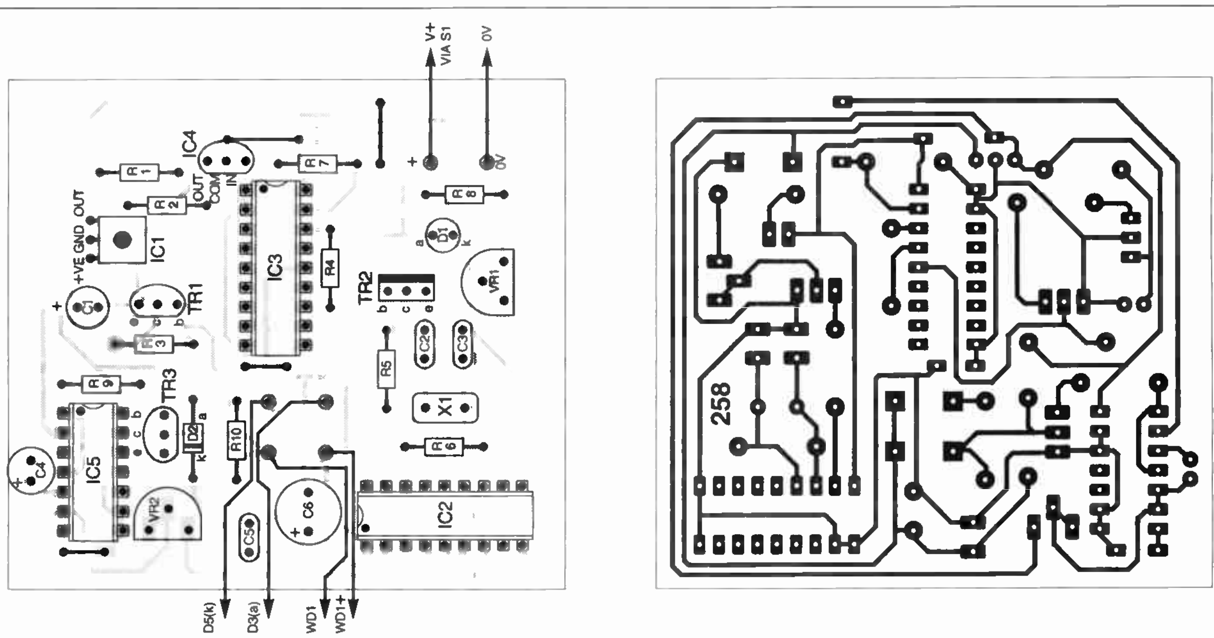


Fig.3. Printed circuit board topside component layout and (top right) full size underside copper foil master.

copper foil master are shown in Fig.3. This board is available from the *EPE PCB Service*, code 258.

Begin construction by soldering in the resistors and the four wire links. Ensure the correct orientation in the p.c.b. for components C1, C4, C6, TR1 to TR3, D1 and D2. Capacitors C2, C3 and C5 may be connected either way round.

Note that on the IR diode, D1, the long leg is likely to be the cathode (k), but check this with the component supplier's catalogue.

Infra-red receiver IC1 has a "dome" on its sensitive side which should face outwards from the p.c.b. Once soldered in, IC1 should be bent back to so that the dome is facing upwards.

Use i.c. sockets for IC2, IC3 and IC5. Do not insert the dual-in-line (d.i.l.) i.c.s until construction has been completed and fully checked.

CASING

Two plastic cases will be needed as the l.e.d.s need their own separate case in order to be seen through the rear windscreen of the car.

The circuit board is mounted in its own case on small p.c.b. supports which firmly secure it in place, see Fig.4. Drill holes in the case to suit the positions of the IR receiver and IR diode, see photographs. The hole for the IR receiver should not be too small otherwise the range will be reduced. If maximum range is required then the IR receiver should be positioned right by the hole.

If you prefer to have plugged connections for the power supply input and for the output to the l.e.d.s, suitable holes should also be drilled for their sockets. You also need a hole for the power on/off switch if you decide to use one, although one was not used on the prototype.

Additionally, two holes are required to allow adjustment access to the two preset potentiometers, using a small screwdriver. All holes should be drilled accurately to correspond with their respective components.

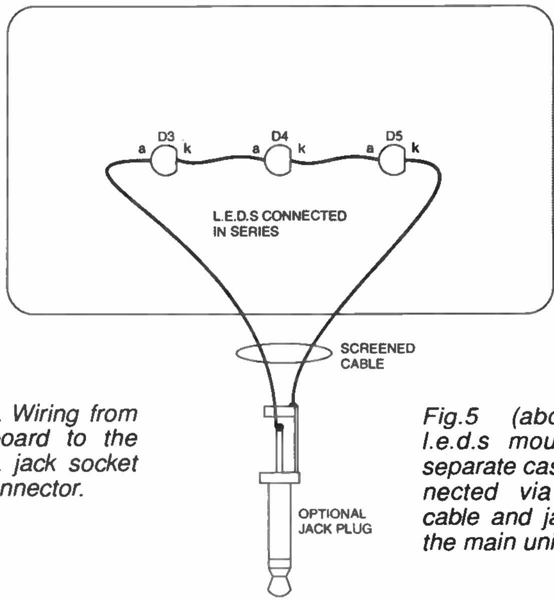
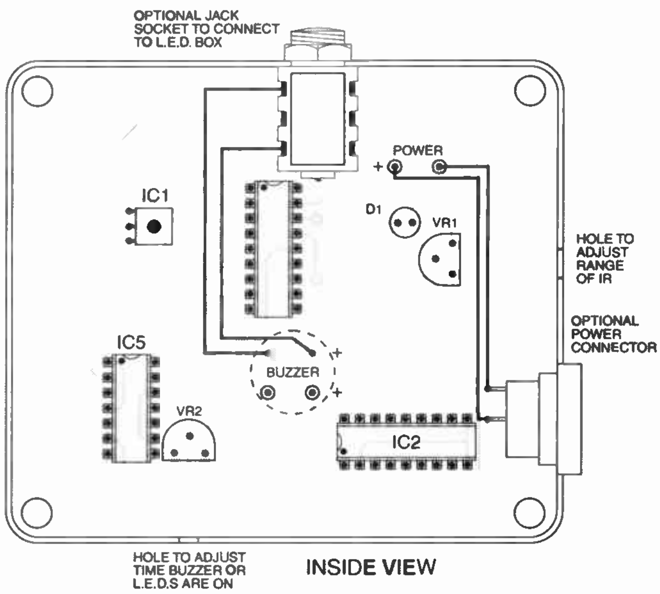


Fig.5 (above). The l.e.d.s mounted in a separate case and connected via screened cable and jack plug to the main unit.

Fig.4 (below). Wiring from the circuit board to the optional l.e.d. jack socket and power connector.



The l.e.d.s mounted in their separate case can be connected to the circuit using single screened wire, as shown in Fig.5.

TESTING

The first check is to make sure the voltage regulator IC4 is the correct way around. Connect the circuit to the 12V power supply and then check that 5V is present on the output pin of IC4. If it is, then disconnect the power and insert the remaining chips, correctly orientated.

Testing of the IR modules presents a problem as if one doesn't work then the other will seem not to be working as well. If in doubt use a voltmeter or oscilloscope as follows:

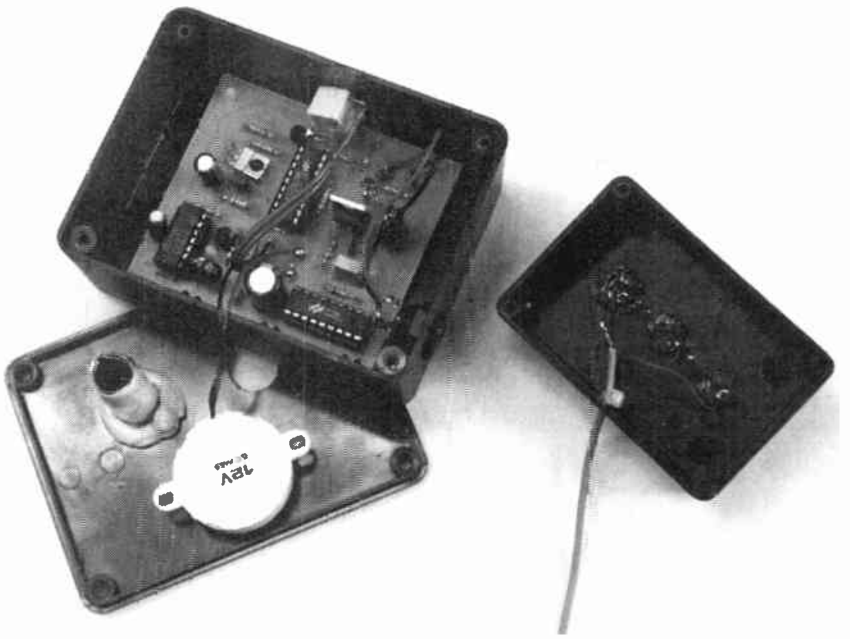
Test the voltage on the VT pin (pin 17) on IC3 of the receiver module. It should normally be at 0V but change to about 5V when a signal is received. Now check the voltage on the pins of IC1. Pin 3 should be at 5V and pin 2 at 0V. When a signal is not being received, pin 1 (the output pin) should be at just under 4V. When a signal is received this voltage should fall by about 1V.

Note that as the signal is oscillating, a voltmeter provides a rather approximate guide to voltage. If an oscilloscope is available it should be possible to view the encoded signal, in which case the trace will rise and fall between 4V and 0V. If this test fails then try sending a signal from a TV remote control unit. The signal will not be decoded, but you will at least know if the receiver i.c. is working, and hence determine if the fault lies in the transmitter or receiver or both.

If the output from IC1 is working, test the signal at pin 14 (Din) of IC3 on the receiver module. It should be at about 0V when no signal is received, rising to about 1·3V (as seen on a voltmeter) when a signal is received. Again, an oscilloscope will show that the signal actually pulses to about 5V.

If the VT pin on the receiver is working then simple voltmeter tests should establish the position of any other faults.

If the circuit is triggered straight away then IC1 may be receiving IR straight from the IR diode D1, through stray reflection inside the case. If this happens the transmitter should be surrounded by a rolled piece of black card.



The Transmitter/Receiver case and the smaller l.e.d. box with their lids removed. Note the "tube" of black card to stop stray reflections from reaching the IR receiver chip.

SETTING UP

The presets VR1 and VR2 can be adjusted to suit the user's own particular needs. The following is a summary of their functions:

VR1: Adjusts the range of the IR beam by decreasing or increasing the power going through IR diode D1. Reducing the resistance extends the range.

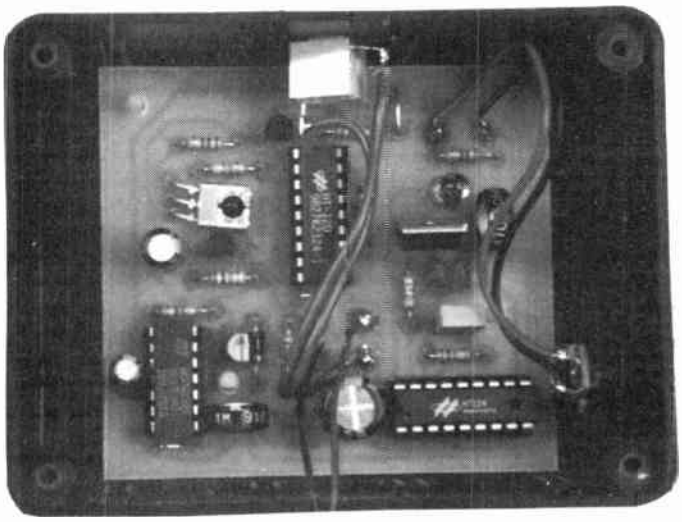
VR2: Sets the time the buzzer and l.e.d.s stay on by controlling how much recharging current is input to the monostable. Reducing the resistance reduces the time.

COMMON PROBLEMS

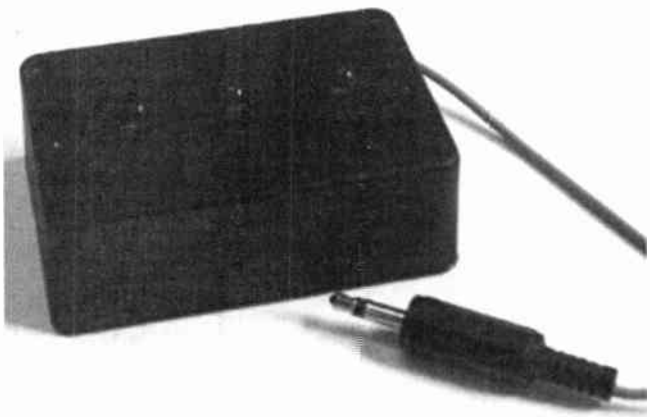
Typical mistakes include dry joints and bridged pads, i.e. adjacent pads accidentally joined together with solder. Other problems include failure to insert wire links. Also check that the components are correctly placed, and the correct way round. Note again that some IR l.e.d.s are unusual in that the longer lead denotes cathode (k).

IN USE

This Parking Warning System should be set up with the IR sensors lining up with the extremity of the car, e.g. bumper. The l.e.d. box should be positioned so as to be seen through the rear windscreen. The time the l.e.d.s and buzzer are on, and the range of the IR can easily be changed using a screwdriver to adjust the presets VR1 and VR2. □



Completed circuit board mounted inside its box.



Completed remote l.e.d. warning box.

New Technology Update

Ian Poole introduces the MRAM which, it is hoped, will pose a real threat to "Flash" memories and others.

MEMORY is one of the crucial elements in today's technology. There have been many improvements in disk based technology over recent years, but there are similar levels of progress taking place in the memory more directly associated with the CPU itself.

To illustrate this, it was less than thirty years ago when ferrite core memory was used. Fortunately this was superseded by electronic forms of memory when the levels of integration of circuits grew to a sufficient degree to allow them to be used.

Now there is a variety of different forms of memory that can be used dependent upon the exact requirement that needs to be fulfilled. SRAM, DRAM, EPROM, EEPROM and a variety of others including Flash memories are available, each having their own forte and area where they perform to their best.

However, if it were possible for only one type of memory to be used then this could lead to more efficient use of the circuitry, and possible cost savings. For this to be feasible, an all purpose, yet low cost memory would need to be available, and this may be just around the corner because a new technology is about to hit the market.

Known as magneto resistance random access memory or MRAM the new memory is creating significant interest in the semiconductor industry. It is a non-volatile form of random access memory claimed to be faster than Flash, which will be its main competitor when it is launched onto the market. However, as prices fall and MRAM gains wider acceptance it is likely that it will be used in many more memory applications.

Specifications

For a given speed and geometry the new MRAM technology consumes less power and this is a particularly important factor in today's technology where many items are battery powered. The power reduction also means that the power supply requirements for the unit as a whole may be reduced, and this can reflect in a decrease in costs – all-important in today's fiercely competitive marketplace.

As the speed of the new devices is faster than Flash. This too is another selling point as the speed of flash devices can be such that it impacts on the operation of the whole unit. Although not much faster at the moment, improvements are anticipated that will give the new technology a significant advantage.

MRAM has further advantages. It does not suffer from the wear out mechanism experienced with Flash devices. Although great improvements have been made in this area with Flash devices, they still have a limited life and this means that they cannot be used in high usage areas of a computer's architecture.

Operation

The operation of the new memories is based around a structure known as a magnetic tunnel junction (MTJ). These devices consist of sandwiches of two ferromagnetic layers separated by thin insulating layers.

A current can flow across the sandwich arising from a tunnelling action and its magnitude is dependent upon the magnetic moments of the magnetic layers. These layers can either be the same, when they are said to be parallel, or in opposite directions when they are said to be antiparallel.

Magnetic tunnel junctions comprise sandwiches of two ferromagnetic (FM) layers separated by a thin insulating layer which acts as a tunnel barrier (Fig.1). In these structures the sense current usually flows parallel to the layers of the structure, while the current write is passed perpendicular to the layers of the MTJ sandwich.

The resistance of the MTJ sandwich depends on the direction of magnetism of the two ferromagnetic layers. Typically, the resistance of the MTJ is lowest when these moments are aligned parallel to one another, and is highest when antiparallel.

To set the state of the memory cell a write current is passed through the structure. This is sufficiently high to alter the direction of magnetism of the thin layer, but not the thicker one. A smaller non-destructive sense current is then used to detect the data stored in the cell.

Construction

A wide range of structures and materials have been investigated to obtain the optimum structure. In view of the potential of the new technology a number of manufacturers are investigating different approaches. Motorola, IBM and many others all believe there is a future for the new idea.

IBM have fabricated junctions using computer-controlled placement of up to eight different metal shadow masks. The masks were successively placed on any one of up to twenty 25mm diameter wafers with a placement accuracy of approximately ±40μm. By using different masks, between 10 to 74 junctions of a size of approximately 80 x 80μm^2 could be fashioned on each wafer.

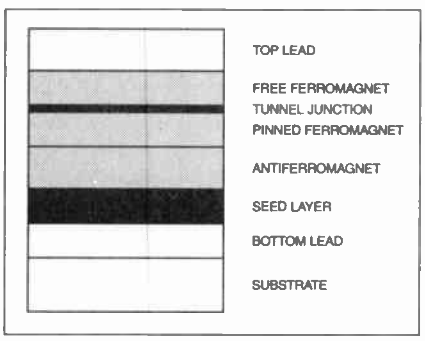


Fig.1. Structure of an MRAM cell.

The tunnel barrier was formed by *in-situ* plasma oxidation of a thin aluminium layer deposited at ambient temperature. Using this technique, large levels of variation in resistance due to magnetoresistive effects were seen. Investigations into the dependence of MR on the ferromagnetic metals comprising the electrodes were made.

It was anticipated that the magnitude of the MR would largely be dependent on the interface between the tunnel barrier and the magnetic electrodes. It was found that thick layers of certain non-ferromagnetic metals could be inserted between the tunnel barrier and the magnetic electrode without quenching the MR effect. However, the MR was quenched by incomplete oxidation of the aluminium layer.

Other Developments

IBM is not the only manufacturer investigating these structures. Apart from Motorola, IMEC, Europe's leading research centre for the development and licensing of state-of-the-art microelectronics technologies, is also making significant developments with MRAM technology.

They have succeeded in developing a demonstration MRAM matrix cell array with a DRAM style of architecture. This brings MRAM technology a step closer to the production of a viable alternative to the existing non-volatile memory. The memories produced in this development used a similar structure to that employed by IBM, i.e. two magnetic layers separated by an insulating layer.

Bit-selective addressing was based around a GaAs diode. The GaAs technology was selected because of its flexibility and tolerance relative to silicon.

In the next stage of development it is hoped to use a silicon diode or transistor to reduce the fabrication costs. This will bring the final version nearer and ensure that its unit costs will be such that it can effectively compete with existing technologies.

The new MRAM technology is an exciting development that could revolutionise current trends in electronic memory. The migration from magnetic core memory in the early 1970s proved to be a major step forwards. Now the introduction of MRAMs could provide similar levels of benefit.

News . . .

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

DIGITAL FINGERPRINTING

Digital cameras can now not only assess vehicle speed limit violation, but also detect fingerprints on banknotes. Barry Fox reports.

CRIMINALS beware. An adventurous local police force in the West of England is pioneering the use of electronic imaging to lift faint fingerprints from banknotes and cheques. The system relies on watermarking technology developed for electronic speed trap cameras but spurned by the Home Office. The mark stops lawyers discrediting fingerprint evidence by arguing that digital images can be easily doctored.

Three years ago Esther Neate, senior fingerprinting development officer at the Wiltshire Constabulary, persuaded the force to go out on a limb and replace the ageing film equipment in her lab with an all-digital system.

"The FBI and a few forces round the world are mixing film and digital technology, but we are first to replace film completely" says Neate.

Chemical Integrity

Prints from a sweaty finger are 95 per cent water and five per cent salts, amino acids and fats. Suspect banknotes and cheques are serially treated with 14 different chemicals such as ninhydrin, and a photograph taken at each stage because each chemical reacts with a different sweat component and destroys the previous reaction. By the end of the treatment, the paper is stained, toxic, and useless as evidence. So any case hangs on the quality and integrity of the photos.

High intensity white light is focussed on the print area by fibre optics, and the image captured on disc by a high resolution digital camera with 3648 × 4623 image sensor; 12-bit monochrome coding captures subtle greys in a 13 Megabyte file.

Because the image is in digital code, the lab can use Fourier Transform analysis to separate the regular pattern of banknote printing from the irregular fingerprint. Labs have tried to do this with film and colour filters, but electronic analysis produces much clearer pictures.

An identifying watermark, with date, time and place, is embedded in the image using VeriData iDem software from British company Signum Technologies of Witney. The mark is invisible to the eye but can be detected by analysis of the image file. If even one pixel in the image is altered, it shows.

Speed Trapping

Signum developed VeriData for electronic speed traps, but in April '99 the Home Office approved the use of SVDD (Speed Violation Detection Deterrent) digital cameras as long as the images are securely encrypted or carried by the closed data networks used on motorways.

SVDD was tested on the M1 and M20, in Leicester and Kent and approved on 1 April 1999 for private data networks. Cameras use infra-red flash to log the time taken for a car to travel a mile. They were catching 4000 a day but no summonses were issued. Now that the cameras are Type Approved the police and local councils can install them – but they are expensive.

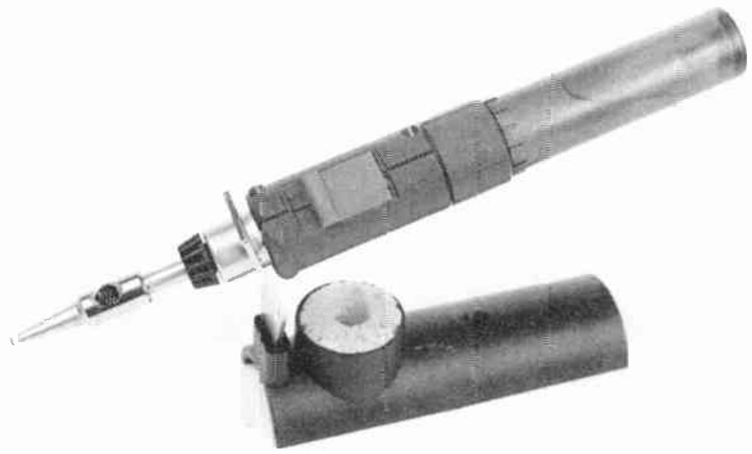
Says Signum's Marketing Manager Alan Bartlett, "The UK authorities are working on the principle that most motorists will not go to the expense of legally challenging a speeding fine. In the US people just shoot the speed cameras to pieces anyway. But 30 year jail sentences can hang on fingerprint evidence which will be challenged."

The Wiltshire Constabulary will not identify individual cases which have relied on digitally recorded evidence. "But for the last 18 months all cases this lab has handled have used the process," says Esther Neate.

Wiltshire's camera can work with a laptop PC running Windows NT, to capture fingerprints or footprints at the crime scene.

Police forces in Singapore, Turkey, Australia, New Zealand, Belgium and the US are now asking the fingerprinting laboratory in Devizes to help them set up similar systems.

CORDLESS SOLDERING IRON



BS Manufacturing tell us that their latest soldering iron, the P100, sets a completely new standard by offering precision heating power in the form of a tiny pen-style tool. The P100 is 19cm long and weighs just 57g, delivering up to 120W output – double that of some competitive irons, allowing it to be used for heavy duty electrical work and silver soldering, in addition to precision electronics and model making applications.

The fuel used is liquid butane/propane gas, stored in the translucent handle. The tank can be refilled from a standard gas canister (cigarette lighter type). Typically each refill provides around 45 minutes of continuous use. Gas is ignited by means of a spark from a flint inside the tool's cap, with its flow regulated using a slider, allowing fine adjustment down to 20W.

A wide range of attachments for the P100 are offered, to configure it for soldering, hot knife cutting, slicing, heating, igniting, shrink wrapping, melting, shaping and other uses. A rich choice of tips for soldering/desoldering is available, from 4·8mm wedges to chisels and angles as small as 1mm.

The iron costs around £18 and may be purchased online (via the web site below), or from distributors.

For more information contact BS Manufacturing Ltd., Strawhall Industrial Estate, Carlow, Ireland. Tel: +353 (0)503 41340. Fax: +353 (0)503 40363. E-mail: sales@vulkangt.com. Web: http://www.vulkangt.com.

Portable Power

"RUN virtually anything in your car!" exclaims a Press Release from Merlin Equipment. Merlin's Cherokee unit simply plugs into a car's cigarette lighter and converts low voltage battery power to standard 230V a.c. mains power. A normal UK 13A socket on the unit allows direct connection to appliances.

The Cherokee 150 is capable of supplying up to 150 watts of power continuously. For appliances that require a surge of power (TVs for example), it can provide 300 watts instantaneously. The converter is overload, overheat and short-circuit protected. In the event of the input battery voltage dropping below 10·8V, the unit will cut out – ensuring that you can re-start your car's engine!

Merlin have a large range of other products designed for in-car, caravan or boat use.

For more details, contact Merlin Equipment, Dept EPE, Unit 1, Hithercroft Court, Lupton Road, Wallingford, Oxon OX10 9BT. Tel: 01491 824333. Fax: 01491 824466. E-mail: sales@the-merlin-group.com. Web: http://www.the-merlin-group.com.

CELLPHONE DATA WAR

By Barry Fox

RIVAL British cellphone networks Orange and One-2-One have started a GSM data speed war that will replicate round the world. Most countries now use Europe's digital GSM system but E-mail and Internet access, at 9·6Kbps, is painfully slow.

The completely new Universal Mobile Telecommunications System promises data rates up to 2Mbits/s, but will not be ready until 2002.

Orange recently launched a new service called High Speed Circuit Switched Data, which hikes the speed to 28·8Kbps. One-2-One will wait a year until different technology, called General Packet Radio Service, is ready. Both systems are authorised by ETSI, the European Telecommunications Standards Institute, but are not fully compatible.

HSCSD uses less error correction to increase the basic GSM data rate to 14·4Kbps, and then gangs channels together to give 28·8Kbps or higher.

GPRS works on the assumption that most users do not need constant data speed. A pool of capacity serves several users at the same time, with bits allocated as and when they are needed. One-2-One plans a GPRS service for September 2000, with speeds up to 56Kbps, rising to 112Kbps by 2001.

"HSCSD is a technology cul-de-sac" says Craig Tillotson, One-2-One's Director of Strategy. "GPRS hardware will cope with HSCSD, but HSCSD hardware will not handle GPRS. And if Orange pass on the true cost to subscribers, HSCSD access will cost at least ten times as much as GPRS.

Not so, says Stuart Scott, Orange's Manager of Internet Products. "We have not yet set tariffs, but our target is to add only a very small premium".

Filter Software – Free!

MICROCHIP, those ingenious PIC manufacturers, have told us that you can now download some filter design software from their web site, *free!* FilterLab is a software design tool which simplifies the design of active filter systems using op.amps as analogue filters. It provides full schematic diagrams of filter circuits with component values and display of the frequency response.

FilterLab supports the design of low-pass filters up to 8th order, with Chebyshev, Bessel or Butterworth responses, from frequencies of 0·1Hz to 10MHz. Once the filter response has been identified, FilterLab generates Bode plots and the circuit diagram. It also generates a Spice model for time domain analysis, streamlining the design process.

To download Filterlab, access Microchip's site at:
http://www.microchip.com.

Power Lines and Health

THE National Radiological Protection Board (NRPB) is to investigate recent claims that a causal link between power lines and human health can be established. It states that these claims need to be compared with the findings of the first paper from the UK Childhood Cancer Study (UKCCS) which shows no increased risk of childhood cancer associated with magnetic fields from the electricity supply. This definitive study, looking at actual cases of childhood cancer and controls, is the largest of its type in the world.

For more information, contact NRPB, Chilton, Didcot, Oxon OX11 0RQ. Tel: 01235 822744. Fax: 01235 822746. Web: http://www.nrpb.org.uk.

Electronic Purse

One of the many documents that have come to us in connection with the *Smart Card 2000* exhibition and conference (8-10 Feb 2000, Olympia, London), highlights the question "Have Europe's banks invested millions developing a product no-one wants?". The product referred to is the "electronic purse".

Electronic purses have been the cherished goal of banks and other global organisations for around 10 years. Apparently, though, in many markets consumer feedback indicates they are not a viable proposition.

The concept of a cashless society is proving difficult for the consumer to accept. If the public is not ecstatic about the concept, neither are many of Europe's bankers who are facing losses of up to two euro per purse card per annum. In some countries the costs of persuading the customer to load and use the card exceed incomes by several times.

So will we be jingling the coins in our pockets in 10 years time? As we go to press, such matters are due to be discussed by delegates at the conference.

Constructional Project

HIGH PERFORMANCE REGENERATIVE RECEIVER

RAYMOND HAIGH

Part One

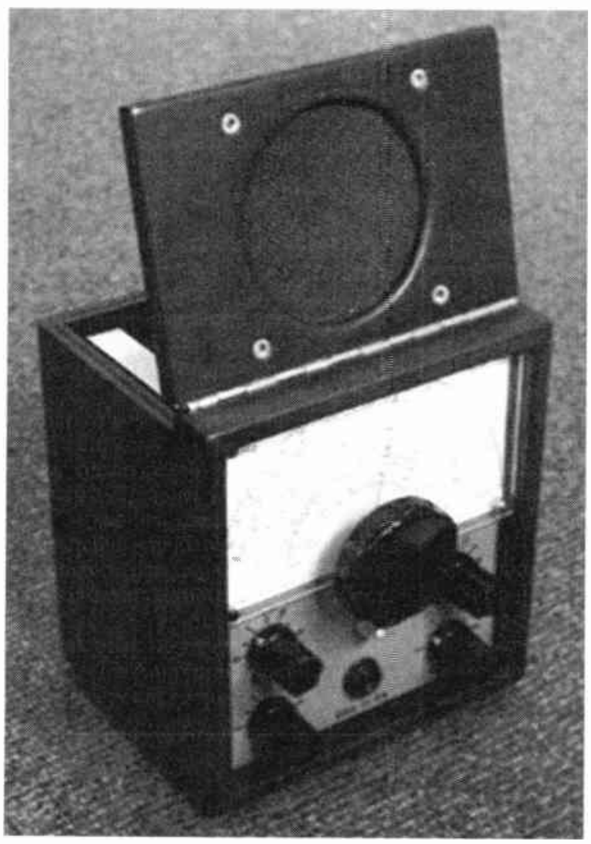
Provides continuous coverage from 130kHz to 30MHz. Capable of receiving broadcast and amateur stations from around the world.

ORIGINS OF REGENERATION

ALMOST a hundred years ago, scientists and engineers in Europe and America were trying to develop more sensitive circuits for the reception of radio signals.

C. S. Franklin in England and A. Meissner in Germany were both working on similar lines, but the credit for discovering the benefits of applying positive feedback to a tuned circuit is generally attributed to that great American radio pioneer, E. H. Armstrong. Known as "regeneration", the technique produces a truly dramatic increase in receiver sensitivity and selectivity.

Armstrong filed his patent in October 1913, just two months before his 23rd birthday. At this amazingly young age he had pushed forward the frontiers of technology and made man's dream of long-distance radio reception a reality.



HOW IT WORKS

Tuned circuits, formed by an inductor (coil) and a capacitor, are crucial to the working of radio receivers. By varying one of the components (usually the capacitor), the circuit can be tuned to resonate at a particular frequency.

This combination magnifies a signal to which it is tuned. The degree of magnification is dependant on the quality of the tuned circuit, and this is defined by a figure of merit known as the *Q*-factor. A figure of 100 is common. If a signal of 1mV is applied to a tuned circuit with a "Q" of 100, a voltage of 100 × 1mV, or 0·1V will be developed across it.

Armstrong (and others) discovered that, by connecting a triode valve to the tuned circuit and feeding back a tiny portion of the amplified signal to the coil, its *Q* can be dramatically increased. By this means, *Q* factors of several thousand can be achieved before the onset of oscillation, and the wanted signal is greatly amplified.

It is this phenomenon which imparts such a high degree of sensitivity and selectivity to simple regenerative receivers.

POPULARITY

Regenerative radio sets were produced in large numbers throughout the 'twenties. Skill is required to get the best out of radios of this kind: in particular, the regeneration control has to be carefully adjusted when receiving weak signals. Largely because of this, the easily operated superhet (also invented by Armstrong) began to challenge the popularity of the regen' in the 'thirties.

During the Second World War, Germany manufactured regenerative sets for military use, and the British incorporated circuits of this kind into clandestine transceivers. Manufacture for domestic listeners continued almost to the end of the valve era, with Ever-Ready producing a two-valve battery-operated set (their Model H) during the 'fifties.

AVOIDING PROBLEMS

Regenerative receivers are easily overloaded by powerful signals. They are also affected by aerial characteristics.

When an aerial system, which is directly connected to the tuned circuit, is resonant at the reception frequency (or a harmonic), it absorbs energy and inhibits regeneration. Known as "suck-out", the phenomenon manifests itself as dead spots in the tuning range.

Overload and "suck-out", together with an erratic feedback control, can ruin the performance of regenerative radios. They are avoided in this design.

WAVE TRAP

Powerful local radio transmitters can swamp regenerative receivers (they even cause problems with superhets of advanced design). The answer to this is the inclusion of what is known as a "wave trap".

An inductor L1 and capacitor C1 form a parallel tuned circuit which presents a high impedance at resonance, see Fig.1. When the inductor/capacitor combination is set to the frequency of the offending transmitter it blocks it out.

The problem is invariably encountered on Medium Waves, and suitable component values to tackle this problem, should it arise, are scheduled in Table 1.

CIRCUIT DETAILS

The circuit diagram of the High Performance Regenerative Receiver is shown in Fig.1. Grounded-base transistor, TR1, acts as an r.f. amplifier. Whilst its most important function is to isolate the regenerative stage from the aerial, it also provides a useful amount of gain.

Signal input is fed to the emitter (e) of TR1, and potentiometer VR1 acts as an attenuator: an essential feature which prevents overload on strong signals. Bias is fixed by resistors R2 and R3, and C4 is the base (b) bypass capacitor. The r.f. stage is decoupled from the supply rail by R1, C2 and C3.

The output impedance of a grounded-base stage is high enough for TR1 to be connected directly to the tuned circuit, and the use of a *pnp* device enables its collector (c) to be taken to supply negative via the coil L2.

DETECTOR

Old valve receivers invariably combined the functions of signal detection and regeneration (or *Q* multiplication) in a single stage. With the use of transistors, better results, without recourse to specially designed coils, can be achieved by separating them.

Field effect transistor TR2, biased by resistor R5 into the non-linear region of its characteristic curve, functions as a sensitive, drain-bend detector.

Source decoupling at r.f and a.f. is provided by capacitors C5 and C6. The output of TR2 is developed across drain load resistor R4 and C9, R8 and C14 remove residual r.f.

Q-FACTOR

Dual-gate MOSFET TR3 provides the modest amount of r.f. gain required for regeneration or *Q* multiplication. Arranged as a Hartley oscillator, feedback from TR3 source (s) is connected to a tapping on coil L2, via bias components resistor R6 and capacitor C8.

Preset potentiometer VR4 is included on the printed circuit board (p.c.b.) for use during the setting-up process, after which it is shorted out and replaced by fixed resistor R6. Bypass capacitor C8 assists regeneration when the feedback winding is comparatively small. It is not required on all coil ranges.

Feedback, or regeneration, is controlled by potentiometer VR2, which adjusts the voltage on gate 2 of TR3, thereby varying its gain. Preset VR3 fixes the range of control, capacitor C12 decouples gate 2 and eliminates potentiometer noise, and resistor R10 and capacitor C13 decouple the stage from the supply rail.

When the tuning coil L2 is removed for band changing, the signal gates of TR2 and TR3 are kept at 0V by resistor R7.

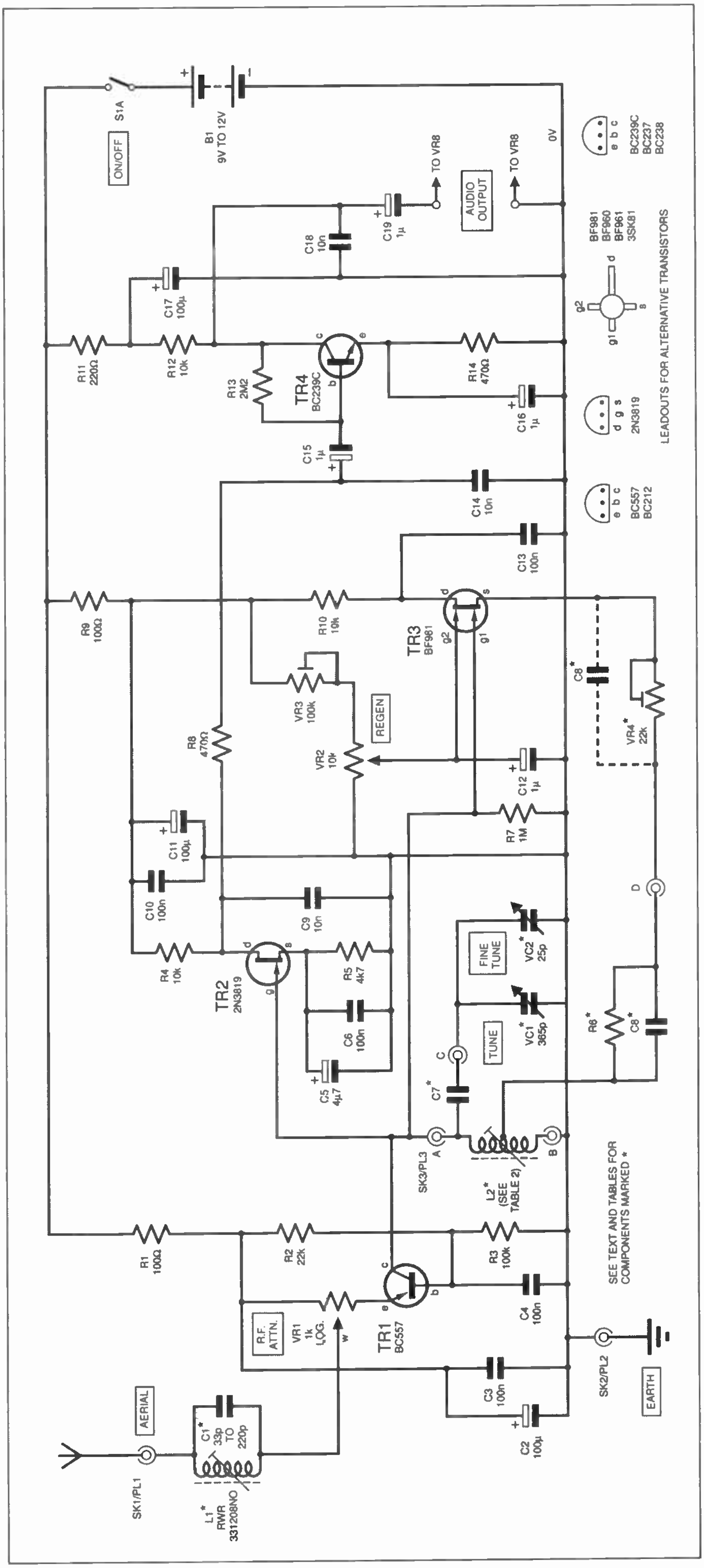


Fig.1. Circuit diagram of the High Performance Regenerative Receiver.

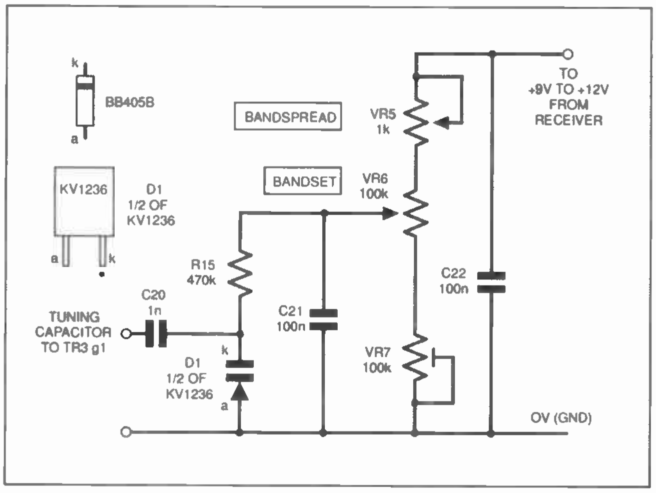


Fig.2. Alternative electronic tuning system. For fine tuning only, delete VR5 and C22, use a BB405B varicap diode and reduce C20 to 50pF.

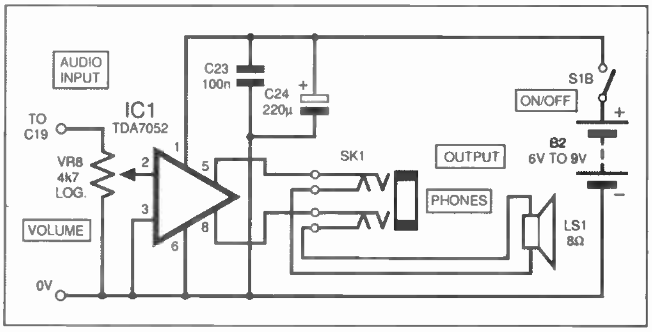


Fig.3. The audio power amplifier stage.

Table 1

Wave Trap Frequency Coverage
TOKO RWR331208NO coil and different values of C1
(See Fig.7 for details of coil base wiring)

C1 pF	*Frequency (kHz) at maximum inductance (core fully in)*	*Frequency (kHz) at minimum inductance (core fully out)*
33	1300	1700
47	1100	1400
68	900	1200
120	700	900
220	550	700

COMPONENTS

See SHOP TALK page

Resistors

R1, R9	100Ω (2 off)
R2	22k
R3	100k
R4, R10, R12	10k (3 off)
R5	4k7
R6	various values (see text and Table 2 – next month)
R7	1M
R8, R14	470Ω (2 off)
R11	220Ω
R13	2M2
*R15	470k

All 0·25W 5% carbon film

Potentiometers

VR1	1k rotary carbon (log law if obtainable)
VR2	10k rotary carbon, lin.
VR3, *VR7	100k enclosed preset, horiz. (2 off)
VR4	22k enclosed preset, horizontal
*VR5	1k rotary carbon, lin.
*VR6	100k rotary carbon, lin.
VR8	4k7 rotary carbon, log.

Capacitors

C1	See Table 1: axial polystyrene
C2, C11, C17	100µF radial elect. (3 off)
C3, C4, C6, C10, C13, *C21, *C22, C23	100nF disc ceramic (8 off)
C5	4µ7 radial elect.
C7	See text and Table 2: axial polystyrene
C8	See Table 2 (next month): ceramic (5 off)
C9, C14, C18	10n disc ceramic (3 off)
C12, C15, C16, C19	1µ radial elect. (4 off)
*C20	1n (1000p) or 50p polystyrene (See Fig.2).
C24	220µF radial elect.
VC1	365p Jackson O-type air-spaced tuning capacitor (see text)
VC2	25p Jackson C804 type air-spaced tuning capacitor (see text)

All capacitors 12V working or greater

Semiconductors

*D1	KV1236, KV1235 or BB405B varicap diode (see text)
TR1	BC557 *pnp* silicon transistor
TR2	2N3819 *n*-channel field effect transistor
TR3	BF981 *n*-channel dual-gate MOSFET
TR4	BC239C *npn* silicon transistor
IC1	TDA7052 low voltage 1W power amp

Miscellaneous

L1	RWR331208NO inductor (TOKO), only required if "wave trap" is needed (see text)
L2	tuning band coils (TOKO), see Table 2 (next month and text (8 off)
PL1 to PL8	9-pin D-type plugs for L2 (8 off) see Table 2 for other components
S1	d.p.d.t. toggle switch
SK1, SK2	screw terminal post (Aerial and Earth)
SK3	9-pin D-type socket (for plug-in tuning coils)
SK4	switched stereo jack socket
B1	9V to 12V battery pack
B2	6V to 9V battery pack

Printed circuit boards available from *EPE PCB Service*, codes 254 (Rec.), 255 (Elec. Tuning) and 256 (Amp); 9-pin D-type plug (8 off for tuning coils); aluminium or diecast box; 8-pin d.i.l. socket; plastic control knobs (4 small, 1 large); reduction drive for tuning capacitor; multi-strand connecting wire; card for tuning dial; nuts, bolts, washers and stand-offs; solder pins, solder etc.

Note: All components marked with an asterisk (*) are for the optional electronic tuning system.

Approx. Cost Guidance Only **£35** ***excluding batts. and tuning caps.***

TUNED CIRCUIT

The receiver is tuned by inductor (coil) L2 and variable capacitors VC1 and VC2. The larger of the two capacitors, VC1, acts as a coarse (Bandset) tuning control. The smaller one, VC2, provides fine (Bandspread) tuning. These components are discussed later.

Fixed capacitor C7 limits the maximum value of VC1 on the shortwave ranges. The reduced swing makes tuning less critical and consistent regeneration easier to achieve.

Details of the coverage obtained with a range of Toko coils, together with the associated values of C7, R6 and C8, are given in Table 2 – next month.

AUDIO AMPLIFIER

The base (b) and emitter (e) bias of audio amplifier, TR4, are fixed by resistors R13 and R14. Signal output is developed across collector (c) load resistor R12; and R11 and C17 decouple the stage from the supply.

The low value of emitter bypass capacitor C16 results in gain-reducing negative feedback at the lower audio frequencies. This improves clarity. Coupling and d.c. blocking capacitors C15 and C19 have a low value for the same reason.

Response to the higher audio frequencies is curtailed by capacitor C18. Constructors who find the tone too "bright" should increase the value of this component to 47nF or 100nF.

ELECTRONIC TUNING

The use of a separate Q-multiplier stage (TR3) makes the receiver tolerant of electronic tuning. (The somewhat modest *Q* of high capacitance varicap diodes inhibits the operation of most regenerative sets).

A suitable, add-on, electronic tuning circuit is given in Fig.2. Potentiometer VR6 controls the reverse bias on varicap diode D1 and varies its junction capacitance. This forms the coarse, or Bandset, tuning control.

Potentiometer VR5 permits a small adjustment of the bias voltage, and acts as the fine, or Bandspread, control. Preset

VR7 fixes the lowest level the bias voltage can fall to, thereby determining the maximum value of the tuning capacitance. (Diode junction capacitance increases as the reverse bias is reduced.)

The varicap diode D1 is coupled into the main circuit via d.c. blocking capacitor C20 and resistor R15 isolates the signal path from the potentiometer chain. Potentiometer noise is prevented by capacitors C21 and C22.

High value varicap diodes have a relatively large minimum capacitance, and an additional coil may be needed in order to secure continuous coverage. Furthermore, performance above 20MHz or so is not quite as satisfactory as that afforded by a traditional variable capacitor.

These disadvantages do not apply when the electronic tuning circuit is used with a v.h.f. diode solely to provide fine tuning (VR5 is omitted and the top end of VR6 is connected directly to the positive supply rail). This arrangement has the advantage of low cost and conveys a freedom to locate the d.c. operated Bandspread control in a position remote from the tuned circuit. The prototype Receiver, shown in the photographs, incorporates this arrangement.

POWER AMPLIFIER

The circuit diagram of the additional, single chip, audio power amplifier stage is given in Fig.3. This amplifier has its own 6V to 9V power supply to avoid any possible interaction with the receiver section. Designed around a TDA7052 low voltage power amp i.c., the only external components are capacitors C23 and C24 which ensure the stability of the device. Potentiometer VR8 acts as the volume, or a.f. gain, control.

The power amplifier IC1 is short-circuit protected, requires no heatsink and can deliver a clean 1W of audio into an 8 ohm speaker with a 6V supply. It is also claimed that there are no switch-on or switch-off clicks with this device.

POWER SUPPLIES

Current drain is extremely modest, being only 2mA for the radio section and 50mA for the power amplifier when it is delivering a good speaker volume (5mA when 'phones are used).

Battery supplies are, therefore, eminently suitable, and any possibility of hum and interference from the mains is avoided (regenerative receivers are very susceptible to this and require a carefully designed supply unit when they are mains powered).

The power amplifier current swings between 6mA and 60mA or more when it is being driven hard. The resulting supply voltage fluctuations would disturb the operation of the *Q*-multiplier, despite heavy decoupling.

Separate battery supplies for the Receiver and Power Amplifier sections are, therefore, strongly recommended. They are essential when electronic tuning is adopted. A double-pole toggle switch, S1a and S1b, connects the two separate battery packs into circuit.

COMPONENTS

Before we commence construction, a few words now on choice of components may help. Readers are also directed to the *Shoptalk* page for details of possible suppliers for some off those "hard to find" items.

Coils

All of the inductors used in this Receiver are from the Toko range. Their frequency coverage is shown in Table 1 and Table 2 together with suitable tuning capacitor values.

Coils can also be hand wound. As a very rough guide, when 20mm to 25mm diameter formers are used, feedback tappings should be about 10 turns up from the "earthy" end on Long waves, 5 turns on Medium waves and 2 or 3 turns on Shortwaves.

Transistors

Transistor types are not critical. The *Q*-multiplier circuit works well with a range of dual-gate MOSFETS, including the 40673 and the MFE201. The 3N201 was not tried, but it should prove satisfactory.

A 2N2905 *pnp* transistor worked well in the r.f. stage, and a 2N5827 or a 2N5828 should be suitable for TR4.

The alternative devices mentioned here have different case styles to those depicted in Fig.1, and the lead-outs ***must*** *be checked.*

Tuning Capacitors

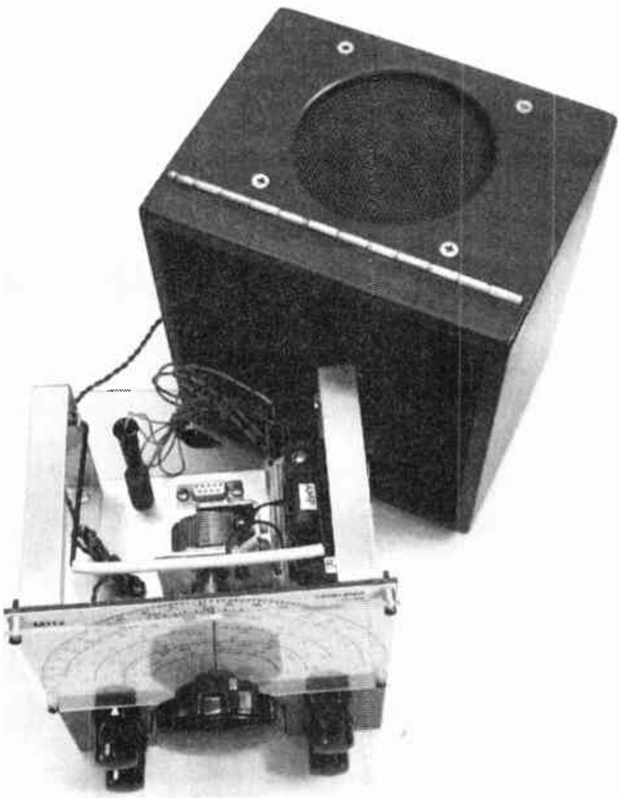
A Jackson 365pF O-type air-spaced tuning capacitor is the preferred component for bandset control VC1 and a 25pF Jackson C804 type is ideal for VC2, the Bandspread control. If this latter value produces a bandspread tuning rate which is too fast, connect a 10pF or 5pF polystyrene capacitor in series with it to reduce its swing.

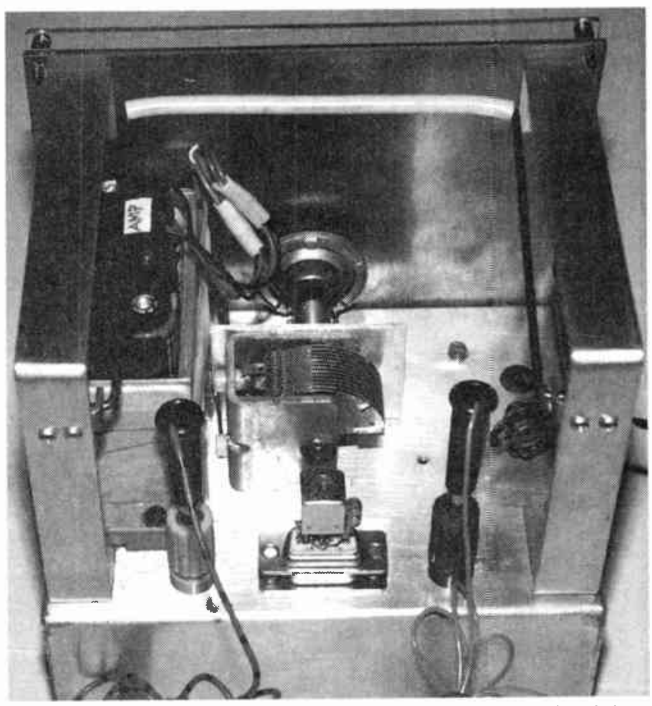
Inexpensive, polythene dielectric variables, of the kind used in transistor portables, can also be used. Some of these have comparatively low values, and both sections may need connecting in parallel to obtain the required tuning range. (A swing of at least a 10pF to 200pF is needed to give continuous coverage from 150kHz to 30MHz with the coils listed in Table 2). The 25pF f.m. tuning section of one of these capacitors can act as the bandspread control VC2.

If salvaged tuning capacitors are used, make sure that they are clean and dry, that the rotor contacts are satisfactory, and that the vanes are not shorting.

Varicap diodes are retailed by a number of suppliers and should not be too hard to find. Any 450pF varicap designed for 9V bias, should be suitable for full electronic tuning.

Next Month: Constructional details.





The chassis of the prototype was fabricated from aluminium and a wooden case with hinged lid holding the loudspeaker made to house the receiver. The lid can be raised and held up by a hinged wire frame (shown above) when in use.

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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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A $3^1/_2$ digit pocket-sized l.c.d. multimeter which measures a.c. and d.c. voltage, d.c. current and resistance. It can also test diodes and bipolar transistors.

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

★ LETTER OF THE MONTH ★

TEACH-INS PLUS EPE ONLINE

Dear EPE,

Thank you for not only the new *Teach-In 2000* series, but for the *Teach-In 1998* series as well. I credit knowledge gained from that for helping to secure a new job. Many companies are now giving a written skills test for technical positions and I would not have been able to pass the electronic and digital portions without your magazine. (My experience is in hydraulic and pneumatic systems.) The series was so well written, I learned enough basic electronics as well as digital to be hired.

I have since completed a well-known correspondence course in basic electronics for which my employer will reimburse me. I found your *Teach-In* series to be better written and more understandable than theirs. I also wish they had been able to provide the interactive software I downloaded for the *Teach-In 2000* series. It is always useful to reinforce what you have read with practice.

I have subscribed to the *Online* version of your magazine and am looking forward to every issue. I have a few suggestions which I would like to see if possible.

I enjoyed the PDF files being separate files so that I could save the *Teach-In 2000* from the Nov '99 issue to a floppy disk to view it at work on breaks and between service calls. (Remember the "paperless office" hype?). I am not able to do that with the Dec '99 issue. The only way to carry the information with me now is to print those pages out as the whole file is over 3Mb. I hope you have plans to make the complete series and the previous *Teach-In* series available for purchase via the Internet as well. This would be most helpful to readers like myself in Macon, USA, whose only source for *EPE* is one bookstore which stocks four copies. I missed some of the *PIC Tutorial* because it was sold out.

Thanks for a great publication.

Alan Craig, Macon, Georgia, USA, via the Net

Alan E-mailed his comments to our On-Line Editor Alan Winstanley, who E-mailed back:

We're really pleased to hear that *Teach-In 98* was of benefit to you, your compliments are much appreciated. Writing that series was hard work! We tried to mix together the essential theory along with some practical work. It was also difficult to co-ordinate the material originating from four writers, to a very tight monthly deadline. The advent of digital cameras helped a lot.

The development and production time for *Teach-In 98* was shorter than that of *Teach-In 2000*, which has been in preparation for at least a year. There has therefore been much more time available to develop the *Teach-In 2000* programs (*It hasn't felt like it! JB*), and its author John Becker is very skilled at producing QBasic electronics demo or test and measurement software.

It is possible to buy photostats of any out-of-print *EPE Back Issue* articles direct from the UK. These can be ordered via our secure server, accessible from the *EPE* web site at **http://www.epemag.wimborne.co.uk**.

Alan W also forwarded Alan C's queries on EPE Online *to its Editor Max in Alabama, USA, from where the electronic version is served out. Max responded:*

Thank you for your kind comments – it's always great to receive positive feedback. Sorry to hear that you would prefer to receive the *Online* magazine as multiple small PDFs. In fact, the main reason we decided to move to a single large PDF is that a lot of readers requested it that way (to make it easier to print out the entire issue in one go).

However, you will be happy to know that once the *Teach-In 2000* series is finished, we are planning on offering the whole series on a single CD (actually a mini-CD that would fit into your wallet, so that you can easily read the articles whilst on the road).

Furthermore, we're also planning on offering the entire set of *EPE* 1999 issues on these mini-CDs for ease of reference. Watch our web page at **www.epemag.com** for more details in the near future.

PERSEVERENCE

Dear EPE,

I have had the *PIC Electric* project (Feb-Mar '96) hanging around for some time, and much to my irritation I have been unable to resolve a problem with it: the l.e.d. display continually shows flashing FFFF. The middle FF are fairly stable, but the outer two FF segments are dimmer and flash in a more pronounced fashion.

The circuitry has been constructed on p.c.b.s purchased from you, using recommended components obtained through RS. I have checked connections and component layout and can find no problem with these. I have tried down-loading the program for the PIC a number of times, from a '486 66MHz PC. Using both the on-board components, *Simple PIC Programmer* and also the *PIC Tutor* board, I always end with the same results. Adjustment via the calibration buttons appears to do little. The +15V, –15V, +5V and TP7 check out OK. The A-D reference voltage has been adjusted as advised. Please could you offer some suggestions?

Steve Gooch, via the Net

I wondered if Steve had a power supply regulation problem, the rectified output of REC1 not providing sufficient voltage when the display has many digits active. This could affect synchronisation and indeed the correct operation of the PIC. Making this suggestion to Steve, he later replied:

Thanks for your suggestion. The problem was with the PIC programming. Why, remains a mystery, data transmission speed? A preprogrammed chip from Magenta cured all, however. Thanks for the excellent mag – and the back-up support.

PIC16F877 PROBLEM SOLVED

Here's another tale with a happy ending. First the problem:

Dear EPE,

Many thanks for the *PIC16F87x Mini Tutorial* (Oct '99). It was just what the doctor ordered, the inclusion of the Basic program was a masterstroke, my attempts to calculate baud rates had produced some improbable results, most of which would not have fitted into an 8-bit register.

However, I am experiencing difficulties reprogramming a PIC16F877. I've built a board along the lines of your *Data Logger* (Aug-Sept '99), minus provision for EEPROMS, and connected it to my *EPE PIC Tutorial* (Mar-May '98) board and all went well. I ran the input port test program of *Toolkit Mk2* (May-Jun '99), all voltages present and correct, plugged in my '877 and compiled and programmed **TKTEST4** into the PIC. It ran and the l.e.d.s flashed.

I then compiled (with no errors) my own program (well actually most of it was yours from *Mini Tut*) intended to initialise the USART with a baud rate of 31.250kHz and loop 10101010 to give a nice squarewave out of the port. I re-configured the PIC and then programmed it with my own program. Nothing appeared to be working, so I assumed that there was a problem with my program and re-loaded **TKTEST4**. Nothing happened, the PIC appeared dead. It seemed impossible to program it now. In case the PIC had developed a fault I plugged in another. **TKTEST4** went straight in and ran. I then attempted with my own program again and I have exactly the same problem i.e. I cannot re-load **TKTEST4** successfully.

I have thoroughly checked my board, *PIC Tutorial* board, etc. and can see no dry joints. I have checked the clock with an oscilloscope and the 4MHz clock is running, I have re-checked all voltages with the input port test program of *Toolkit Mk2* again and all voltages are present and correct, the 12V programming voltage switches between 12V and 5V as it should.

Derek Johnson, via the Net

That, then, is the outline of Derek's PIC problem, and he had obviously taken the correct steps in trying to determine the cause of the problem. The only thing that occurred to me was that it might be a PIC configuration problem – the settings having become corrupted in some way. I suggested such to Derek and recommended that he reconfigured as I described in Mini Tut.

Then comes the following reply back from Derek a couple of weeks later:

Have cured my problem! – by accidentally re-compiling **TKTEST1** and loading it. It ran straight away. The problem with my program was due to having already defined **PAGE1** and **PAGE0** in the header. I then re-equated them to suit the **SETBAUD** routine in your *Mini Tut*. I assumed that it would be OK to use either routine, to select pages. Apparently not. After removing the equates for **RP0** and **RP1** from the header, the program ran.

Many thanks for your concern.

An interesting situation and solution - from which all us PIC programmers should learn a lesson!

TASM, MPASM MEANS SPASM

Dear EPE,

Recently I got hold of the *Simple PIC Programmer* as featured in *EPE* Feb '96. Once built it has all worked fine and has spurred me on to delve deeper into PIC programming, However, I would appreciate it if you could just clear up a couple of things that are driving me bonkers.

Firstly, the kit came with TASM. I assume that TASM is a forerunner of MPASM which I see and hear about wherever I go, and a specially written (guessing again) program called **SEND.EXE**. The prog is compiled with TASM and downloaded to the chip via the parallel port, all well and good.

Next I decided to get "EASYPic'n" to start learning. This is where it's all got a bit cloudy. EASYpic'n writes out the code ready to be compiled by MPASM. Undeterred by this I tried to use TASM instead (it's all I have!). Of course doing this throws up lots of errors and it takes a while to sort them out. At first this wasn't too bad, but as the progs move on its all getting a bit too much.

Now, I did download MPASM from Microchip's website and thought that would be it. (Ha, as if!) Of course MPASM converts my **.ASM** files to **.HEX** files. But when it comes to downloading to the chip, **SEND.EXE** needs to see **.OBJ** files. (Dare I ask what the difference is?) which is fine with TASM but no good with the hex files of MPASM. So what do I do with these hex files?

Next I downloaded MPLAB from Microchip. This is fine and I could probably get used to that. The thing is I'm not sure if that has something built in that will do something with the hex files and then download them. Maybe its Picstart Plus.

Any reference to programming the chip seems to refer to serial connection, and guess what – my TASM thingy plugs into the parallel port. Is my kit a bit of a dinosaur.? How do I get my MPASM generated hex files to the chip? Do I now need a serial programmer instead? (I bet this is where free downloads end.)

Is there another *EPE* project which gets around these problems.

Mick Tinker, via the Net

Such confusion Mick! First let me say that you seem not to have been a regular reader of EPE, *otherwise your knowledge of PIC programming requirements and techniques would have increased through reading the several articles that we have published on the subject since the* Simple PIC Programmer.

In particular you should read the PIC Tutorial *series of Mar-May '98 (which discusses PIC programming at some length),* PIC Toolkit Mk1 *of July 98 (which discusses not only programming but also the differences between MPASM and TASM),* PIC Toolkit Mk2 *of May-June '99 (which is a much enhanced version of the Mk1 and has many of the features you obviously have need for, including the ability to translate between MPASM and TASM – it also allows the newer PIC16F87x series to be programmed, as well as the '84 series).*

We strongly recommend that you, and other readers in a similar position, should read these articles, which I am sure will clear up a fair number of your problems. I would comment, though, that as you have MPLAB you should make an in-depth attempt to get to know it, and to also obtain the other hardware associated with it. As good as Toolkit Mk2 is, it does not cover the full range of PICs that are manufactured, whereas Microchip's hardware/software suites are designed to do so (after all, Microchip are the manufacturers of the PICs and so provide a full backup for their use in industry). Rather than discuss it all further here, do read the above-mentioned articles, available as back issues (or photocopies in some cases) from the EPE *Editorial office.*

FLAWED PIRACY-PROOFING?

Dear EPE,

I found the *Pirate-Proof CDs* (*News*, Dec '99) interesting but flawed. Have the people at C-Dilla forgotten that a computer comes with an Audio Line-in and some more expensive sound cards have digital inputs, and certain CD Players have digital outputs? So if a CD player disregarded the false error correction code would the false code be sent through the digital outputs? (Hmm, I wonder).

But that aside, pirates would just sample from a CD player's audio outputs to a PC's audio inputs, and using a good PC sampler, save on to a hard drive track by track. After doing so they could (without the false code) be put on a CDR disk and then copied as many times as they liked. All in the time it takes to play a regular CD, so it seems the pirates will still be one step ahead, and that it just merely slows them down.

I think true anti-piracy will come when CD media is old hat (I predict in about 10-15 years), and solid state memory sticks or cards are the norm. Using encryption and digital ID tags, the consumer when buying music from a store would have his ID put onto the card, this ID would come from the manufacturer of the card player and would be unique, therefore not allowing it to be played on any other player even if copied.

Darren Portsmouth, via the Net

An interesting point, Darren, and one I am not qualified to comment on. Any readers care to comment further?

PIC vs AVR ETC

Dear EPE

PICs are definitely excellent microcontrollers, but it does not mean they are the only microcontrollers. There are other good microcontrollers like Atmel AVR or Scenix SX. By using only PICs you are limiting your magazine's resources. Some good projects with other microcontrollers will definitely open your magazine to a much wider audience.

I am not saying to throw away the PIC, it should be included, as it is very good for first time programmers, and a lot of your loyals also use PICs, but loyals like myself feel that we should not be confined to a single subject but rather explore all the possibilities.

Let me tell you what happened to me, I am a student and my professor gave an assignment, to design a data logger but to design it from any other microcontroller *except* PICs. None of my colleagues along with me were able to do that. We had to hear a long lecture on how we have gotten used to spoon feeding, and had confined all our attention on a single topic. After graduating and getting a job we might be asked by our superiors to design a project from Atmel AVR, then what will we do?

Ziyad Saeed, via the Net

Editor Mike replied directly to Ziyad:

I can understand that as a student you will need to learn about other microcontrollers, but you should realise that for the type of projects we publish the PIC is usually the best and easiest solution.

We have published projects for the Atmel AVR microcontrollers but few readers were interested. Whilst we do publish a range of educational items we cannot undertake to teach you about all the subjects you will undertake – sometimes you will need to find resources elsewhere.

To which I will add my own comment that I was personally very disappointed that the AVRs did not receive the reader response I had hoped for. I had felt that we should actively demonstrate that microcontrollers other than PICs were in commercial use and I was quite prepared to learn about them for myself and on behalf of you all! But, as few of you have expressed an interest in AVRs, I too shall stick with PICs, which I must add, are not only "good for first time programmers", but are widely used by professional designers in industry.

VOLTAGE MONITOR

Dear EPE,

I am writing in regard to the *Voltage Monitor* Starter Project in the Feb '00 issue. Since I am a beginner and am following the *Teach-In 2000* series, I thought that this would be an excellent project to build and use to ensure that the voltage level of the battery I am using when doing the practical experiments does not fall below a critical level.

You give very clear and easy-to-follow instructions for determining threshold voltages of the detectors when using the device to monitor batteries of voltages different to 12V. But what are these threshold voltages for a 6V battery? I would assume the upper threshold level to be 6V, but I have no idea what the lower one should be. I would be most grateful if you could recommend to me suitable threshold voltages, bearing in mind that the project is to be used in conjunction with the power supply for your *Teach-In* series.

I would like to say that I find the *Teach-In* series excellent. It explains concepts in a clear, thorough and practical way, and I have really enjoyed learning through it.

John Thornton, Sunderland

The Teach-In *circuits should function even with voltage levels well below 5V, even as low as 4V. When new, your 6V battery will probably deliver about 6·5V. I would probably regard 5.5V as being the level at which I would replace the battery, and so set one threshold for a little above that, and another for about 6V as advance warning that "fuel" is beginning to get a bit low. But in many ways, it's a somewhat arbitrary matter since the amount of current being consumed will determine what may be regarded as a reasonable life expectancy for the power remaining in the battery.*

It's like with car driving: my fuel light comes on when the tank is down to a quarter full. It is typically a 500 mile tank and so I know that I probably still have well over a hundred miles before having to walk! A hundred miles on the motorway is less than two hours of fuel remaining. Driving locally to the shops and back, the same fuel probably represents several days.

If you really feel in danger of "running out", keep a back-up fuel supply available, in your case keep another battery handy.

I compliment you, though, on your initiative in this matter. Building the Voltage Monitor *will not only prove to be useful constructional experience, but using it will also help reinforce your concept of electronic power consumption.*

FTP PLUS TI2K

Dear EPE,

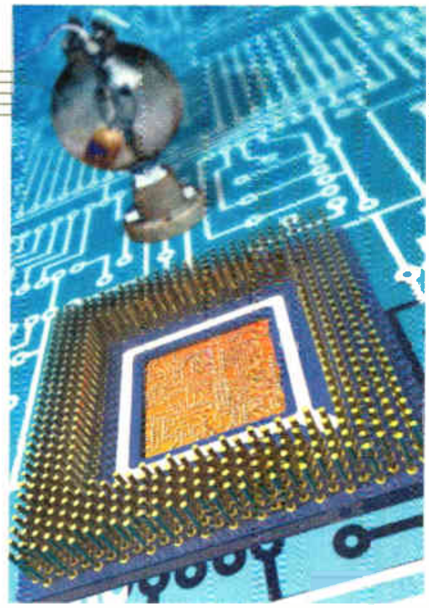
In *Readout* it seems some folks have a problem downloading from the FTP site, or they are getting corrupted code. I always use WS_FTP which is a free shareware FTP program. It's very easy to use for both down and up loading!

I have downloaded the *Teach-In 2000* software and have to say I like it, it will prove very useful. The pots screen is useful and the cap-resistor time constants, can't wait to see how you convert the printer port to a frequency counter! What I would like to see added is a 555 timer time-freq calculator and basic op.amp configuration with gain calc, etc.

Mel Saunders, via the Net

Hopefully, you should know by now – details were given in Feb '00 issue, easy isn't it?! Sorry to disappoint, though, I'm not covering 555s in TI2K. *The aim of the series is to achieve a broader sweep without getting into specific named devices. Besides which, there's been enough published on 555s to fill the British Library twice over (much of it originating in* EPE*) – I've no wish to add to the glut!*

Special Feature



TECHNOLOGY TIMELINES

PART 2 – DAYS OF LATER YORE

CLIVE "MAX" MAXFIELD AND ALVIN BROWN

Boldly going behind the beyond, behind which no-one has boldly gone behind, beyond, before!

THE purpose of this series is to review how we came to be where we are today (technology-wise), and where we look like ending up tomorrow. Our first step is to cast our gaze into the depths of time to consider the state-of-the-art as the world was poised to enter the 20th Century.

In Part 1 we considered physics, electronics and communications prior to 1900. In this installment we shall first examine the state of computing prior to 1900. We shall then turn our attention to the key discoveries in fundamental electronics that occurred in the 20th Century.

COMPUTING PRIOR TO 1900

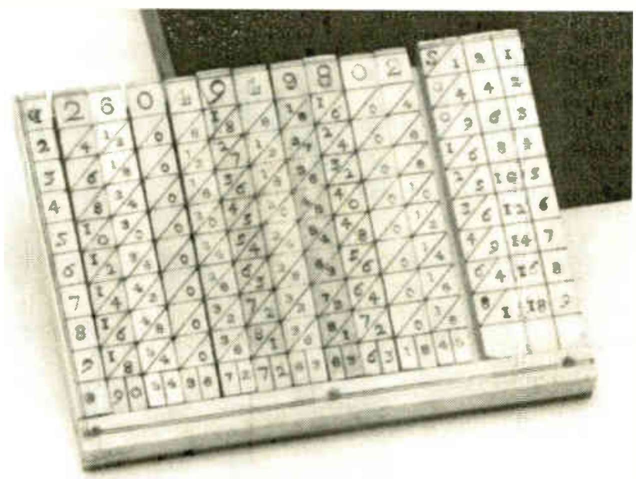
The first tools used as aids to calculation were man's own fingers. Thus, it is no coincidence that *digit* refers to a finger (or toe) as well as a numerical quantity. Similarly, small stones or pebbles could be used to represent larger numbers than fingers and could also store intermediate results for later use. This explains why *calculate* is derived from the Latin word for pebble (*calculus*).

DECIMAL NUMBER SYSTEM

Throughout history, humans have experimented with a variety of different number systems. For example, the ancient Babylonians used a base-60 system, which is why we have 60 seconds in a minute and 60 minutes in an hour. Some people used their fingers and their toes for counting, so they ended up with base-20 systems, which is why we still have special words like *score*, meaning *twenty*.

Similarly, some groups experimented with base-12 systems, which is why we have special words like *dozen* (meaning 12) and *gross* (meaning 12 × 12). The fact that we have 12 months in a year and 24 hours in a day (2 × 12) are also related to these base-12 systems.

However, the number system with which we are most familiar is the decimal system, which is based on ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. The name *decimal* is derived from the Latin *decam*, meaning *ten*. As this system uses ten digits, it is said to be *base-10* or *radix-10*, where the term *radix* comes from the Latin word meaning *root*.



Napier's Bones, simple multiplication tables inscribed on wood or bone. John Napier went on to invent logarithms.
Courtesy of IBM.

THE ABACUS

The first actual calculating mechanism (at least that we know of) is the *abacus*. Some authorities hold that the first abacus was invented by the Babylonians sometime between 1,000 BC and 500 BC, but others believe that it was actually invented by the Chinese.

Although the abacus does not qualify as a mechanical calculator, it certainly stands proud as one of first mechanical aids to calculation.

THE SLIDE RULE

In the early 1600s, Scottish mathematician John Napier invented a tool called *Napier's Bones*. These were simple multiplication tables inscribed on strips of wood or bone. Napier also invented the concept of *logarithms*, which were used as the basis for the slide rule by the English mathematician and clergyman William Oughtred in 1621.

The slide rule was an exceptionally effective tool that remained in common use for over three hundred years. However, like the abacus, the slide rule does not qualify as a mechanical calculator in the modern sense of the word.

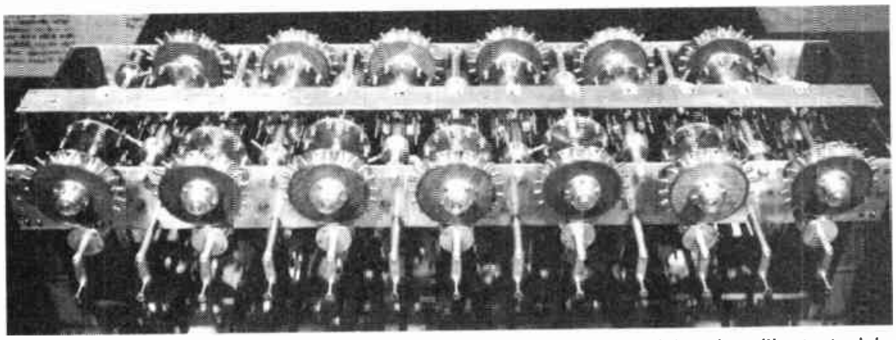
REDISCOVERED NOTEBOOKS

Leonardo da Vinci was a genius: painter, musician, sculptor, architect, engineer, and so forth. It is well known that he sketched concept designs of such futuristic devices as tanks and helicopters, but until quite recently there was no indication that he had ever turned his mind to mechanical calculation.

However, two of da Vinci's notebooks dating from around the 1500s were rediscovered in 1967. These priceless tomes contain a wealth of drawings, some of which may represent a mechanical calculator (see Part 1). Working models of a mechanical calculator loosely based on these drawings have since been constructed, although some people believe the reconstruction is far more sophisticated than anything Leonardo had in mind.

FIRST MECHANICAL CALCULATOR

Sometime around 1625, the German astronomer and mathematician Wilhelm Schickard wrote a letter to a friend stating



A modern construction of a mechanical calculator inspired by that illustrated in Leonardo da Vinci's notebook. Courtesy of IBM.

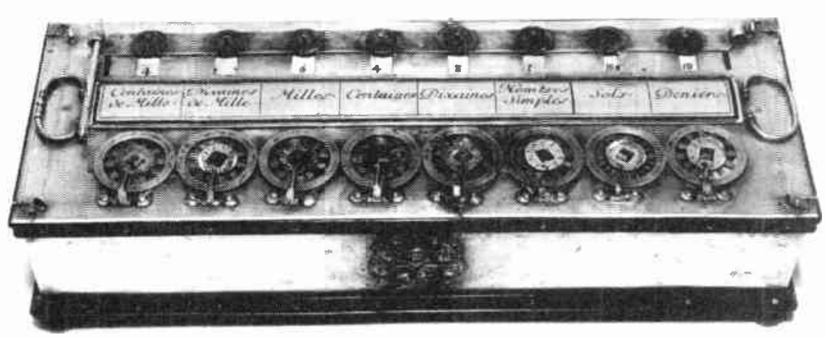
that he had built a machine that "... *immediately computes the given numbers automatically; adds, subtracts, multiplies, and divides*". Unfortunately, the original machine was destroyed in a fire, but working models have since been constructed from Schickard's notes.

ARITHMETIC MACHINE

For reasons unknown, many references ignore Schickard's device and instead credit the French mathematician, physicist and theologian, Blaise Pascal with the invention of the first operational calculating machine. In 1642, Pascal introduced his *Arithmetic Machine*, which could add and subtract numbers (multiplication and division operations were implemented by performing a series of additions or subtractions).

STEP RECKONER

Mechanical calculation was taken a step further in the 1670s by a German Baron called Gottfried von Leibniz. After receiving his bachelor's degree at seventeen years of age, Leibniz developed Pascal's ideas and, in 1671, introduced the *Step Reckoner*. In addition to performing additions and subtractions, the Step Reckoner could multiply, divide, and evaluate square roots.



Blaise Pascal's Arithmetic Machine. Courtesy of IBM.

The mechanical calculators created by Pascal and Leibniz were the forebears of today's desktop computers, and derivations of these devices were in widespread use for over two hundred years until their electronic counterparts finally became available and affordable in the early 1970s.

FIRST MECHANICAL COMPUTER

In the 1800s, books of mathematical tables such as logarithmic and trigonometric functions were in great demand by navigators, engineers, and so forth. Such tables were generated by teams of mathematicians working day and night on derivatives of the primitive mechanical calculators invented by Pascal and Leibniz. These mathematicians were referred to as *computers* because they performed all the computations.

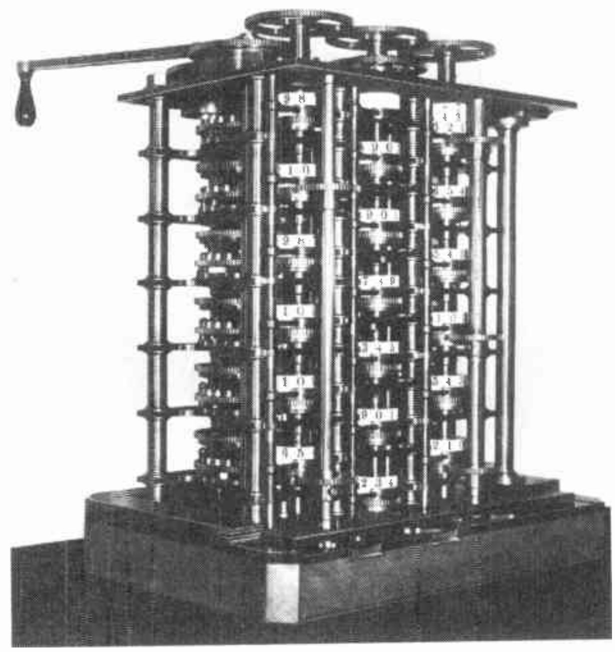
In 1822, the eccentric British mathematician and inventor Charles Babbage proposed building a machine called the *Difference Engine* to automatically calculate these tables.

Babbage had only partially completed the Difference Engine when he conceived the idea of a much more sophisticated machine called an *Analytical Engine*. (This is often referred to as Babbage's Analytical *Steam* Engine, because he intended for it to be powered by steam).

The Analytical Engine included many concepts that would eventually be featured in modern computers, including a processing unit that could change the flow of a program depending on the results of previous computations. Babbage worked on the Analytical Engine from around 1830 until he died in 1871, but sadly it was never completed in his lifetime.

FIRST COMPUTER PROGRAMMER

Augusta Ada Lovelace, the daughter of the English poet Lord Byron, was one of the few people who had any clue what Babbage was talking about. Ada created a program to



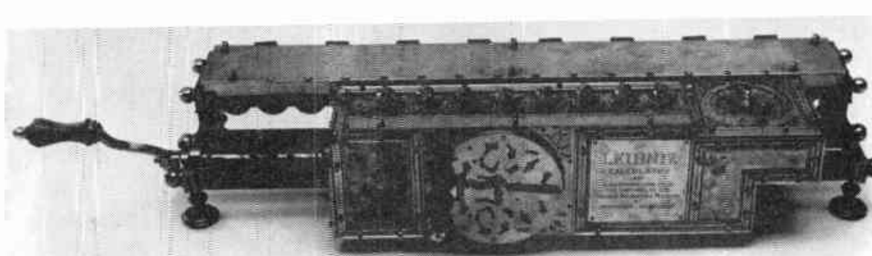
Modern construction of Babbage's Difference Engine. Courtesy of IBM.

compute a mathematical sequence known as *Bernoulli* numbers, which would have been extremely interesting had Babbage's machine ever actually worked.

Ada is now credited as being the first computer programmer, and the ADA programming language was named in her honour in 1979.

In fact, one of Babbage's earlier Difference Engines was eventually assembled by a team at London's Science Museum from his original drawings. The final machine was constructed from cast iron, bronze and steel, consisted of 4,000 components, weighed in at a whopping three tons, and was 10 feet wide and 6·5 feet tall (3m × 2m).

In the early 1990s, more than one hundred and fifty years after its conception,



Gottfried von Leibniz's Step Reckoner of 1671. Courtesy of IBM.

Babbage's Difference Engine performed its first sequence of calculations and returned results to 31 digits of accuracy, which is far more accurate than most of today's electronic pocket calculators!

TABULATING MACHINES

These days we can only imagine the problems besetting the American census takers in the latter part of the 19th Century, because it was estimated that the 1890 census would include more than 62 million Americans.

The problem was that the existing system of making tally marks in small squares on rolls of paper and then adding these marks together by hand was time-consuming, expensive, and prone to error. In fact it was determined that if the existing system were used for the 1890 census, then the processed data would not be ready until after the 1900 census, by which time it would be largely worthless!

During the 1880s, a lecturer at MIT called Herman Hollerith came up with a solution to this problem, which was to use punched cards to represent the census data, and to then read and collate this data using machines.

The result of Hollerith's labours was an automatic tabulating machine with a large number of clock-like counters that were used to accumulate and display results. Operators used switches to instruct the machine to examine each card for certain characteristics, such as gender, profession, marital status, number of children, and so forth.

An electrically controlled sorting mechanism detected any cards that met the specified criteria and gathered them into a separate container. The ability to quickly and easily collate data in this way drove statisticians of the time into a frenzy of excitement.

Hollerith's Tabulator-Sorter unit. Courtesy of IBM.

Following their application to the census problem, Hollerith's machines proved themselves to be extremely useful for a wide variety of applications, and some of the techniques they used were to prove significant in the development of the digital computer in the 20th Century. In fact, in February 1924, Hollerith's company changed its name to International Business Machines, or IBM!

POISED ON THE BRINK . . .

So now we are poised on the brink of the 20th Century. It's 11:59pm on December 31st 1899. Queen Victoria is still on the throne of England. Light bulbs are considered to be amazingly cool (but almost no-one has electricity in their homes). The vacuum tube has yet to be invented. Rudimentary telephones are available only to the favoured few, and *computers* are the ill-used mathematicians who furiously hand-crank their mechanical calculators in the dead of night!

Tick-tock, tick-tock . . . the second hand is wending its way towards the beginning of a new century. Who can guess what surprises the future will hold?

FUNDAMENTAL ELECTRONICS IN THE 20TH CENTURY

For our purposes here, electricity may be considered to consist of vast herds of electrons migrating from one place to another through some conducting medium like a copper wire. The art of electronics comes in controlling these herds: telling them when to start, when to stop, where to go, and what to do when they get there.

However, as with most things (especially small children), control is easier to talk about than it is to achieve. With the exception of simple manipulation and modulation using devices such as transformers, or rectification using crystals, the most sophisticated form of control prior to the beginning of the 20th Century was the mechanical switch (or its electromechanical counterpart, the relay).

When it comes to coarse control like turning a light bulb on or off, then a mechanical switch is definitely worth considering, but if you're looking for fine control, mechanical switches generally leave something to be desired. Similarly, a mechanical device is only of use if you only wish to turn something off every now and then, but such devices have a maximum capability of only a very few cycles per second.

So one key requirement as we entered the 20th Century (*we* meaning the human race, not the authors personally you understand) was for a more sophisticated way to control electricity.

VACUUM TUBES – FLEMING'S DIODES

As we discussed in Part 1, the American Inventor Thomas Alva Edison demonstrated his first incandescent light bulb in 1789 (one year after the English inventor Sir Joseph Wilson Swan demonstrated his bulb, but let's not delve into that debate again here).

Four years later in 1883, an engineer working for Edison – William Hammer – observed that he could detect electrons flowing from the lighted filament to a metal plate mounted inside the bulb. Even though Hammer discovered this phenomena, it subsequently became known as the *Edison Effect*, because Edison was the man in charge.

Sad to relate, Edison himself did not take the time to investigate the effect any further. This was unfortunate, because electronics as we now know it might have taken a giant leap forward had he done so.

In fact it wasn't until the Edison Effect's twenty-first birthday in 1904 that the English electrical engineer, John Ambrose Fleming, filed a patent for the first vacuum tube device based on this effect. (Due to the fact that these devices are created using evacuated glass tubes, they are still referred to simply as *tubes* in America. However in England they became more commonly known as *valves*, because this name (derived from pneumatic and hydraulic valves) better reflected their control function.)

What Fleming had discovered was that the electrons in his vacuum tube only flowed from the cathode (the heated filament) to a positively charged anode. Thus, Fleming had created a form of *diode*, which is a device that only conducts electricity in one direction.

This was of particular interest, because some electrical equipment like radios will only work with unidirectional, or direct current (d.c.), but most electrical supplies are based on alternating current (a.c.), because this provides a more efficient way to transport electricity over long distances. Fleming's vacuum tube diode could therefore be employed in the role of a rectifier to convert a.c. to d.c.

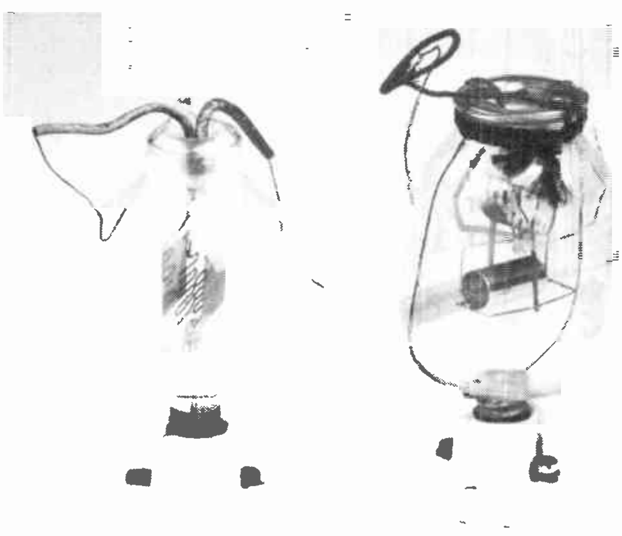
Sir John Fleming (1849-1945), British physicist and inventor of the thermionic valve, in 1900. Courtesy of the Science Photo Library.

LEE DE FOREST'S TRIODES

In 1907, the American inventor Lee de Forest introduced a third electrode called the *grid* into his version of a vacuum tube. The resulting three-terminal device was called a *triode*.

This device was particularly cunning, because a small signal applied to the grid could be used to control a much larger signal flowing between the cathode and the anode. The result was a device that could be used to amplify signals, and de Forest used his triodes to build many of the early radio transmitters (he also presented the first live opera broadcast and the first news report on radio).

In addition to acting as an amplifier, de Forest's triodes could also be used in the role of switches (the presence or absence of a signal on the grid terminal could turn the output – the anode – on or off). This ability to act as switches meant that vacuum tubes were destined to play a significant role in digital computing.



Left: An Audion triode from about 1914. Right: An MO Valve Co. triode from about 1920. Courtesy *Radio Bygones* magazine.

As we shall see in a future part, early digital computers (circa 1940) were either mechanical or electromechanical (based on relays), but they soon came to be constructed from vacuum tube switches, because these were much, much faster.

Unfortunately, vacuum tubes have a number of disadvantages, not the least that the metal forming the cathode evaporates over time causing a performance degradation. Also, in addition to requiring dangerously high voltages, vacuum tubes occupy a lot of space, they generate a lot of waste heat, and they are not particularly reliable, which becomes especially noticeable when they are used in large numbers.

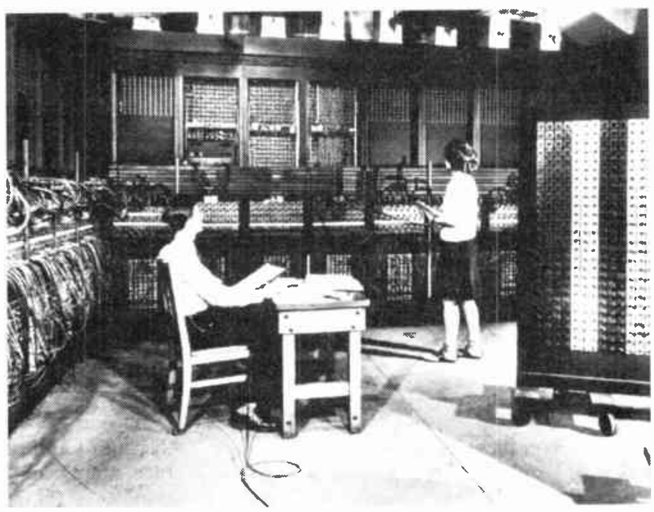
For example, the ENIAC computer, which was constructed at the University of Pennsylvania between 1943 and 1946, used approximately 18,000 vacuum tubes. This monster was 10 feet (3m) tall, occupied 1,000 square feet (93 m^2) of floor space, and required 150 kilowatts of power, which was enough to light a small town.

However, whilst it was a tremendous achievement for its time, ENIAC was painfully unreliable due to the vacuum tube technology of the day. In fact 90 per cent of ENIAC's down-time was attributed to locating and replacing burnt-out tubes – sometimes as many as 50 a day!

CRYSTAL GAZING

The fact that certain crystals have special properties had been known for a long time. For example, in 1880, the French physicist Pierre Curie had discovered the piezoelectric effect. In this case, certain crystalline substances produce an electrical charge if they are squeezed, and correspondingly they change size if an electric current is applied to them.

This effect subsequently found many diverse applications in electronics, from sensors (including microphones) to actuators (including extremely loud alarms).



Part of the ENIAC computer. Courtesy of IBM.

Prior to Fleming inventing his vacuum tube diode, early radios relied on the use of crystals for rectification. At that time no one really understood how crystals could convert an a.c. signal into its d.c. counterpart, and following the advent of the vacuum tube most people could not care less.

However, scientists, inventors and engineers did remain interested in crystals in general, especially as they began to discover more of the special properties associated with different crystalline structures. For example, in 1907 a letter from Mr H.J. Round was published in the American *Electrical World* magazine as follows:

To the editors of Electrical World*: Sirs – During an investigation of the unsymmetrical passage of current through a contact of carborundum and other substances a curious phenomenon was noted. On applying a potential of 10 volts between two points on a crystal of carborundum, the crystal gave out a yellowish light.*

Mr Round went on to note that some crystals gave out green, orange, or blue light. This is quite possibly the first documented reference to the effect upon which light-emitting diodes (l.e.d.s) are based.

Similarly, as far back as 1926, Dr Julius Edgar Lilienfield of New York filed for a patent on what we would now recognize as an *npn* junction transistor being used in the role of an amplifier (the title of the patent was the *Method and apparatus for controlling electric currents).*

SEMICONDUCTORS

Some substances facilitate the conduction of electricity and are therefore known as *conductors*. Other materials resist the flow of electricity, and these are known as *insulators*. What the early pioneers didn't fully understand is that by adding impurities to certain crystalline structures, it is possible to create a special class of materials known as *semiconductors*, which can exhibit both conducting and insulating properties.

Sad to relate, serious research into semiconductors did not really commence until World War II. At that time it was recognized that devices formed from semiconductors had potential as amplifiers and switches. If it proved possible to create them, these new devices could be used to replace prevailing vacuum tube technology, with the advantages that they would be much smaller and lighter, they would consume much less power, and they would be far more reliable.

TRANSISTORS

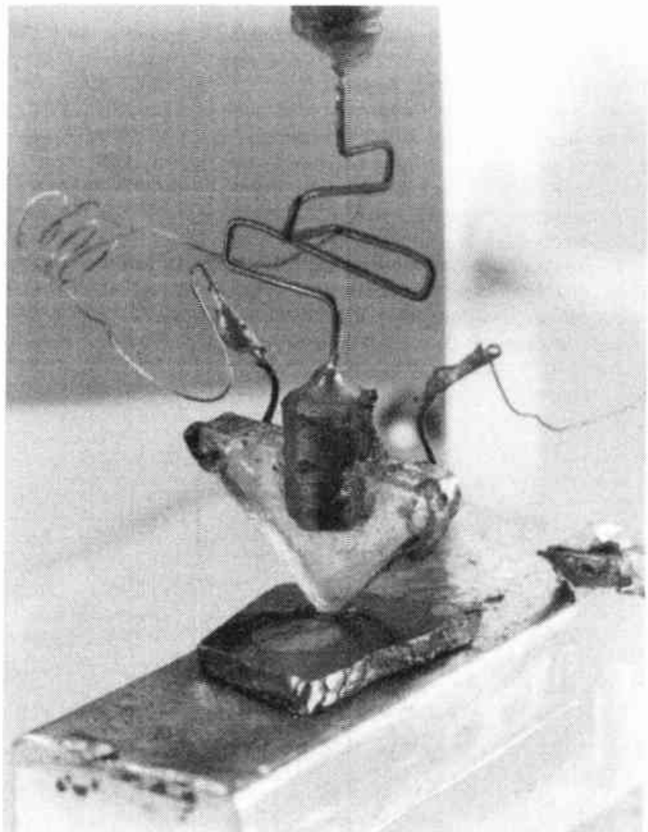
In the early 1940s, scientists at Bell Labs in the United States started to experiment with impure crystals of germanium. The first true semiconductor components were two-terminal diode devices. On the 23rd December 1947, a team comprising the scientist William Bradford Shockley and the theoretical physicists John Bardeen and Walter Brattain succeeded in creating the first point-contact *transistor* (whose name was derived from *trans*fer res*istor*).

Like the triode, this was a three terminal device that could be used both as an amplifier and a switch. Once they had proved that their creation worked, the team broke up to celebrate the Christmas holidays, which is why many (lesser) references state that the first transistor did not make an appearance until 1948.

In 1950, Shockley invented a new type of device called a *bipolar junction transistor* (BJT), which was more reliable, easier and cheaper to build, and gave more consistent results than point contact devices. Then, in 1962, Steven Hofstein and Fredric Heiman at the RCA research laboratory at Princeton, New Jersey, invented a new family of devices called *field effect transistors* (f.e.t.s).

Although germanium exhibits more desirable electrical characteristics, for a variety of reasons silicon is easier to work with, and so by the late 1950s silicon had replaced germanium as the semiconductor of choice. (As silicon is the main constituent of sand and one of the most common elements on earth – silicon accounts for approximately 28 per cent of the Earth's crust – we aren't in any danger of running out of it in the foreseeable future.)

Very quickly after the first transistors had been developed they started to appear in commercial products. For example, 1952 saw the appearance of the transistor-based hearing aid, quickly followed by Sony's pocket-sized transistor radio. It was also obvious to computer scientists that they could now make machines much smaller (the size of a room instead of a house), but only a very few forward thinkers had any idea as to what was yet to come . . .



The first-ever transistor, created on 23 December 1947. The photo scale is approx. twice life size. Courtesy of Bell Laboratories/Lucent Technologies.

INTEGRATED CIRCUITS

Sometime after the invention of the transistor, people began to think that it would be a good idea to be able to fabricate entire circuits on a single piece of semiconductor. In fact, the first public discussion of this concept is generally credited to a British Radar expert, G. W. A. Drummer in a paper he presented as far back as 1952. However, it was not until 1958 that a young engineer called Jack Kilby actually succeeded in creating multiple components as a single device.

To a large extent the demand for miniaturization was driven by the requirements of the American armed forces and also by rocket research. At that time, one technique

TIMELINES

1901: Hubert Booth invents the first vacuum cleaner.

1902: Robert Bosch invents the first spark plug.

1902: America. Millar Hutchinson invents the first electrical hearing aid.

1904: England. John Ambrose Fleming invents the vacuum tube diode rectifier.

1904: First ultraviolet lamps are introduced.

1904: First practical photoelectric cell is developed.

1906: First tungsten-filament lamps are introduced.

1907: America. Lee de Forest creates a three-element amplifier vacuum tube (triode).

1908: Charles Frederick Cross invents Cellophane.

1909: Leo Baekeland patents an artificial plastic that he calls Bakelite.

1909: General Electric introduce the world's first electric toaster.

1910: First electric washing machines are introduced.

1910: France. Georges Claude introduces neon lamps.

1911: Dutch physicist Heike Kamerlingh Onnes discovers superconductivity.

1912: The Titanic sinks on its maiden voyage.

1912: America. Dr Sidney Russell invents the electric blanket.

1913: William D. Coolidge invents hot-tungsten filament X-ray tube. This Coolidge Tube becomes standard generator for medical X-rays.

1914: America. Traffic lights are used for the first time (in Cleveland, Ohio).

1917: Clarence Birdseye preserves food using freezing.

1919: The concept of flip-flop (memory) circuits is invented.

1919: Walter Schottky invents the tetrode (first multiple-grid vacuum tube).

1921: Czech author Karel Capek coins the term *robot* in his play *R.U.R.*

1921: Albert Hull invents the magnetron (a microwave generator).

1921: Canadian-American John Augustus Larson invents the polygraph lie-detector.

1921: First use of quartz crystals to keep radios from wandering off-station.

1923: First neon advertising sign is introduced.

1923: First photoelectric cell is introduced.

1926: America. First "pop-up" bread toaster is introduced.

1926: America. Dr Julius Edgar Lilienfield from New York filed for a patent on what we would now recognize as an *npn* junction transistor being used in the role of an amplifier.

1927: Harold Stephen Black conceives the idea of negative feedback which, amongst other things, makes hi-fi amplifiers possible.

1927: First five-electrode vacuum tube (the pentode) is introduced.

1928: Joseph Schick invents the electric razor.

1928: America. First quartz crystal clock is introduced.

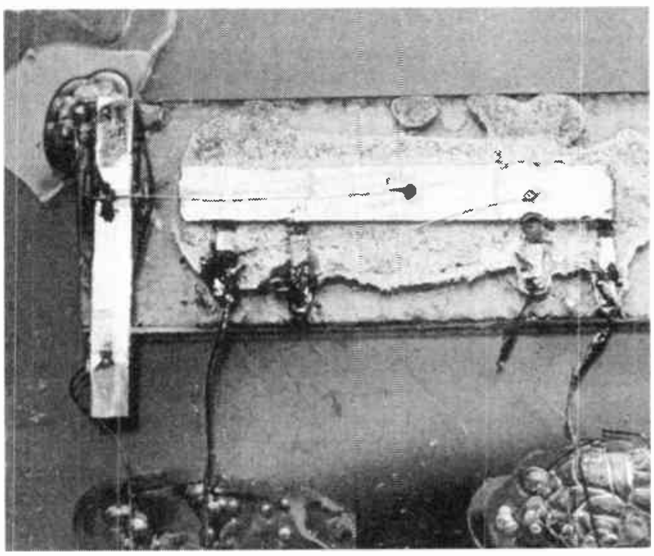
that was receiving a lot of attention was the Micro-Module program, which was sponsored by the US Army Signal Corps.

Using this technique, all of the components were created with a uniform size and shape, and the wiring was built into the components themselves. These Micro-Modules could then be snapped together to form circuits.

Texas Instruments was working on the Micro-Module program when Jack Kilby joined the company in May 1958. In the middle of the summer, most of the plant was to shut down for a mass vacation, but as a new employee Kilby did not have any vacation time coming, so he was left to his own devices.

In a desperate attempt to avoid being consigned to working on Micro-Modules for the rest of his career, Kilby started pondering the fact that multiple devices such as resistors, capacitors and transistors could be fabricated on a single piece of semiconductor and connected together *in situ* to form a complete circuit.

As soon as his boss returned from vacation, Kilby explained his ideas and received permission to experiment further. On 12th September 1958, he powered up his first prototype – a phase shift oscillator – which immediately started to oscillate at approximately 1·3MHz.



The first integrated circuit, created by Jack Kilby of Texas Instruments in 1958. Courtesy of Texas Instruments.

Although manufacturing techniques subsequently took different paths to those used by Kilby, he is still credited with the manufacture of the first true *integrated circuit*.

The original bipolar junction transistors were manufactured using the mesa process (named after flat-topped, table mountains), in which a doped piece of silicon called the *mesa* (or *base*) was mounted on top of a larger piece of silicon, which formed the *collector*. The third terminal – the *emitter* – was created using a smaller piece of silicon, which was embedded in the base.

In 1959, the Swiss physicist Jean Hoerni invented the *planar process* in which optical lithographic techniques were first used to diffuse the base into the collector, then the emitter into the base.

One of Hoerni's colleagues, Robert Noyce, invented a technique for growing a layer of silicon dioxide insulator over the transistor, and then etching this layer to expose small areas over the base and emitter. Thin layers of aluminum were subsequently diffused into these areas to create wires. The processes developed by Hoerni and Noyce led directly to modern integrated circuits.

By 1961, both Fairchild and Texas Instruments had announced the availability of the first commercial planar integrated circuits, comprising simple logic functions. Only nine years later in 1970, Fairchild introduced the first semiconductor-based 256-bit static RAM, while Intel announced the first 1024-bit dynamic RAM.

Then in 1971, Ted Hoff *et al* at Intel invented the world's first *computer on a chip* – the 4004 microprocessor. The successors of this device (the 4040, 8008 and 8080) heralded a new area in computing. Systems small enough to fit on a desk could be created with more processing power than monsters weighing tens of tons only a decade before.

Almost unbelievably, individuals could now own their own personal computer. As we shall see in future parts, the effects of these developments are still unfolding, but it is not excessive to say that electronics in general, and digital computers in particular, have changed the world more significantly than almost any other human invention.

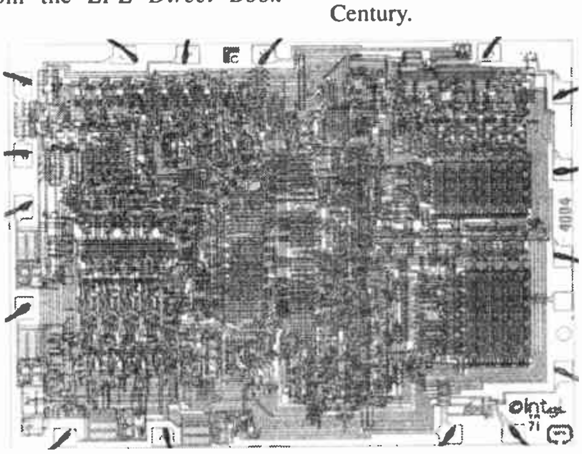
MORE INFO

The way in which components like transistors and integrated circuits perform their magic is discussed in greater detail in *Bebop to the Boolean Boogie (An Unconventional Guide to Electronics)*, while the history of the early computers is discussed in more detail in *Bebop BYTES Back (An Unconventional Guide to Computers)*. By some strange quirk of fate, both of these books are available from the *EPE Direct Book Service*!

1930: America. Sliced bread arrives.
1936: Fluorescent lighting arrives.
1938: Hungarian Lazlo Biro patents the first ball-point pen.
1938: Walter Schottky discovers the existence of holes in the band structure of semiconductors and explains metal/semiconductor interface rectification.
1938: America. Claude E. Shannon publishes an article (based on his Master's thesis at MIT) showing how Boolean algebra could be used to design digital circuits.
1939: Light-emitting diodes were patented by Messers Bay and Szigeti.
1943: German engineer Paul Eisler patents the printed circuit board.
1945: Percy L. Spensor invents the microwave oven (the first units go on sale in 1947).
1947: America. Physicists William Shockley, Walter Brattain, and John Bardeen create the first point-contact germanium transistor on the 23rd December.
1948: First atomic clock constructed.
1950: Maurice Karnaugh invents Karnaugh Maps (circa 1950), which quickly become one of the mainstays of the logic designer's tool-chest.
1950: America. Physicist William Shockley invents first bipolar junction transistor.
1952: England. First public discussion of integrated circuits is credited to a British radar expert, G.W.A. Dummer.
1954: America. C. A. Swanson company markets the first "TV Dinner".
1955: Velcro is patented.
1957: America. Gordon Gould conceives the idea of the laser.
1958: America. Jack Kilby, working for Texas Instruments, succeeds in fabricating multiple components on a single piece of semiconductor.
1959: Swiss physicist Jean Hoerni invents the planar process, in which optical lithographic techniques are used to create transistors.
1959: America. Robert Noyce invents technique for creating microscopic aluminum wires on silicon (leads to development of integrated circuits).
1960: America. Theodore Maimen creates the first laser.

NEXT MONTH

In Part 3, we shall consider the development of communications in the 20th Century.



The first microprocessor, Intel's 4004, of 1971. Courtesy of Intel.

AUTOMATIC TRAIN SIGNAL

ROBERT PENFOLD

An easy-build, low cost starter project for your model railway system

THIS very simple project, suitable for beginners, is a two-colour (red/green) signal for a model railway. It uses a simple form of automatic operation, and if you stop the train in front of the signal it automatically switches from "green" to "red". When the train is restarted the signal automatically switches to "green" again.

To an onlooker it appears as though the signal is changing colour and the train is responding to the change. In reality the train and the signal are both responding to changes in the track voltage. The signal will, in fact, go to "red" wherever the train is stopped on the layout, but this is of no practical importance, as the state of the signal is irrelevant except when the train is approaching it.

SYSTEM OPERATION

The block diagram of Fig.1 helps to explain the way in which the Automatic Train signal functions. The voltage from the track is fed to a full-wave rectifier circuit. The voltage on the track is a d.c. signal, but its polarity depends on the direction of the train.

To operate the main circuit reliably it is important that the input signal has the correct polarity, and the purpose of the rectifier is to ensure that the main circuit is fed with a positive signal regardless of the train's direction. The output of the rectifier is fed to a potentiometer that enables the output voltage to be reduced. This enables the user to adjust the threshold voltage at which the signal changes state.

The threshold level used is not critical, but the signal should not go to red while the train is still moving. On the other hand, some types of train controller never produce an output level that is right down at zero volts, and the threshold level must be high enough to ensure that the signal does go to red when the train stops.

It cannot be safely assumed that the signal across the tracks is a steady d.c. potential. The motor in the train is likely to introduce large amounts of noise onto the track voltage, which might not be a simple d.c. signal anyway. Many train controllers use some form of pulsed output signal, where the motor is controlled by varying the average output signal. Others use the rectified but non-smoothed output from a mains transformer.

In order to avoid problems with noise on the input signal, and to accommodate pulsed controllers, the output from the threshold control is fed to a lowpass filter. This provides a reasonably smooth d.c. output signal at a potential that is equal to the average input voltage.

Finally, this signal is applied to a simple voltage detector circuit. With an input voltage of up to about 1·8V the detector circuit activates the red signal l.e.d., but with higher input potentials it switches on the green l.e.d. instead.

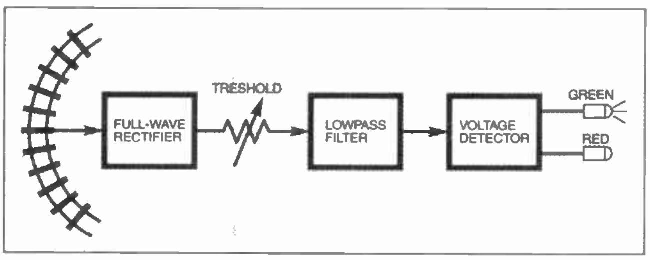


Fig.1. Block diagram for the Automatic Train Signal.

CIRCUIT OPERATION

The full circuit diagram for the Automatic Train Signal is shown in Fig.2. The voltage from the rail tracks is connected to sockets SK1 and SK2, which feed into a full-wave bridge rectifier (D1 to D4).

The positive d.c. output signal from the rectifier circuit is fed to a volume control style variable attenuator (VR1) and then to a simple lowpass filter comprised of resistor R1 and capacitor C1.

The cut-off frequency of this filter is low enough to ensure that there are no problems with flickering of the signal lights when the track voltage is near the threshold level. On the other hand, it is not so low that the unit is slow responding to changes in track voltage.

An operational amplifier, IC1, is used here as a voltage comparator. Resistors R3 and R4 form a potential divider that biases the non-inverting input of IC1 (pin 3) to about 1·8V. The output of IC1 at pin 6 will go high if the inverting input (pin 2) is taken below this potential, or low if it is taken above the reference level.

The voltage fed to the inverting input will be very low with the train stationary, sending the output of IC1 high. As a result red l.e.d. D6 is switched on, but green l.e.d. D5 is switched off.

When the train is started, the voltage fed to the inverting input rises, and eventually becomes greater than the reference level at the non-inverting input. The output of IC1 then switches to the low state, switching off D6 and switching on D5. Things revert to their original states when the train is stopped again, with the red l.e.d. switched on.

ON TRACK

The current consumption of the circuit is about 7mA. A PP3 size battery is just about

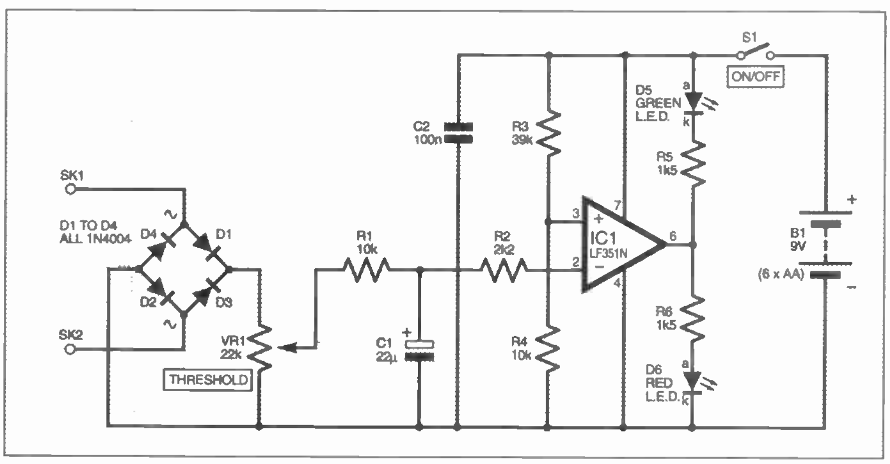


Fig.2. Complete circuit diagram for the Automatic Train Signal.

adequate to supply this, but a battery pack consisting of six AA size cells in a holder will provide cheaper running costs.

Operation from a mains power supply unit is made slightly awkward by the fact that neither supply rail can be earthed. This is because one of the input lines might be earthed, and neither of these lines connects to a supply rail of the signal circuit.

Earthing one rail of the signal circuit could produce an unwanted connection that would prevent the unit from working, and could result in a heavy current flowing through the input rectifier circuit. The most practical solution is to use a 9V or 12V regulated battery eliminator. These use double insulation and have neither supply rail earthed.

CONSTRUCTION

The Automatic Train Signal circuit is built up on a piece of stripboard containing 20 holes by 20 copper tracks. The component layout, together with details of breaks required in the copper strips, is shown in Fig.3.

Construction follows along the normal lines with a standard size board being cut down to the correct size using a hacksaw. Next drill the two mounting holes, which have a diameter of 3mm and accept Metric M2·5 mounting bolts. There are just six breaks in the copper strips. These can be made using a special tool or by using a small hand-held twist drill bit of about 5mm dia.

The board is now ready for the components and the three link-wires to be added. It is generally considered best to start with the small components and work up to the largest, but in this case the components are all quite small.

It is probably best to work across the board methodically, being careful to get everything in the right place. In the cases of IC1, C1, and the four rectifier diodes (D1-D4) you must also be careful to fit them the right way round. The LF351N used for IC1 is not a static sensitive component, but as with any d.i.l. integrated circuit it is still advisable to mount it on the board via a holder.

It might be possible to make the link-wires using the wire trimmed from the resistor leads, but one or two of them might be too long to permit this. They will then have to be made from 22s.w.g. or 24s.w.g. tinned copper wire. Fit single-sided solder pins at the points where connections will be made to the controls, l.e.d.s, and sockets.

COMPONENTS

See SHOP TALK page

Resistors

R1, R4	10k (2 off)
R2	2k2
R3	39k
R5, R6	1k5 (2 off)

All 0·25W 5% carbon film

Potentiometer

VR1	22k rotary carbon, lin.

Capacitors

C1	22µ radial elect. 25V
C2	100n ceramic

Semiconductors

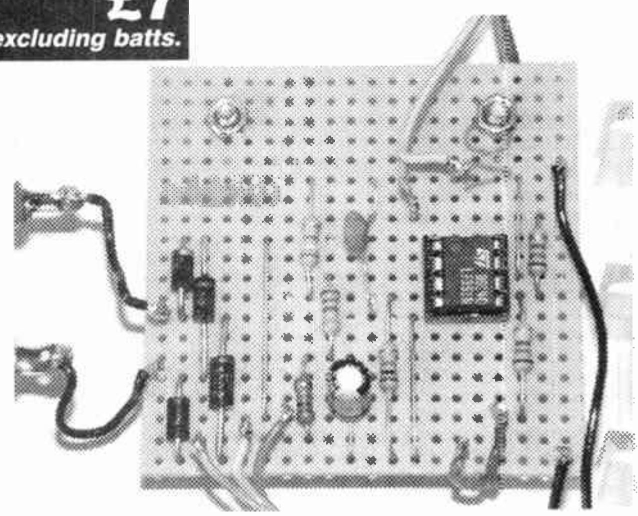
D1 to D4	1N4004 rectifier diode (4 off)
D5	green l.e.d., 3mm or 5mm dia. (see text)
D6	red l.e.d., 3mm or 5mm dia. (see text)
IC1	LF351N op.amp

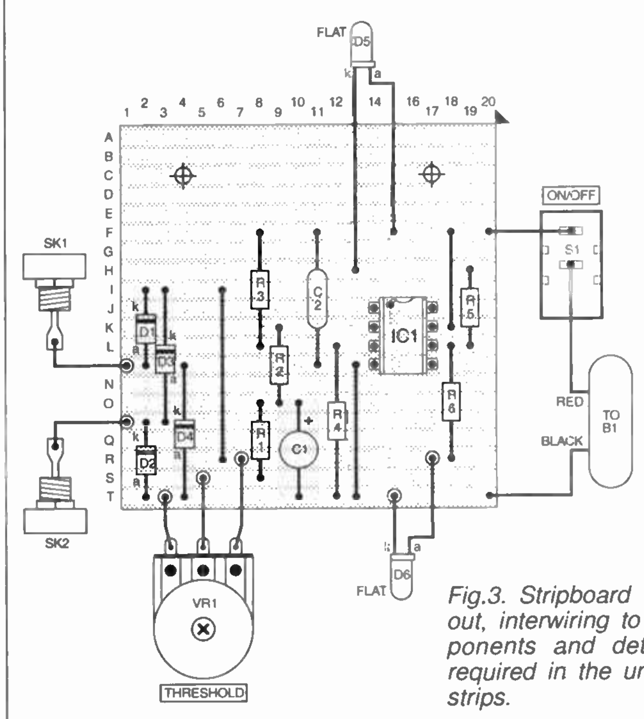
Miscellaneous

B1	9V battery pack (6 x AA cells in holder)
S1	s.p.s.t. miniature toggle switch
SK1, SK2	4mm socket (2 off)

Medium size plastic case (see text); 0·1 inch pitch stripboard, size 20 holes by 20 strips; 8-pin d.i.l. holder; control knob; PP3 battery clip; multistrand connecting wire; single-sided solder pins; solder, etc.

Approx. Cost Guidance Only £7 excluding batts.





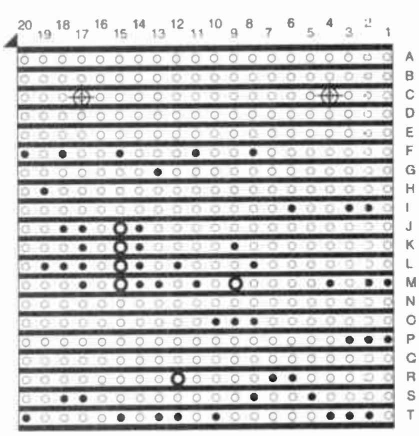
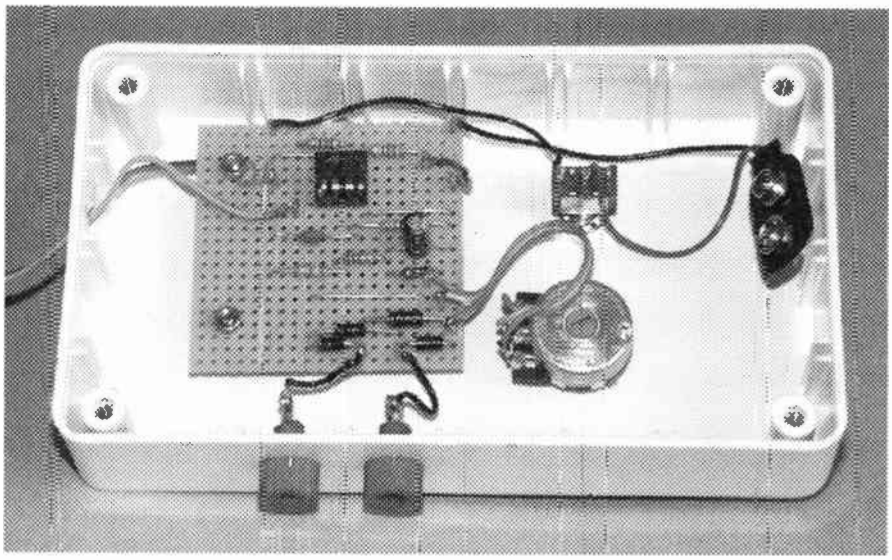


Fig.3. Stripboard component layout, interwiring to off-board components and details of breaks required in the underside copper strips.



Layout of components inside the small plastic box. Note, the input sockets must be fed with the track voltage.

CASING UP

If the unit is powered from a PP3 size battery it should be possible to fit it into practically any small plastic box. A medium size case about 150mm or so long will have to be used if an AA battery pack is to be accommodated.

Threshold control VR1 and On/Off switch S2 are mounted on the front panel, while input sockets SK1 and SK2 are mounted on one side or at the rear of the case, see photographs. An exit hole for the lead to the signal l.e.d.s is required in one side or the rear of the unit.

The circuit board is mounted in any convenient space, and it is advisable to use some extra nuts or short spacers between the board and the case. This avoids any tendency for the board to buckle and break when the mounting nuts are tightened.

To complete the main unit the hard wiring is added. This is all shown in Fig.3 and is perfectly straightforward.

SIGNAL BOX

Construction of the "signal" is left to the ingenuity of individual constructors. At its most basic the signal can just consist of a very small plastic box for the two l.e.d.s. However, it should not be too difficult to fabricate a more convincing signal from balsa wood, bits of dowel, etc. Provided you know what you are doing, it would probably be possible to adapt a ready-made signal "tower" to work with this circuit.

The size of the signal must be varied to suit the gauge of the model railway, as must the size of the two l.e.d.s. For the usual smaller gauges 3mm dia. l.e.d.s are the best choice, but for larger gauges 5mm types would be better. The l.e.d. current is not very high, so "high brightness" types are preferable.

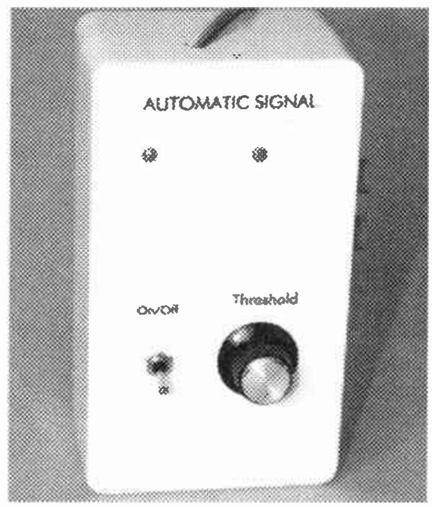
Unlike filament bulbs, l.e.d.s will only work if they are connected with the correct polarity. Having the cathode (k) lead slightly shorter than the anode (a) lead is the normal way in which the polarity of an l.e.d. is indicated. There may also be a "flat" on the cathode side of the encapsulation.

TESTING

Input sockets SK1 and SK2 must be fed with the track voltage, and the way in which this is done must be varied to suit the equipment with which the signal is used. In most cases the easiest way is to make up a twin lead fitted with 4mm plugs to connect to SK1 and SK2, and small, insulated covered, crocodile clips at the other end. The power connectors on the track are often quite crude, and will permit power to be tapped off using the crocodile clips.

Alternatively, by simply leaving some bare wire at the ends of the leads it might be possible to make connections to the screw or spring connectors on the train controller, being careful to leave the connections to the track intact. Failing that, it will be necessary to make up a dual supply lead to enable both the signal and the track to be fed from the controller.

With Threshold control VR1 at a roughly middle setting the signal should work quite well, with "red" and "green" signals being obtained when the train is respectively stopped and running fast. The signal will probably be at "red" when the train moves very slowly, or possibly at "green" when the train has stopped. A little experimentation with various settings for VR1 should soon get the signal switching states at the start/stop track voltage of the train.



Note that the more simple types of controller tend to provide a start voltage that is much higher than the one at which the train stops. The threshold voltage of the signal then has to be set at a compromise level somewhere between these two voltages. □

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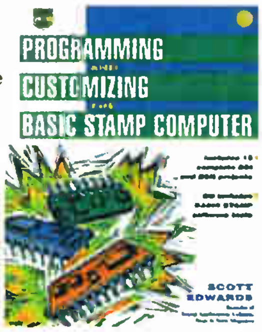

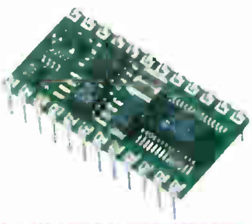

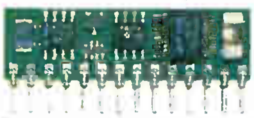

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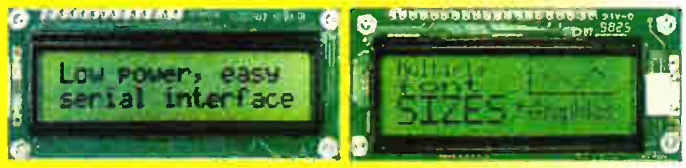

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Forwards,backwards and left/right turn when feelers detect object in path. Up to 2 hours roving from 4xAA Nicads. Chips pre-programmed but programme may be changed (software supplied). Body parts pre-cut.
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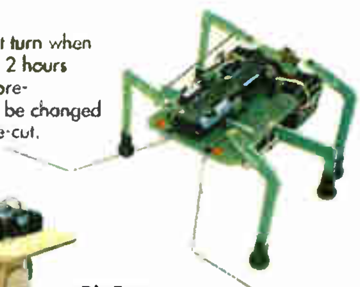

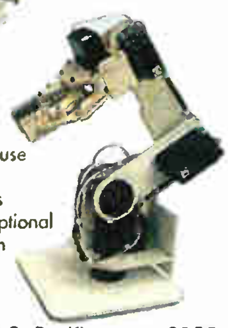

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7 Output lines (5v @ 20mA) may be set to momentary or toggle action.
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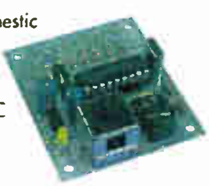

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Constructional Project

EPE ICEBREAKER

MARK STUART

A real-time PIC In-Circuit Emulator, programmer, debugger and development system.

THIS project combines Microchip's MPLAB development software with the advanced self-debugging features of the latest PIC chips. The result is a user-friendly advanced development system for a very low cost.

DEVELOPMENT SYSTEMS

Developing projects with microcontrollers is extremely interesting, especially the ability to alter the way hardware responds just by making simple changes to program code.

The problem is that each change of code has to be written, compiled (converted into suitable form for loading) and programmed into a chip before it can be tested. Several low cost systems – such as the *EPE PIC-tutor* are available and are adequate for the development of simple programs, but for larger changes and programs it can be tedious, and errors are almost as easy to introduce as to eliminate.

Better methods of testing programs rely on more advanced software that can "run" in a virtual chip on a PC screen and advanced hardware which communicates with the program in the PC, reads input pins, and switches output pins to match the levels of the virtual chip. Such a system is called an In-Circuit Emulator or "ICE" and professional systems are available for practically every type of microcontroller.

The problem with this is cost. A professional ICE for the PIC series of chips costs a reasonable £2000 or so – not a lot if you are a professional programmer being paid twice that each month – but for an amateur!

Just lately a new type of development system has appeared called In-Circuit Debugging (ICD). This requires a chip with special built in hardware (known as a Background Debugger) and software which can communicate its status via a serial link.

The chip is fitted to its working p.c.b. and all external hardware is connected and active. Code is then programmed, run, and debugged under PC control, until it is running correctly. For Microchip PIC users, the good news is that the PIC16F877 and its close relatives the '876, '874, and '873 have built in ICD facilities and can be used to develop code which can be run in these and smaller chips in the range – such as the most popular PIC16F84.

PIC IN-CIRCUIT DEBUGGING

This article is intended as an easy introduction to ICD with very simple demonstration programs, users can then progress to using the more complicated features of the chips. It is *not* intended as a programming tutorial but the operation of some programs is described in the course of demonstrating the ICD hardware.

Simple programs can be loaded, run and debugged without knowing much about the entire ICD system which is extremely complicated and occupies many pages of the PIC data sheets. The Microchip web site (**http://www.microchip.com**) provides an enormous amount of information for those wishing to know more.

MINIMUM ICD SET UP

The minimum hardware required for ICD, using the PIC16F877, is shown in Fig.1. Communication to a computer serial port is achieved via the Port RB6 and RB7 pins of the chip which cannot be used for other functions. As there are plenty of other port pins available this is not a significant limitation.

Port RB6 receives data from the computer, and RB7 transmits data to the computer. Both of these pins operate at simple 0V to 5V logic levels. Some computer serial port output pins swing 10V positive and negative, and so limiting resistors and 5·1V Zener diodes are used for protection.

The serial data sent back to the computer should also be capable of swinging 10V, but it has been found that practically all computers read serial data correctly when 0V to 5V swings are used. A third connection links the serial port RTS output to the VPP or $\overline{\text{MCLR}}$ pin of the chip. This allows control of the programming voltage

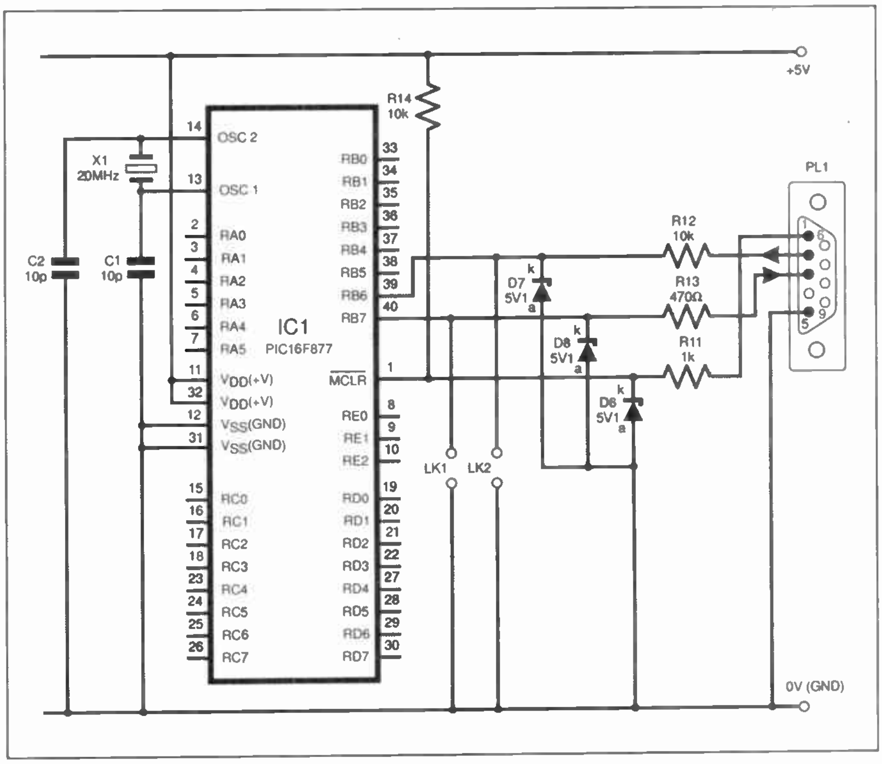


Fig.1. Minimum circuit for using the PIC16F877 as a "background" debugger.

(programming at 5V, as opposed to the 12V normally required) and resetting of the chip by the computer.

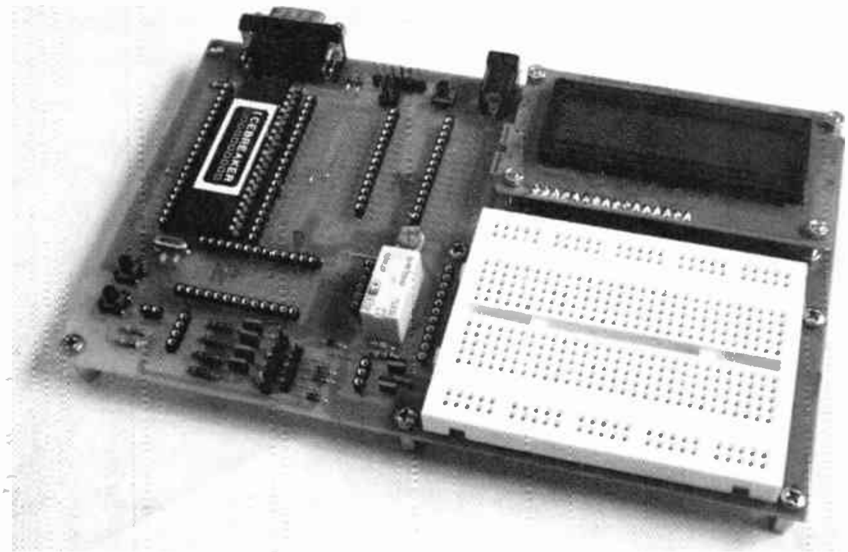
After a Reset, the chip checks if pins RB6 and RB7 are shorted to 0V. If they are, it ignores the ICD functions and just runs the code directly starting from location 0. Links fitted in the positions marked LK enforce this option.

As well as the hardware connections, the computer needs to run a program to communicate with the chip, and the chip must have a program to communicate with the computer. The program in the chip is loaded and copy-protected into the upper half of the chip's 8K program memory.

It may seem wasteful to use half of the chip's memory for protected code, but in practice, the 4K remaining is a vast amount of space for the PIC program and it is very doubtful that it will ever be filled. Once working code has been developed and debugged it can be loaded and will run alone in any chip in the 16x range – the protected communication code is required only in the chip used for debugging.

Connections for suitable serial leads are shown in Table 1. These are standard connections, but can be made up with 4-way cable (flat telephone cable is ideal) if required. Take care when making leads to get the pin numbering correct – it is very confusing, the only safe way is to read the moulded numbers on the connectors.

The port connections for the PIC 16F877/874 and the alternative connections for the 28-pin PIC16F876/873 versions of the chip are shown in Fig.2.



HARDWARE

Whilst the minimum system could be used, it is unlikely that any PIC application would operate without external hardware. Most systems have power supplies, input switches, output devices and so on. It is irritating and time consuming to have to set up these simple hardware requirements when the object is to get a program written and tested. *EPE* ICEbreaker was designed to include a number of input and output devices along with a solderless connection system so that many applications could be tested from a notebook PC without the use of a soldering iron.

The full ICEbreaker circuit diagram is shown in Fig.3, whilst Fig.4 gives the p.c.b. details.

Resistors R11 to R13, and R14, Zener diodes D6 to D8 and links LK1/2 are the same as the minimum system. PL2 allows the power and computer connections to be extended so that the PIC could be fitted into another board with other hardware and still debugged via the same computer lead.

Voltage regulator IC2 allows a range of power adaptors to be used connected to 2·1mm power socket SK5. Links 3 and 4 allow positive inner or outer connections to be set. If accidental power reversal is possible, the positive link connection can be made using a 1A diode (e.g. 1N4001) instead of a piece of wire. Power is indicated by l.e.d. D5 via resistor R8.

Switch S1 provides an alternative hardware reset which can be useful for stopping programs quickly and for restarting from location 0.

For ICD operation the PIC needs accurate timing. A 20MHz crystal X1 together with capacitors C1 and C2 provide the standard oscillator components. Alternative positions (X2) and (C3, C4) are to be used with 28-pin chips.

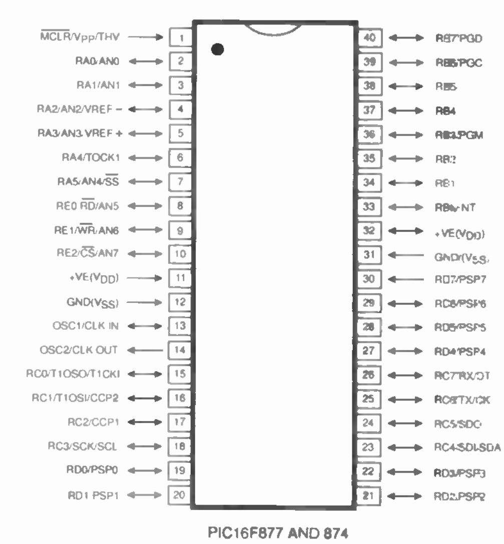
Resistors R15 and R16 allow *RC* oscillator options to be used if required for testing or running fully debugged code, but as *RC* oscillator stability is poor, this option is not recommended for ICD use. Other crystal frequencies can be used and the computer serial port speed altered accordingly. 20MHz gives the fastest communication (38,400 BAUD) and is best if there are no other special frequency requirements.

Stepping motor driving is a very popular PIC application. Transistors TR1 to TR4 and associated resistors R2 to R5 and protection diodes D1 to D4 provide four open collector drivers for four-phase unipolar motors. Connectors PL3 and PL4 allow for 2·54mm and 2mm pitch motor connectors. Input to the drivers is via SK4. The transistors can also be used individually as simple open-collector *npn* switches for driving relays, lamps and similar loads up to 24V and 400mA.

Two other output transistors are fitted. TR5 is a simple open collector *npn* device and TR6 drives a double-pole changeover

Table 1: Serial Lead Connections

ICE	9-way to 9-way	Computer
1		7
2		3 TxD
3		2 RxD
5		5 GND
	9-way to 25-way	
1		4
2		2 TxD
3		3 RxD
5		7



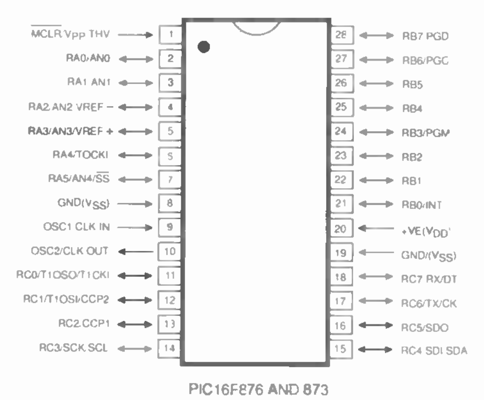


Fig.2. Port connections for the PIC16F877/874 and the alternative 28-pin PIC16F876/873.

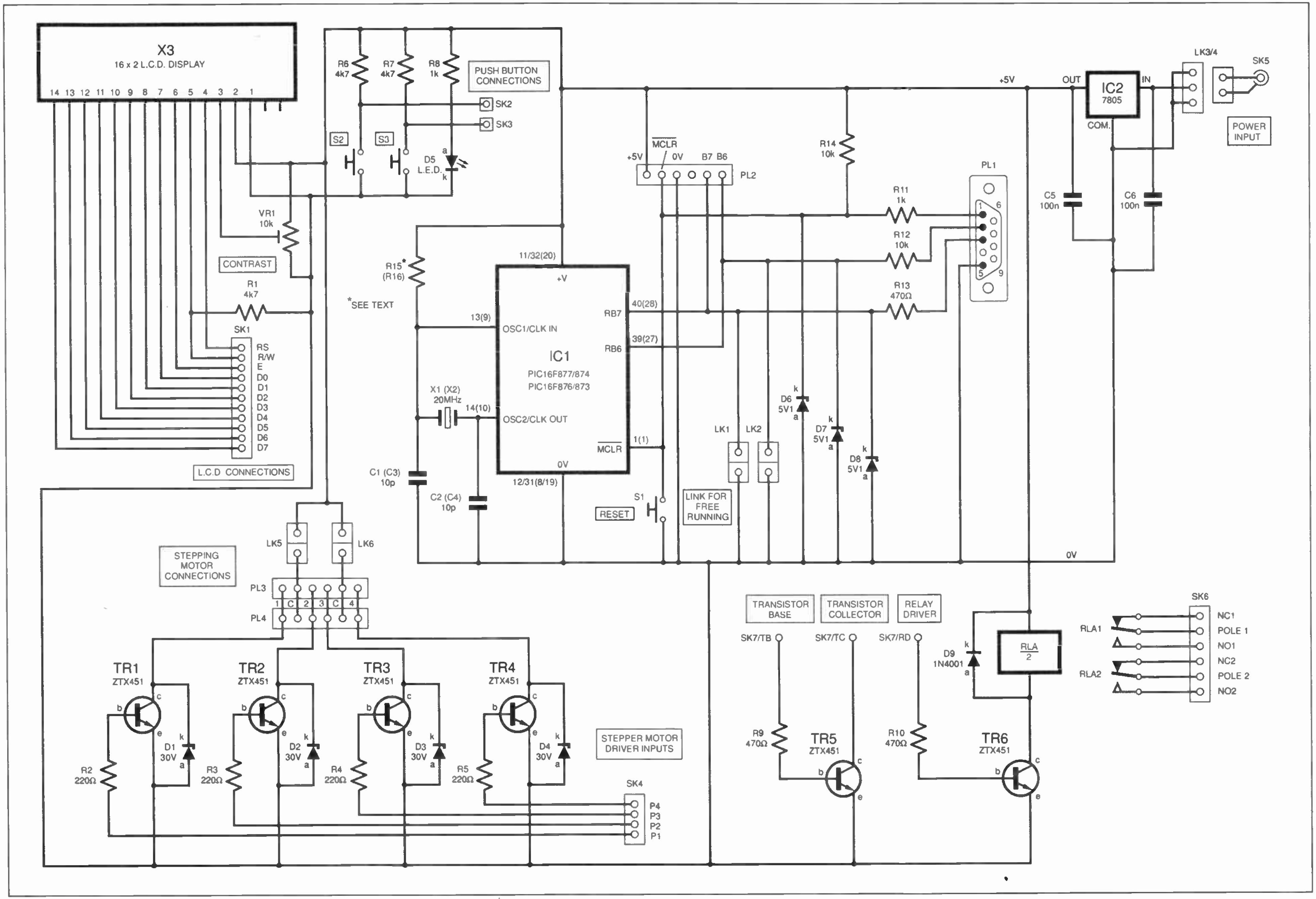


Fig.3. Complete circuit diagram for the EPE ICEbreaker.

relay RLA. These two devices are useful for bidirectional control of a d.c. motor. RLA can be wired as a reversing switch and the motor can be turned on and off by TR5.

Many applications require display of information, and an intelligent l.c.d. module is an ideal display device. X3 has standard 4- or 8-bit drive capability, and requires a minimum of six output lines for driving. All pins are available at connector SK1. Preset VR1 allows the contrast of the l.c.d. to be altered to suit the lighting conditions and viewing angle.

Just two input devices are fitted. S2 and S3 are simple single-pole push-to-make switches with pull-up resistors R6 and R7.

Whilst the circuit diagram seems simple, the p.c.b. layout shows that there are far more connection points, and that a prototyping area with a solderless breadboard is provided. Each side of the main i.c. sockets there are spaces for rows of turned-pin sockets. The inner two rows connect to the adjacent i.c. pins, whilst the outer two rows are power and ground connections.

Turned-pin socket strips can be fitted in all rows, but it is more practical to have a single row of sockets each side of the chip and leave the other spaces blank so that pull up or pull down resistors can be soldered in position if required. An additional "patch" area is provided below IC1 and is ideal for adding "permanent" hardware such as l.e.d.s or presets.

ICEBREAKER SOFTWARE

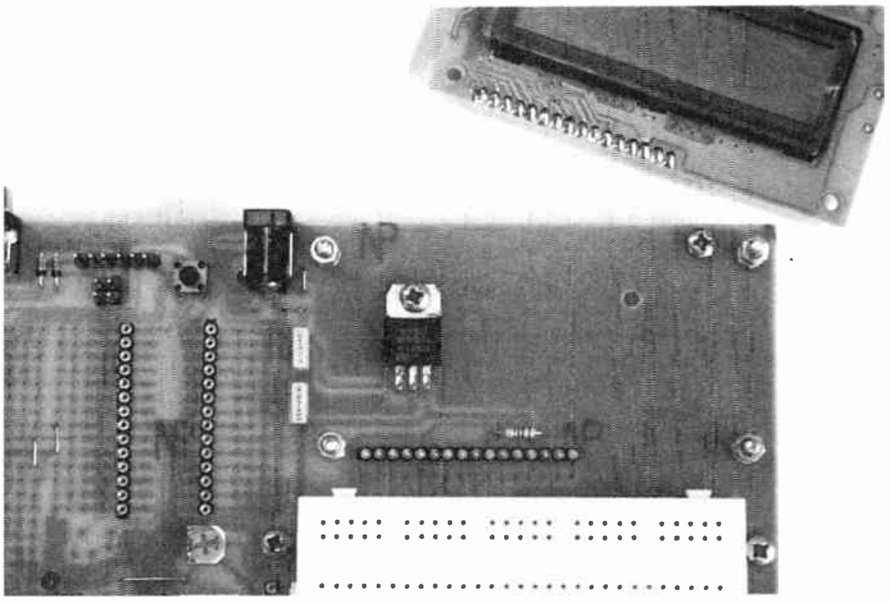
ICEbreaker must be run from a PC with at least *Windows 95*. This helps keep the software simple, and is not a serious restriction as PCs that can run Win95 are available at very low prices. A standard Pentium 133 without special sound, graphics or multimedia is more than adequate provided it has a spare serial port (COM 1 – 4).

The software is designed to be run in conjunction with Microchip's MPLAB software. This is available from many sources – the Microchip web site is the ideal one as it allows the very latest version to be loaded, alternatively the Microchip CD-ROM is widely available and good for those without internet access.

MPLAB is used in "editor only" mode to allow assembly language source code to be written and then assembled to produce the necessary **.HEX** code for programming into the chip. MPLAB also produces a .COD file which is used by the ICEbreaker software to keep track of the program execution when debugging, single stepping and running the program. Like many other PC programs MPLAB has a lot of features that are not regularly used, however the advanced features don't get in the way when using it at the simple level required by ICEbreaker.

The ICEbreaker software is a simple stand-alone application that can be run directly from a floppy disk if necessary. This article assumes that the contents of the ICEbreaker disk are copied into a new folder (directory) on the C-drive which has been labelled **'icebreak'**. The only files required are **icebreak.exe** and **icebreak.ini** but it is also convenient to store program files in the same directory.

ICEbreaker and MPLAB should be run together, and the 'Alt' and 'Tab' keys or the taskbar buttons used to switch from one to the other.



Display module removed from the p.c.b. to reveal the regulator i.c. mounted underneath.

CONSTRUCTION

The *EPE* ICEbreaker printed circuit board component layout and full size copper foil master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 257.

Assembly of the board is straightforward. Begin by fitting seven 12mm pillars with short M3 screws before adding any components. Refer to the component layout drawing and then fit plain uninsulated wire links in all of the positions shown. Fit two-way pin headers in the position for LK1 and LK2 so that two shorting links can be connected if required.

Links LK3 and LK4 provide the facility to set the input power socket for positive or negative inner connection. For positive inner fit the links in position B, for negative fit them in position A. As mentioned previously it is possible to add a diode in place of one of the links to protect against polarity reversal. To do this, fit the cathode of the diode to the point marked with a + sign, and the anode of the diode to the appropriate A or B position.

Fit the diodes and resistors next, taking care to identify the type and polarity. Usually the cathodes are marked with a black or dark blue band which should be positioned to match the line on the component layout diagram. The transistors TR1 to TR6 are all the same type and are fitted with their curved sides as shown in the diagram. They should be fitted close to the board surface so that they cannot get bent and moved around when the board is handled.

Use turned-pin socket strips for the 40 and 28-way i.c. positions, and position a second row of sockets alongside. Note that there is also the option of a narrow bodied version of the 28-pin device, and holes have been drilled to allow for this type to be used. If required, socket strips can be fitted for both types without causing any difficulty. Also fit turned-pin socket strips for SK1, SK2, SK3, SK4, SK6, and the three connections TB, TC, and RD. Also fit two 13-way strips to the upper and lower rows of the patch area – these are the positive and negative "rails" and make very convenient connection points for taking power to the breadboard.

Fit pin headers for PL2, PL3 and PL4 – the holes for these are made tight to give extra support and so the pins may need pressing home against a hard surface. Fit pushswitches S1, S2 and S3, preset VR1, relay RLA and the voltage regulator IC2; an M3 screw and nut should be used to secure the tab. A heatsink is not required for most applications, but there is space to fit a low profile type, or even a small piece of aluminium if higher current loads are to be used.

The 20MHz crystal and its associated capacitors C1 and C2 should be fitted if the (usual) 40-pin device is being used for IC1. If a 28-pin version is used then fit these components to the alternative locations X2, C3 and C4. If both types of device may be used, it is possible to fit two crystals and two pairs of capacitors.

DISPLAY MODULE

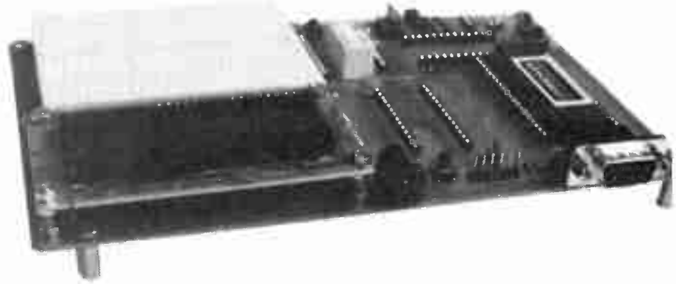
The l.c.d. module fits above the board on 16mm long 6BA or M2.5 screws. Fit the four screws from the track side of the board and secure them with nuts. Fit four more nuts and position them equally so that the l.c.d. lies level and approximately 10mm from the board. The connections to the l.c.d. are made to allow it to be unplugged for access to IC2 and for use in other applications.

Fit a 16-way pin-to-pin connector to the board, with the slightly thinner pins upwards. Fit (but do not solder) a 16-way wirewrap turned-pin socket strip to the l.c.d. so that the sockets face downwards and plug onto the pin-to-pin connector. Make sure the l.c.d. is level, solder the wire wrap pins to the l.c.d. and cut off the excess. The l.c.d. can now be secured by fitting another four nuts.

The serial port connector PL2 and power connector SK5 fit directly onto the board. Make sure that they are pressed fully home before soldering.

The solderless breadboard is secured to the board simply by its self-adhesive backing. Make sure that it is accurately positioned (and the right way up) before pressing it firmly into place.

EPE ICEBREAKER



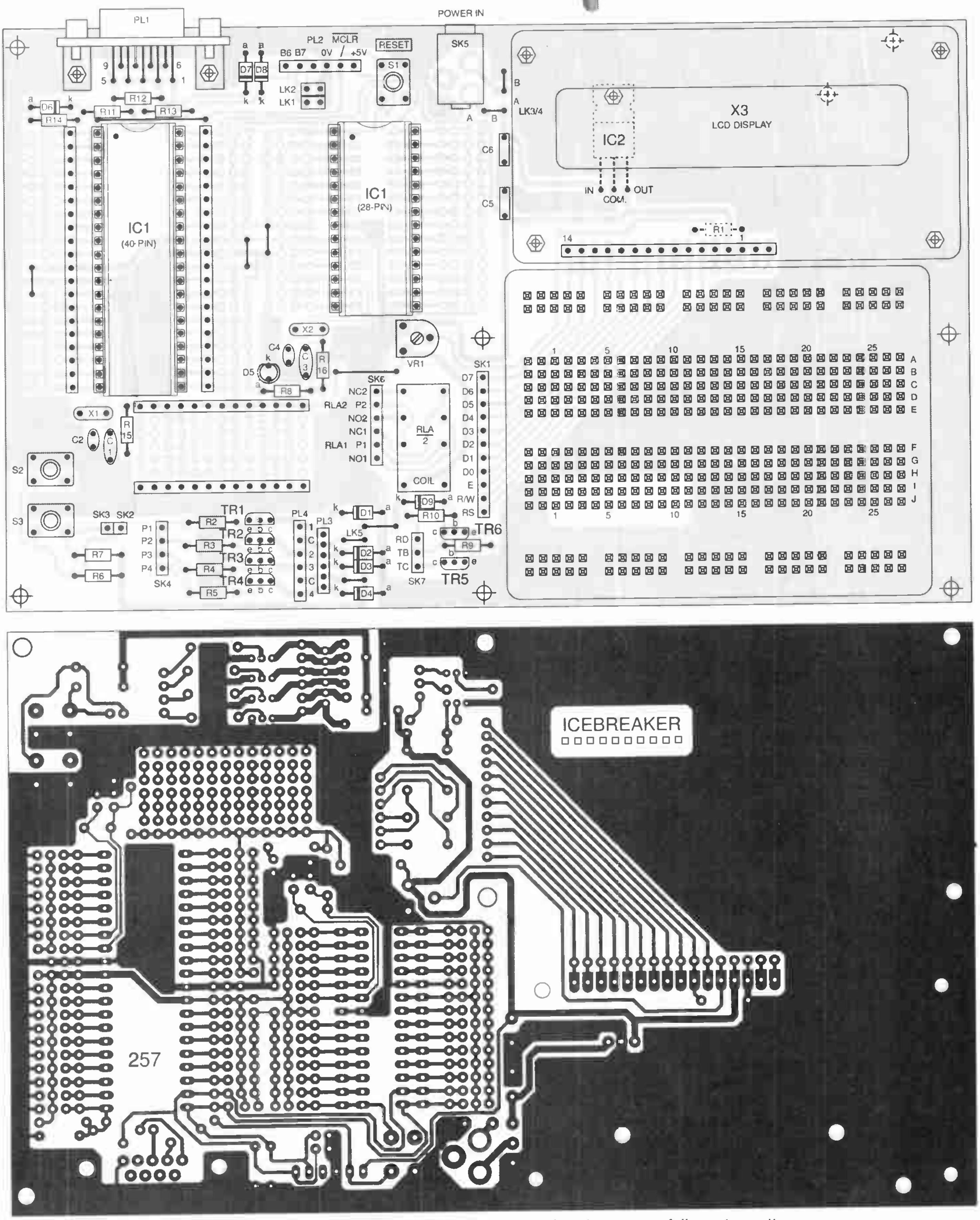


Fig.4. Printed circuit board component layout and full size copper foil master pattern.

TESTING

Once the hardware has been assembled and before fitting IC1, check for dry joints, solder bridges and component polarities.

Once everything looks correct, connect the power supply. Check that D5 lights and, if a meter is available, check the 5V regulated supply. The l.c.d. contrast control VR1 should alter the density of a single top row of block characters as the l.c.d. initialises itself for one-line mode.

Switch off, insert IC1 and connect a suitable lead between SK1 and the serial port of the PC which has MPLAB and the ICEbreaker software (see *Shoptalk* page) installed.

COMPONENTS

Resistors
R1, R6, R7 — 4k7 (3 off)
R2 to R5 — 220Ω (4 off)
R8, R11 — 1k (2 off)
R9, R10, R13 — 470Ω (3 off)
R12, R14 — 10k (2 off)
R15, R16 — See text
All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers
VR1 — 10k carbon preset

Capacitors
C1 to C4 — 10p ceramic, 2·5mm pitch (4 off) – see text
C5, C6 — 100n multilayer polyester (2 off)

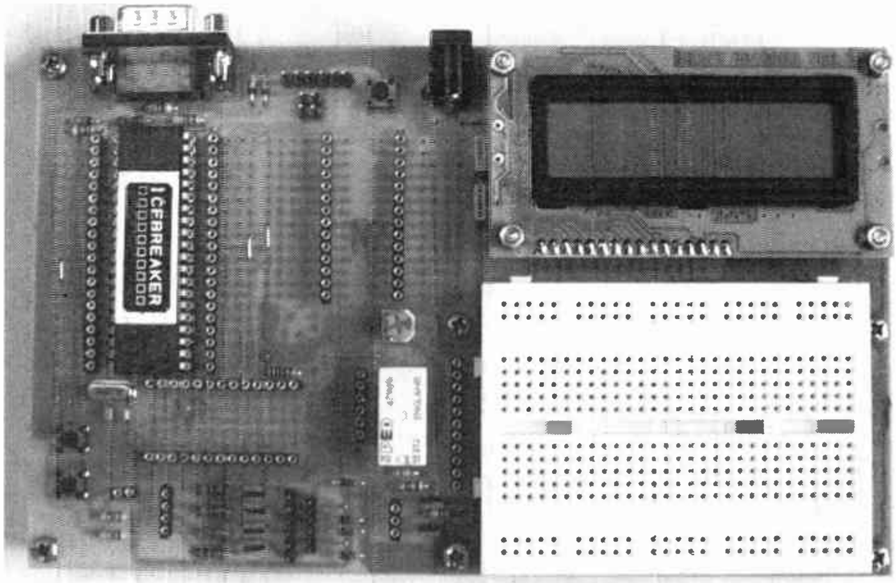
Semiconductors
D1 to D4 — 30V 400mW Zener diode (4 off)
D5 — 3mm low-current l.e.d. red
D6 to D8 — 5·1V 400mW Zener diode (3 off)
D9 — 1N4001 diode
TR1 to TR6 — ZTX451 *npn* transistor (6 off)
IC1 — PIC16F877P20 pre-programmed
IC2 — 7805 voltage regulator
X1 (X2) — 20MHz low-profile crystal (see text)
X3 — 16x2 alphanumeric l.c.d. module

Miscellaneous
Socket strips to make up the following: 11-way (SK1); 1-way (SK2, SK3 – 2 off); 4-way (SK4); 6-way (SK6)
SK5 — 2·1mm p.c.b. power connector
S1 to S3 — s.p.s.t. push-to-make switch (3 off)
RLA — d.p.c.o. 5V coil relay (BT47)

Printed circuit board available from the *EPE PCB Service*, code 257; breadboard; 9-way 90° male D-type connector (PL1); 6-way 0·1in. pin header (PL2, PL4 – 2 off) 6-way pin strip, 2mm pitch (PL3); 2-way 0·1in. pin header with DP link plug (2 off – LK1, LK2); socket strips, 20-way (4 off), 14-way (2 off), 13-way (2 off); 16-way pin-to-pin strip for l.c.d.; 16-way long-pin socket strip for l.c.d.

Hardware: 12mm M3 HEX pillars (7 off); M3 screw x 6mm (7 off); screws CSK (4 off) and 12 nuts (6BA or M2·5) for l.c.d. mounting.

Approx. Cost Guidance Only £38



Layout of components on the completed EPE *ICEbreaker p.c.b.*

SOFTWARE INITIALISATION

Run MPLAB, select the 'project' tab and then 'new project'. In the directory box select **c:\icebreak** and set up a project named **ib.prj** and edit the project so that it contains the simple test program **ib1.asm** which is included on the ICEbreaker disk. Close the project edit window then select 'File' and **ib1.asm**. This will open the **ib1.asm** file on the MPLAB screen.

Next select 'Project' and 'Make project'. This will then run the MPASM program and produce files called **ib1.lst**, **ib1.hex**, **ib1.cod**, and **ib1.err** in the **icebreak** directory. The **ib1.err** file will contain a few warning messages which can be ignored.

Leave MPLAB running but minimise it by clicking on the appropriate box. Open the **icebreak** file and double click on **icebreak.exe** to start the program. The screen will display the main ICEbreaker window as shown in Fig.5, and possibly the Watch and Source windows (Figs. 7 and 8). In the main ICEbreaker window click on 'Options' and then select 'Programmer' this will produce the communications set up box shown in Fig 6. In this box set up the serial COM port that you are using. If a 20MHz crystal is fitted the Baud box must be set to 38400. Other crystal frequencies can be used and the Baud rate adjusted proportionally – e.g. a 5MHz crystal would operate at 38400/4 or 9600 Baud. Once set up close the box by pressing OK.

Back in the main box select 'File' and 'Open' which will reveal a standard file select dialogue window listing the files in the **icebreak** directory. Select and load **ib1.asm** and then open the source code window by selecting 'Window' and then 'Source'. The window should contain the **ib1.asm** source file with numbered lines as shown in Fig.7.

Before the program can be run it must be sent to IC1 by selecting 'Program' and then 'Program' in the main ICEbreaker window. A progress bar appears and ICEbreaker sends the program to the first 4K of the program memory in IC1. Once this is completed, it should be possible to step, run, and reset the code one line at a time using the 'Step' button in the main window. In single step mode, at each step, a highlight line progresses through the source code window, and the main ICEbreaker window shows the Program Counter, the contents of the W register and the Status register bits.

Sometimes the highlight does not track the source code exactly, and is one line

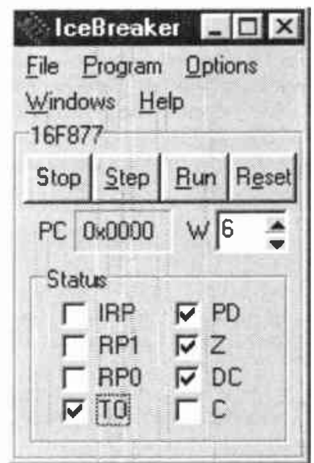


Fig.5. Main ICEbreaker window.

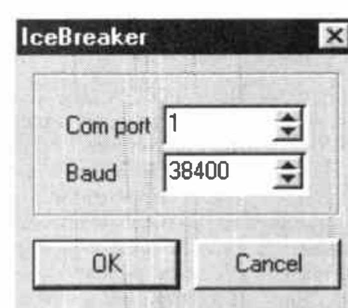


Fig.6. Set up box.

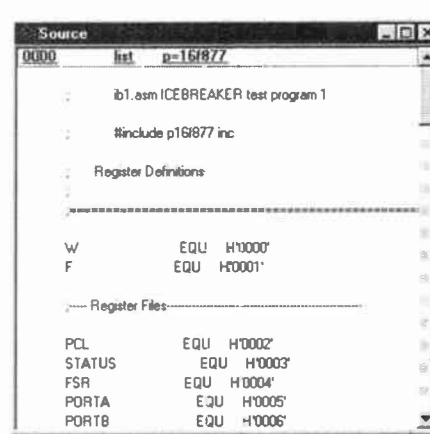


Fig.7. Source file window.

above or below the current line. This is due to the communications between the computer and IC1 and depends upon the way some of the source code is written; it is only a minor inconvenience as the actual line of code is easily worked out from the program counter in the ICEbreaker main window.

Other registers may be set up in the 'Watch' window – select 'Windows' 'Watch' in the main window. Fig.8 shows the main Watch window and Fig.9 the 'Add' window. Registers may also be 'Watched' by setting the first location and entering the number of registers in the 'Array' box.

The selector box in the 'Watch Add' window allows a choice of locations, labels and registers to be selected. It is important to understand that some of these options are not what they seem, for example the W option returns not the value of the W register, but the number 0 which has been assigned to the label W in the fifth line of the source code.

TESTING A PROGRAM

Once some familiarity has been achieved with the ICEbreaker windows, it is time to connect some hardware and see how it operates. As with all good microcontroller hardware systems, the first thing to do is flash an l.e.d.! The **ib1.asm** program counts up through PORTA which is set to output mode, and so all that is necessary is to connect an l.e.d. from pin 2 of IC1 via a current limiting resistor (anything from 100Ω to 2k2) to 0V.

Using solid core 1/0·6 connecting wire links it is an easy matter to put the l.e.d. and resistor on the breadboard and make the two connections to the turned-pin socket strips. The row of 13 sockets at the bottom of the patch area is a good place to find 0V. Provided the program has been set up correctly and loaded into IC1, the l.e.d. should flash when the program is set to 'Run'

In order to flash the l.e.d. slowly, the program has three nested counting loops. To single step through them would take years, and so it is impractical to go right through all of the states of PORTA. The alternative to single stepping is to insert a breakpoint and run the program to there.

Select 'Options', 'Breakpoint' from the main ICEbreaker window and set the value to 24. Fig.10 shows the 'Breakpoint' setting window. Entering a breakpoint highlights the line in the 'Source' window. 'Reset' and then 'Run' the program and it will now stop at the breakpoint. Press run again and it will loop again to the same breakpoint – each time incrementing the value at PORTA so that the l.e.d. on PORTA 0 turns on and off alternately. Try connecting the l.e.d. to IC1 pin 3 PORTA 1 and see that it switches every other loop.

Now that an l.e.d. can be flashed, it is just a few more steps to controlling all sorts of peripheral devices, and whilst the PIC16F877 cannot run the proverbial 'Power Station' it is capable of an amazing number of very complicated feats. The development of longer programs controlling more hardware is so much easier when it is possible to test the programs quickly in this way. Single stepping and watching the program and data registers allows even complicated routines to be tested and debugged, and simple changes can be made and checked immediately.

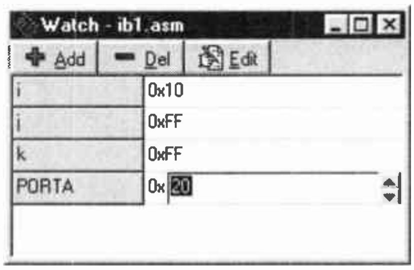


Fig.8. EPE *ICEbreaker 'Watch' window.*

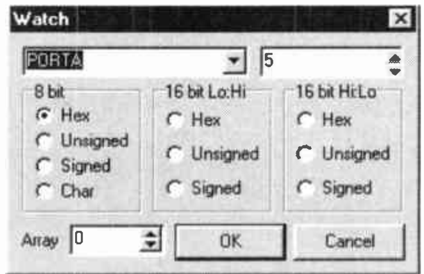


Fig.9. ICEbeaker 'Watch Add' window.

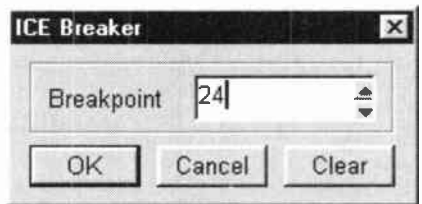


Fig.10. ICEbreaker 'Breakpoint' window.

To make a simple change to the **ib1** program, select 'Program', 'Code' from the icebreaker main menu and then select location 14. The contents can be read and should be 30FF which means MOVLW FF. Modify the value to 3010 which will load the value 10 instead of FF and press the 'Write' button. Clear the breakpoint 'Run' the program and see the change in speed.

The program in IC1 has been modified, but remember that the Source Code has not, and so will need changing to the new value once the required speed has been set. To modify the source code run MPLAB, modify **ib1.asm**, recompile the code by selecting 'Project', 'Make project' (or by pressing the appropriate shortcut button) and then switch back to ICEbreaker .

Select 'File', 'Re open' and the modified source code will appear in the ICEbreaker 'Source' window. To complete the operation select 'Program', 'Program' and the new code will be loaded into IC1. Although the program in IC1 had already been modified it is always good practice to reprogram with the newly compiled code to prevent simple errors creeping in – especially when a number of modifications might have been made.

As well as changes to the program memory, the same procedure can be used to modify the EEPROM, and register files. Changing register file contents is particularly useful when combined with single stepping as it allows routines to be tested with a range of values, for example a timing loop can be set up with 00 in the loop counting register and single stepped to see what happens at the end of the loop.

Once experience is gained, the range of tools available will be understood, and it will become easy to set up and check simple routines and combine them into full programs.

OTHER PROGRAMS

Program **ib2.asm** is a simple driver for the stepping motor. Connect PORTA 0 to 3 to the four stepping motor drive sockets P1 to P4 and then follow the procedures used for **ib1.asm** to compile, load and run the program. Notes are included in the code that suggest modifications that can be made to the code for altering speed, direction, and duration of travel.

Program **ib3.asm** runs the l.c.d. It uses six connections from PORTC 2 to 8 to connect to RS, E, and D4, 5, 6, and 7 of the display in that order. The code initialises the display, and then can be set up as a subroutine to write any character to any display location. The source code has notes to explain the operation and to suggest possible changes for more advanced applications.

COMPLETED PROGRAMS

Once a program has been debugged and is working correctly it can be programmed into another PIC16F877 or any other suitable PIC chip using an appropriate programmer (*PIC Toolkit Mk2* is ideal) – the ICEbreaker code does not have to be in the chip and so any blank chip can be used with this method. The ICEbreaker board can only program chips that already contain the special **icebreak** code – this is necessary because the chip has to communicate with the PC via the standard serial port interface. Chips with **icebreak** code are readily available – see *Shoptalk*.

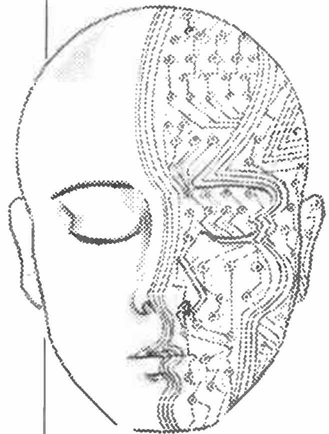
Once programmed, ICEbreaker chips will run normally in other circuits if required to do so but it is important to make sure that the two pins RB6 and RB7 are connected to 0V. This is because the ICEbreaker software automatically starts to run, and immediately checks for ground connections on these pins. If it finds that they are grounded, the program jumps to location 0000 and starts running the program from there, as a normal chip would.

THE NEXT STEPS

It is tempting to continue and describe the many features of the PIC16F877, but it really is an impossible task because the chip is so powerful (but see *PIC16F87x Mini Tutorial* – Oct '99). The beauty of the PIC range of devices is that it is possible to run the same code on many different chips.

EPE ICEbreaker allows programs that are intended to be run on much simpler chips to be checked and debugged. All that is necessary is to ensure that the ports and register addresses are compatible with the smaller chips. Applications for the PIC16F84 are particularly suitable for development using ICEbreaker, and so the programs previously published by *EPE* can be used. Note though that the MPLAB environment uses MPASM code, and so the *PIC Toolkit Mk2* software will be necessary to convert the original TASM source code to MPASM assembly language.

ICEbreaker provides an advanced way to learn programming. Along with the PIC programming and data sheets, and back issues of *EPE* it will become an indispensable tool for learning, development, and testing of PIC projects. □



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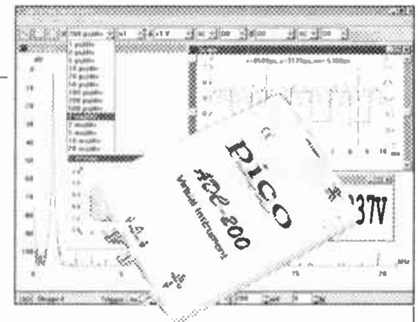

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Delay-On Timer – More Time To Boot

A SIMPLE circuit was needed to turn on a computer cooling fan a short period after the power was applied, and so the Delay-On Timer of Fig.1 was devised. It consists of a thyristor CSR1, which acts as a latch to turn on the relay RLA.

The thyristor CSR1 is triggered by a signal to its gate, and is delayed by the *RC* network comprising resistor R1 and capacitor C1. It continues to conduct once the trigger signal has been received.

With the thyristor and *RC* values shown, the delay is around 10 seconds before the relay is activated. Other thyristors could be substituted.

The circuit was constructed on a small piece of stripboard and has been used successfully in a PC, where it allows the PC to boot up before the fan is switched on.

Abdul Rahman Mansor, Penang, Malaysia.

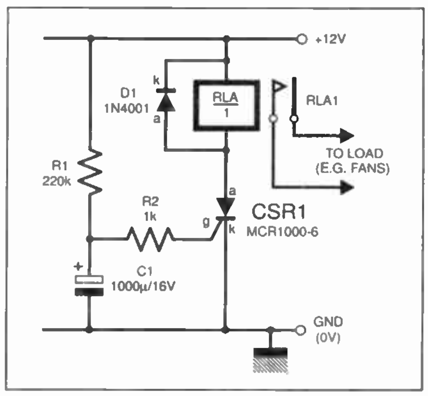

Fig.1. Delay-On Timer circuit.

BE INTERACTIVE

IU is *your* forum where you can offer others readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!

555 Power Supply – On The Panel

A 555-BASED oscillator circuit is shown in Fig.2 which provides an inexpensive d.c. isolated power supply for digital panel meters, without the need for transformers or inductors. The circuit oscillates at approximately 60kHz, as determined by resistors R1, R2 and capacitor C1 as normal.

The output square-wave pulses are fed into a modified Cockroft-Walton multiplier which features two Schottky diodes D1 and D2. The charge stored on capacitor C5 gives a voltage slightly less than the 555 supply voltage, and is sufficient to drive most l.c.d. panel meters which only require a few microamps.

A 9·1V Zener diode D3 provides good output regulation up to about 1mA. The maximum d.c. voltage isolation is the voltage ratings of capacitors C3 and C4 minus the supply voltage. The circuit runs from 3V to 15V and a low drop-out regulator could be used for operation at higher voltages (at lower voltages the full 9·1V may not be achieved). Note that a CMOS timer should be used for IC1.

A.N. Joubert, Fichardt Park, South Africa.

PIC Adaptor Socket – Pinwise

AFTER experimenting with Arizona PIC microcontrollers, using the excellent *EPE PIC Tutorial* circuit board, I needed to use an external oscillator for one of my own experiments. Rather than modify the board, I built the simple plug-in adapter socket shown in Fig.3.

Using a pressed contact 18-pin d.i.l. socket (a turned-pin type will not work), I carefully folded pin 15 and pin 16 out to the side. This socket was then inserted into the existing socket already on the board, and the PIC pressed into the new adaptor socket. A sliver of plastic tape prevented any contact between the folded out pins and the original socket.

The external oscillator was powered from the board and its output was connected to pin 16 of the adapter. Note that in this configuration, there is no connection to pin 15.

A. Langton, Aberdeen, Scotland.

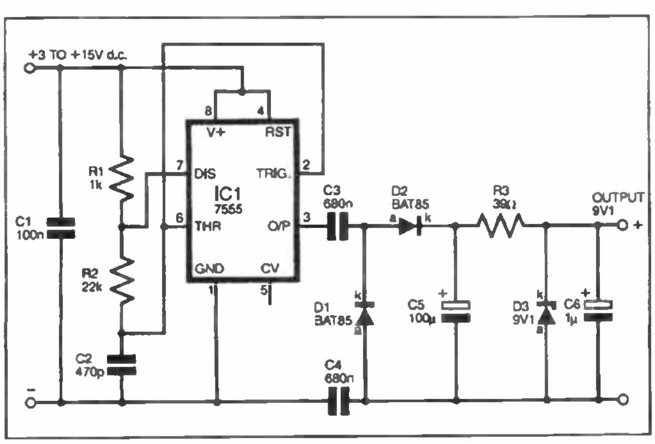

Fig.2. Power supply circuit using a CMOS timer chip.

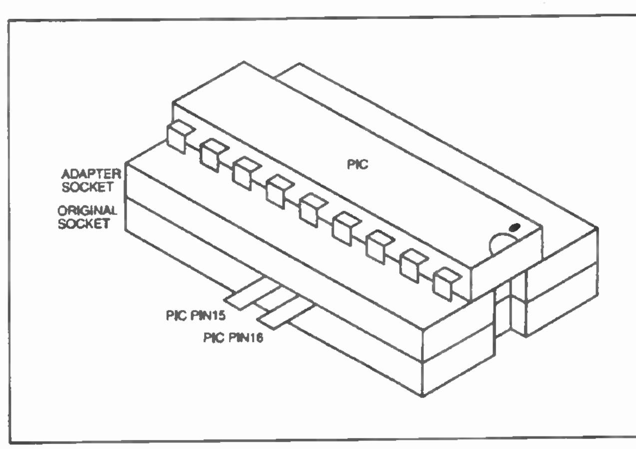

Fig.3. Simple plug-in adaptor socket.

Shaky Dice – It's a Rollover

A SIMPLE but novel circuit application for a custom die chip is shown in Fig.4. This circuit imitates a traditional die in that it starts "rolling" when you shake it.

It is based around the Holtek HT2070A chip which will generate a traditional style of die readout when the sealed vibration switch S2 is operated. The piezo sounder WD1 is a disc transducer which emits a sound as well, and it operates from a 3V battery controlled by a miniature toggle switch S1.

Our own model was housed between two semi-transparent curved coloured disco light filters which were bolted together using nylon fasteners around the rim. (The filters can be carefully drilled for this purpose.) The circuit was then installed with the light-emitting diodes, D1 to D7, being arranged in an H-shape as shown.

Andy and Rose Morell, Winchester.

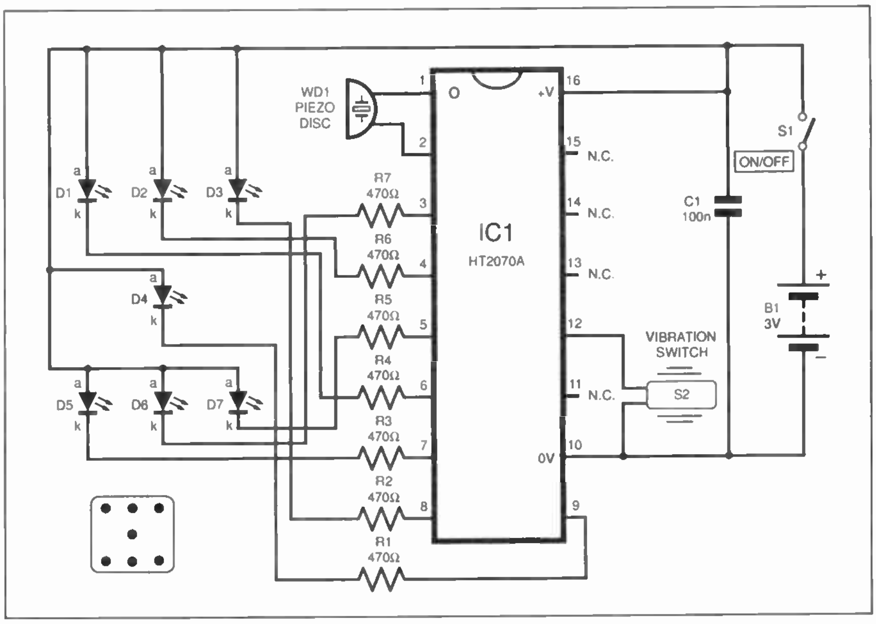

Fig.4. Circuit diagram for the Shaky Dice.

Making a Bidirectional Printer Port – Printout

OLD PCs are cheap enough to be dedicated to driving electronic projects such as the simple *32kHz PC Frequency Counter* of June 1999 *EPE*. However, old PCs tend not to have *bidirectional* printer ports. The data latch tristate lines are permanently enabled, so a "read" of the printer port returns the last data written to the port. Furthermore, data forced onto the port from outside can cause brief emissions of smoke!

However, it is simple to modify many ISA printer cards to be bidirectional. Suitable boards are those with, say, one parallel, two serial, and a game port. The multi I/O boards with IDE and floppy interfaces using proprietary packages are not likely to be modifiable. A card with discrete TTL chips is needed.

Look for a board with TTL chips type '374, '174, '245. The '374 will have pin 1 ($\overline{OE}$) tied to ground. My suggestion is to cut the track between pin 1 and ground, or snip pin 1 above the board. Run a wire from pin 1 of the '374 to pin 17 of the 25-pin parallel printer port connector. This uses $\overline{SLCT}$ as the direction control bit. Most printer driver software will hold this line low, and the port will work normally to a printer.

In order to read the port, hold $\overline{SLCT}$ high, and read the data register. It is worthwhile using this signal to enable the buffer on your external device too . . . invert it and apply to the $\overline{OE}$ of The buffer. For example, the frequency counter project has the $\overline{OE2}$ pins (pin 19) of the '541 buffers permanently enabled. Drive them from inverted $\overline{SLCT}$, and the lines won't "smoke".

Graham Lees, Christchurch, New Zealand.

SHOP TALK with David Barrington

EPE ICEbreaker

Apart from the specially programmed PIC16F877 microcontroller chip, most of the other components needed to construct the *EPE ICEbreaker* project are fairly common items. The "firmware" program in the chip is loaded and *copy-protected* (in the upper half of the 8K program memory) and is not available in any other way – you *must* purchase the preprogrammed PIC chip to build this project.

We have reached a special agreement whereby we are able to offer a ready-programmed, 20MHz version, PIC16F877 chip *together* with the printed circuit board (code 257) – see *EPE PCB Service* page 229. Also, the ICEbreaker software, including the simple test program and demo programs, is available from the *EPE* FTP site: **ftp://epemag.wimborne.co.uk/pubs/PICS/ICEbreaker**, and on the disk which comes with the p.c.b./chip.

A special package has been put together by **Magenta Electronics** (see their ad. on page 200) which contains the following: preprogrammed 16F877 (20MHz version), printed circuit board, solderless breadboard, l.c.d. display module, floppy disk, BT47 relay, 9-way PC serial lead (25-way extra), and all other components. They have even included a low-voltage stepper motor and mains adaptor, "plug" type, power supply.

All this for just £34.99 plus £3 post and packing. For full details contact **Magenta Electronics** (☎ ***012283 565 435***, web **http://www.magenta2000.co.uk** or E-mail: **sales@magenta2000.co.uk**.

Finally, we understand that some overseas readers (particularly in USA) may have difficulty in obtaining the ZTX transistor. The designer informs us that most general purpose *npn* types rated at 1A 60V should work (not tried) in this set-up.

High Performance Regenerative Receiver

Some of the components needed for the *High Performance Regenerative Receiver* may be hard to track down. We have not included the Jackson type tuning capacitors in our pricing for this project, as it will depend on the condition and "newness" of these variables. We suggest you shop around for these items as they could add as much as £30, or nearly double the price, of this Receiver. Try **Bull Electrical** and **J&N Factors**, who may be able to offer a good price, if they still stock them. Also try **Mainline Surplus Sales** (☎ ***0870 241 0810***).

We found that some of the type numbers quoted for the TOKO tuning range coils did not tally with our information and could have caused real problems. However, thanks to the designer's, Raymond Haig, efforts in double-checking with the TOKO suppliers, we now have the correct type numbers.

The TOKO coil numbers and ranges used in the Receiver have been set out in a table (next month) and were purchased from **Bonex Ltd** (☎ ***01753 549502***), type numbers and order codes are as follows: CAN1A350EK, 380-350; RWO6A7752EK, 357-752; RWR331208NO, 351-208; 154FN8A6438EK, 356-438; KANK3426R, 363-426; KANK3337R, 363-337; MKXNAK3428R, 363-767.

The rest of the components for this project should be widely stocked. The three Receiver printed circuit boards are available as a set and are obtainable from the *EPE PCB Service*, see page 229.

We could not close without saying that the author has produced a really "professional" Regen. Receiver – almost a piece of nostalgic art!

Parking Warning System

A few dedicated parts are called up for the *Parking Warning System* and may not be obtainable from your usual local component stockist. The PIC260435 infra-red sensor/amplifier/demodulator came from **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), code 139-877. (This device has nothing to do with PIC microcontrollers.)

Turning to the HT12B or HT12A encoder and the HT12D decoder i.c.s, these caused considerable sourcing problems last time they were used in a published design. At that time, they appeared in a well known company's catalogue, but, in fact, they had discontinued stocking them. To solve this problem **FML Electronics** (☎ ***01677 425840*** – see their ad) purchased some specially and, at the time of going to press, we understand they still have stocks.

The rest of the components, including the ceramic resonator, should be readily available items. Just one point, specify the **L** suffix when ordering the BC184L general purpose transistor as other types have differing pinouts to this one.

The single-sided printed circuit board is available from the *EPE PCB Service*, code 258.

Automatic Train Signal

All parts, including the LF351N i.c., for the Automatic Train Signal, this month's "starter project", should be stocked by our regular components advertisers. The choice of l.e.d.s, 3mm or 5mm, will depend on gauge and size of your model railway layout. The l.e.d. current is not very high, so "high brightness" types are preferable.

PLEASE TAKE NOTE

Scratch Blanker **(Jan '00)**

We have been informed that the MN3004 delay-line and the MN3101 clock generator i.c.s, called for in the Scratch Blanker, are no longer produced or stocked by Maplin. However, we understand that **Sky Electronics** (☎ ***020 8450 0995***) have some.

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

ELECTRONICS CD-ROMS

ANALOGUE ELECTRONICS

by Mike Tooley

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.

FUNCTIONS

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

COVERAGE

Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections); **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators; **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections); **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections); **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators; **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

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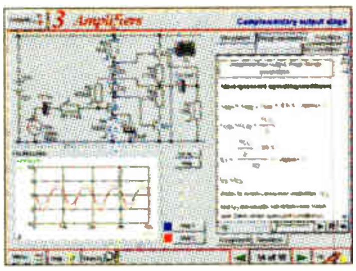
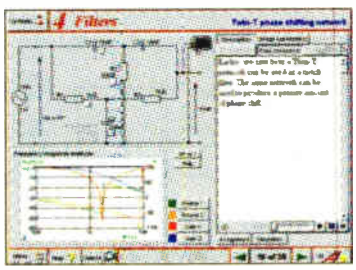
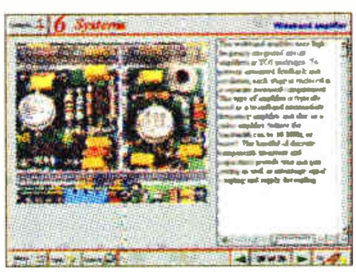


Complimentary output stage.



Twin-T phase shifting network

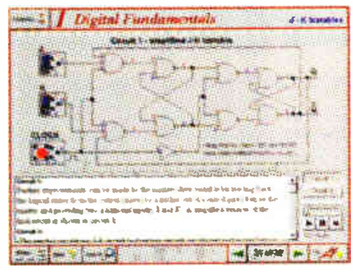


Gallery – Wideband Amplifier

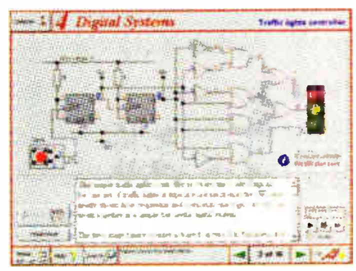
DIGITAL ELECTRONICS

by Mike Tooley

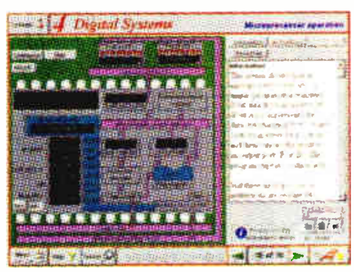
Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (below), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.



Virtual laboratory – Flip-Flops



Virtual laboratory – Traffic Lights



Microprocessor

FUNDAMENTALS

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

COMBINATIONAL LOGIC

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

SEQUENTIAL LOGIC

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

DIGITAL SYSTEMS

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

GALLERY

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

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

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

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

TWO APPLICATIONS ON ONE CD-ROM

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

Electronic Circuits & Components provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding as they proceed through the sections on the CD-ROM. Sections on the disk include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits*** . ***Active Circuits***

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

Hobbyist/Student	£34 inc VAT
Institutional (Schools/HE/FE/Industry)	£89 *plus* VAT
Institutional 10 user (Network Licence)	£169 *plus* VAT

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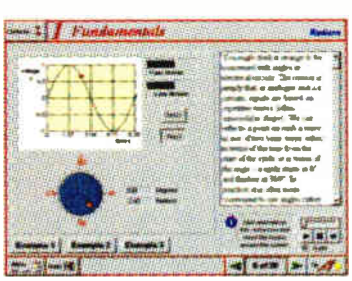
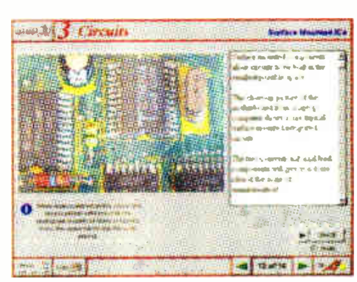
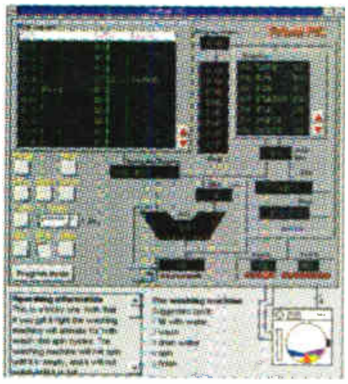


Virtual laboratory – sinusoids

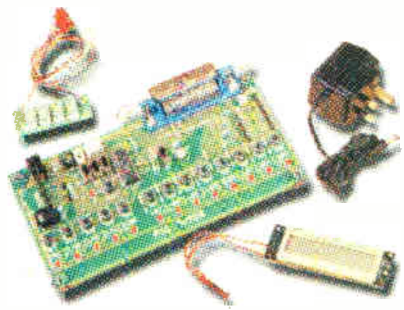


Circuit technology screen

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



The Virtual PIC



Deluxe PICtutor Hardware

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

HARDWARE

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

PICtutor CD-ROM

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

HARDWARE

Standard PICtutor Development Kit .... **£47 inc. VAT**
Deluxe PICtutor Development Kit .... **£99 *plus* VAT**
Deluxe Export Version .... **£96 *plus* VAT**
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MODULAR CIRCUIT DESIGN by Max Horsey and Philip Clayton

This CD-ROM contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects.
Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

Single User Version £19.95 inc. VAT
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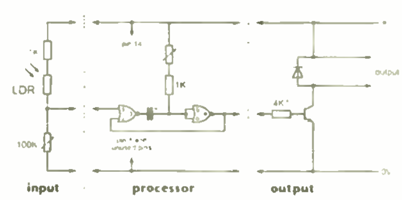
designing your circuit
simply select your modules from the wide choice available. read how they work and join them up to make your circuit



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

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

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

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Note: The software on each version is the same, only the licence for use varies.

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Demos (not Modular Circuit Design) available on the ***EPE CD-ROM No. 1*** (Free with the November '98 issue of *Everyday Practical Electronics* magazine) – send £2 for this CD-ROM if you require the demos. **Minimum order** for credit card payment is £5.

ee50b

EPE/ETI Tutorial Series

TEACH-IN 2000

Part Five – Waveforms, Frequency and Time

JOHN BECKER

What we are doing during this *Teach-In 2000* series (of at least 10 parts) is to lead you through the fascinating maze of what electronics is all about! We are assuming that you know nothing about the subject, and are taking individual components and concepts in simple steps and showing you, with lots of examples, what you can achieve, and without it taxing your brain too much!

In the first four parts we discussed and gave you practical experience of several types of commonly used electronic components. Last month we also showed you how to interface your experimental circuits to a PC-compatible computer, allowing pulse waveforms to be displayed on screen. We now discuss other waveforms and how to observe them on your PC, adding just one more component to your breadboard.

GREETINGS again. We expect you've got your breadboard coupled to the computer, all powered-up and ready to go. But, wait, is the oscillator on your breadboard the same as that described in Fig.4.1 and Fig.4.3 of *Teach-In* Part 4 last month? If not, make it so, then we're ready to start . . .

MAKING WAVES

Last month, we left you with the suggestion that you should explore two of our simulation programs: Computer as Frequency Counter and Pulse Input Waveform Display.

In the second of these programs, at some stage of your experimentation, hopefully you produced a screen display that looks something like that in Photo 5.1. It is *waveforms* that are the main subject of our discussion this month.

Before that, though, we shall discuss a little more fully not just the above two programs, but also the preceding one, Parallel Port Data Display/Set. In doing so we shall also introduce you to the first of several concepts in Digital Logic, that of the AND function.

From the main menu, call up the Parallel Port Data Display/Set program to your screen. Connect the computer's parallel port to your breadboard, *without* the oscillator connected to any of the five input points (IN0 to IN4).

INPUT REGISTER

Now look at the Direct Input Byte box on the screen (Photo 4.8 last month). What you should see is the Orig Byte value shown as 10000xxx binary (where x can be either 1 or 0). This indicates that the computer's input port *register* (a special form of digital storage device) believes that its eight bits are at the logic states shown.

Your breadboard interface circuit only uses five bits, but which five of the eight bits apparently available? Probably from your experiments you already know the answer, the left-hand five, bit 7 to bit 3 are those used in connection with breadboard inputs IN4 to IN0.

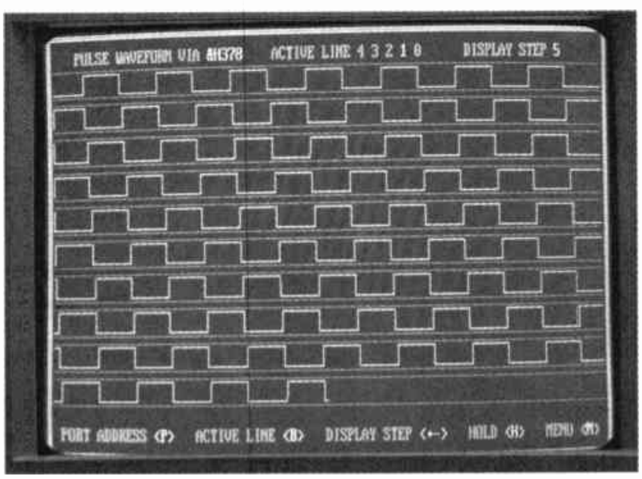


Photo 5.1 Typical pulse waveforms input to the computer via the simple interface board.

As far as the computer is concerned, bits 2 to 0 are not to do with data input (what their logic values are depends on your computer system – the author's various computers return different values).

What might also be puzzling you (although you've possible just shrugged your shoulders over it and thought *that's the way it is*), is that bit 7 is always set at the opposite logic to what you expect through connecting signals to IN4 on the board. Well, you're right, that *is* the way it is, bit 7 *is* inverted by the computer.

Underneath the upper boxes is the correction formula used to change the value directly received by the port register (box 1) to that in box 2, Corrected Input Byte. The meaning will become clear after Binary Logic has been discussed in Part 6. Basically, all that is being done is to re-invert bit 7 and shift all the bits along to the right by three places. This allows the correct logic on all five breadboard inputs to be seen as such in box 2, as the New Byte.

This type of manipulation can be extremely useful when using the computer as an item of test gear to monitor a digital circuit.

FREQUENCY COUNTER

It is also possible to read the status of each register bit by ANDing it with particular binary values (a Binary Logic subject coming in Part 6), and this is what is done in the Computer as the Frequency Counter program. Call it up from the menu, and couple your oscillator IC1a pin 2) to IN0 as you have done before. It is best if diodes D2 and D3 are omitted and a 1kΩ resister used in position D3 (also as you've done before).

You will have discovered that the program only responds to frequency input signals from one interface input path at a time, and that for this path to be seen as active by the program, the Active Bit in the screen box has to be appropriately set from the keyboard (key <B>). Each active bit has an associated AND value stated – each value is one of the powers of decimal 2:

BIT	POWER	DECIMAL	BINARY
7	2^7	128	10000000
6	2^6	64	01000000
5	2^5	32	00100000
4	2^4	16	00010000
3	2^3	8	00001000

When ANDing one binary number with another, individual bits in the answer will only be at logic 1 if the same bit in both starting values is also at logic 1. If either or both bits are at logic 0, so the same bit in the answer will also be at logic 0. For example, to test for bit 4 being high in a register that probably has other bits set as well (bits 3 and 6 in this example):

Register value = 01011000 (decimal 88)
AND value = 00010000 (decimal 16)
ANDed answer = 00010000 (decimal 16)
therefore bit 4 is high. Conversely:

Register value = 01001000 (decimal 72)
AND value = 00010000 (decimal 16)
ANDed answer = 00000000 (decimal 0)
therefore bit 4 is low.

Thus all that is needed to isolate the status of a bit is to AND it with the required value. If the bit is low an answer of zero will result; if it's high an answer greater than zero will result. So you simply check whether or not the answer is zero and act accordingly. The AND command/facility is a powerful tool in computing and electronics.

Note that in the computer program that actually controls what you are now seeing on screen, binary values cannot be recognised as such, consequently the *decimal* equivalent is that used in the Frequency Counter program.

This program has been written to isolate the bit as selected in the screen box and to detect each time it changes state during a period of one second, dividing the answer by two to find out how many times the bit has been high in that period. This result is displayed on screen as the (approximate) frequency at which your oscillator is running.

The internationally agreed unit of frequency is the *Hertz*, abbreviated to Hz, as shown on the screen. (Strictly speaking, Hertz in this context should be written with a lower-case initial – *hertz*.) In the present example we have a frequency of 1Hz (one cycle per second. Back in history, frequency was actually defined in cycles per second – c.p.s., c/s or cps).

PULSE DISPLAY

In the Pulse Input Waveform Display program (call it up on screen), AND is again used to isolate the selected bit. In this case, though, the result causes the drawing of a horizontal line to represent the bit's status, high or low. The "vertical" line is simply drawn by the program at the detected transition between logic levels.

Having completed one crossing of the screen, the waveform re-commences on the next allocated path, erasing any previous waveform. The rate of transition is selectable via the Display Step option (note that this does not actually change the rate at which the register input is examined – *sampled* – it just changes the distance the line travels for each sample). It is not possible to assess frequency from this display (a true oscilloscope would allow this to be done, however).

The facilities offered by this display and the previous pulse counting program can be of great use when testing other circuits in the future.

HARMONICS

We would now like to illustrate a problem that can occur when monitoring a waveform, and one which can also affect the correct response when digital electronic circuits are used in real-life situations – that of relative rates of response between one circuit and another. The effectiveness of the illustration on screen, though, rests on how fast your computer is running. If it runs too slowly, it may be difficult for the required effect to be produced. Nonetheless, let's try it.

First, set your oscillator to a slow speed so that the individual pulses (as square waves – equal length highs and lows) are clearly seen and with wide spacing. It is probably best to select a Display Step value of 10 (use the <+> key).

Slowly increase the oscillator's rate and watch the pulses close up to each other (you may need to change capacitor C1 to a smaller value). Eventually, the pulses will be so close together that you can probably not distinguish between them.

Continue to increase the frequency – what you should see next (your computer's sampling speed permitting) is that as you increase the frequency, the waveform spaces start to widen, probably with uneven spacing (see Photo 5.2). *Why?*

The answer is not that your oscillator has decided to run erratically or more slowly all of a sudden. What is happening is that the computer now does not have time to respond to each pulse. So what you are seeing on screen is a *sub-harmonic* of the actual frequency being monitored. The unevenness of the spacing is due to the computer's sampling rate and the speed of the oscillator not being synchronised.

If you try this with the Frequency Counter program, you will see the apparent frequency rate change downwards as the transition to sub-harmonic sampling occurs.

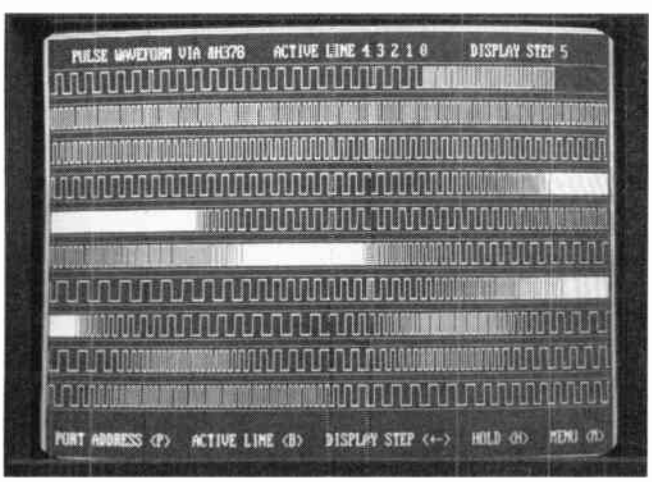


Photo 5.2. Example of "under-sampled" pulse waveforms input to the computer via the simple interface board.

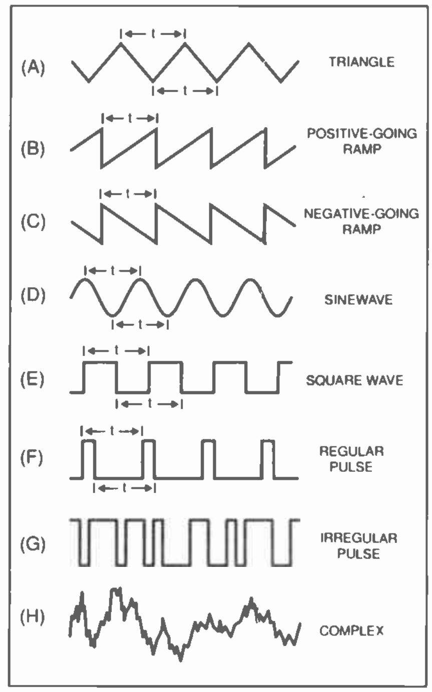


Fig.5.1. Examples of waveform types. Frequency measurements can be assessed for periods arrowed for (A) to (F), but cannot be meaningfully measured for irregular or complex waveforms.

It is even possible that as the oscillator's frequency is increased still further, sampling may occur on every *third* pulse, or every *fourth* pulse, and so on, almost indefinitely. It is unlikely, though, that our demonstration program will actually allow you to go beyond one-in-three.

This situation is one that you have to consider very carefully when using a frequency counter or oscilloscope (whether as true items of test equipment, or as computer-based sampling programs). It is also something to be considered when you start designing digital logic circuits – can all the digital integrated circuits keep pace with the rate at which others expect them to? Highly unpredictable results can occur if they can't!

Not only does the problem reveal itself in *digital* electronics, but you can also experience allied situations when dealing with *analogue* signals – a signal at one frequency adversely (or desirably in some cases) affecting a signal at another.

In a future part we shall show you how two analogue signals respond to each other.

WAVEFORM TYPES DISPLAY

Put your breadboard assembly to one side for the moment (you'll need it again for the Experimental article, though). Let's show you examples of some different waveform types. We shall also explain how you can do some simple calculations in respect of frequency and time. From the main menu select Frequency and Time (well, what else?!).

Examples of seven different types of waveform will be seen on screen (see Photo 5.3 and Fig.5.1) as follows:

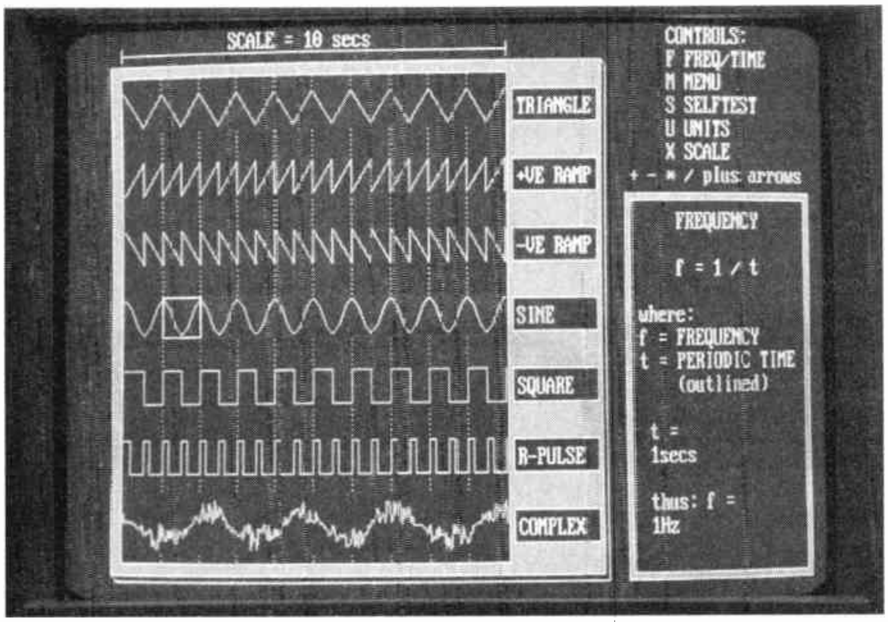


Photo 5.3. Waveforms similar to those in Fig.5.1 as displayed on the interactive computer screen. Their periods are changeable and allow frequency and timing calculations to be demonstrated.

- Triangle
- +VE Ramp (positive-going ramp – upwards)
- –VE Ramp (negative-going ramp – downwards)
- Sine
- Square
- R-Pulse (regular pulse)
- Complex

In fact an eighth waveform is available via the screen – press the down arrow key three times. Where R-Pulse was will now become I-Pulse (Irregular Pulse) and the pulses will be seen to be very irregular.

SCALING AND CALCULATIONS

The screen display is scaled, at present to represent a period of 10 seconds from the start of any waveform to its end. Vertical dotted lines indicate the 1 second interval points.

Press the up arrow key so that the orange background is on the square wave.

Note the point at which any one of the pulses first becomes high and the point at which it ends being low (and the next pulse commences). You will see that the square wave has a white box around it to indicate this period. In Fig.5.1 it is represented by the "t" arrows.

This period is known as a *cycle*. On screen you will see that it takes just one second. When a waveform consists of many equal length cycles its *frequency* is defined as the number of cycles that occur in one second, which, as we said a few paragraphs back, is expressed in Hertz.

In the right-hand box you will see that the time (t) for one pulse and its consequent frequency (f) is stated:

t = 1 secs, f = 1Hz

Press key <X> to change the screen's scale to 1 second. Each vertically dotted interval is now 0.1 seconds. The frequency represented is therefore 10 cycles per second – 10Hz. The right-hand box confirms this.

You/we have been able to do the conversion from time to frequency in our heads, almost instinctively. As shown in the box, though, there is a formula for it:

$$f = 1/t$$

Conversely, if you want to find out the cycle period (time) of a waveform whose frequency you know, the formula becomes:

$$t = 1/f$$

Press <F> and this formula will be shown, together with the calculated answer.

Press any of the <+ – * /> keys to expand or contract the waveform, and variously swap between the two formulae using <F>. The units in which f and t are expressed are changeable by using <U>.

These formulae can be applied to any regular waveform, including the first six on screen (and in Fig.5.1). With irregular waveforms, such as those for I-Pulse and Complex, periodic time and frequency for the waveform as whole cannot be ascertained.

All that can be assessed from the irregular pulse, for example, is the period of any individual pulse. In terms of overall frequency of the waveform, this answer is meaningless.

It is possible, of course, to use a frequency counter with this irregular pulse chain and determine the number of pulses that occur in any 1 second, but the answer for each 1-second sampling period is likely to be different.

With the complex waveform, there are in fact a great many different frequencies involved in its make up, but they are all likely to be at different amplitudes. To separate each frequency and its amplitude out from the main waveform requires very complex equipment (such as a *frequency analyser* – expensive!).

WELL-DEFINED

It should also be obvious that even with a well-defined waveform, you need to be able to time the *complete* period of a cycle. It does not matter, though, at which point you actually start the timing.

With the square wave you can start timing as the pulse rises (at its *leading edge*) and end at the start of the leading edge of the second pulse. Alternatively, you can start as the pulse falls (at its *trailing edge*) and end as the next pulse's trailing edge begins to fall. The white outline box on the waveform illustrates this point when you set it to lower frequencies (also see Fig.5.1).

When looking at a waveform on a screen (whether it is a computer screen as in this simulation, or an oscilloscope screen), the commencement of a cycle does not necessarily occur where you first see the waveform appear; the cycle may have started long before the screen responded to it. Always take a measurement when it is obvious where the exact start of the cycle occurs. Our simulation program, you will notice, takes this into account.

Examine the position of the white box for all the waveforms that can display it and observe at which points of a cycle measurements may be taken.

It is worth noting that most oscilloscopes have a facility for placing a horizontal line across the screen. This can be moved up or down and placed so that it crosses any point on the waveforms. Timing measurements can then be taken between any two or more points where the horizontal and waveform lines cross.

SELF-TEST

For a bit of timely entertainment, we've added a Self-Test option to test your use of time and frequency calculations – press <S> to enter or exit it.

CYCLE POWER

In Part 3 we explained that the amount of current consumed by a circuit can be defined according to the voltage applied across it and the resistance through which it flows, I = V/R. When the voltage is at a nice steady d.c. level and the resistance is constant, the current drawn is the same at all instants of measurement.

If we want to calculate current (or any of the factors defined in Ohm's Law and its derivatives – Part 3) in relation to a changing voltage (e.g. waveform) rather than steady conditions, the situation becomes more complex.

For any particular instant, we can of course say that conditions are constant at that instant, and calculate accordingly. However, we often need to know the current drawn over a *period* of time, rather than instantaneously.

With a square wave or regular pulse waveform, average current can be calculated according to the period for which the pulse is high (full current flow) relative to the period for which it is low (minimum current flow).

When the pulse is changing between 0V and a known voltage value, it's just a matter of ratios of the on to off (high to low) periods of the pulse.

For example, if a 0V to +5V pulse is high for 0·5 seconds and low for 0·5 seconds (i.e. a square wave), we can say that the *average* current drawn in one second is half that which would be drawn if the *maximum* current flowed for 1·0 seconds.

If the on-off periods are not equal, the formula used is just:

Average Current = On Period/Cycle Period × Maximum Current.

For the above example, and assuming a continuous maximum current of 2 amps, this relationship becomes:

Iaverage = Ton/Tcycle × Imax = 0·5 sec/1 sec × 2 amps = 1 amp per second.

TRIANGULATION

For waveforms such as triangle and ramp, the calculations are just as simple, irrespective of their relative rise and fall times.

By definition, the voltage of triangle waveforms rises at one constant rate, and falls at another constant rate. This is true irrespective of the relative rates of rise and fall for the waveform.

In the case of a uniformly-shaped triangle (isosceles – having two equal sides), rise and fall periods are equal in length. Note that a ramp waveform is a special case of triangle, in which the vertical edge occurs instantaneously, making the ramp duration the same as the cycle period. (In fact an *instantaneous* change in level *never* occurs in electronics – every change takes time, see Part 6 next month.)

The maximum peak current is a predictable or measurable value (that when the voltage is at its maximum), so too is the minimum current (that when the voltage is at 0V, i.e. a current of zero amps).

Consequently, when a triangular waveform is alternating between 0V and a given maximum voltage, the average current drawn during one cycle is half that of the peak current.

Do you remember from school days how you found the area of a triangle having sides of different lengths? (See Fig.5.2.) The principle for finding average current per unit of time in respect of a triangular waveform is the same: multiply the height (voltage or current) by the length (time) and divide by two, e.g.:

Iav = Imax × Tcycle/2, or:
Iav = (Imax/2) per cycle time

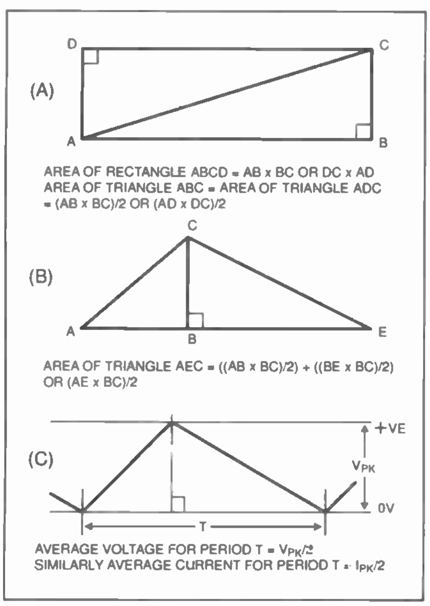


Fig.5.2. Geometric relationships (A and B) as applied to voltage and current calculations (C).

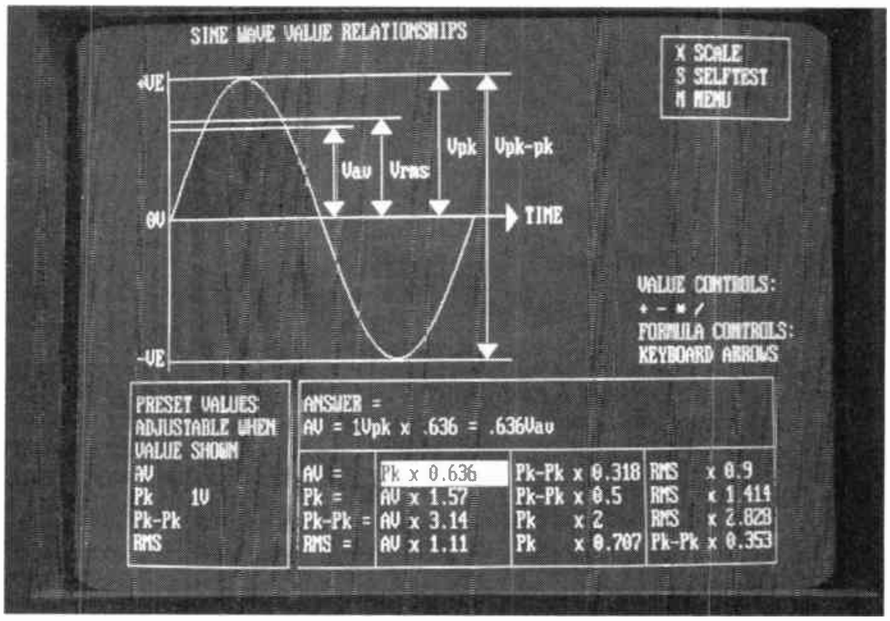


Photo 5.4. Sine wave value relationships as displayed on the interactive computer screen.

Suppose a peak current of 100mA is drawn when power is supplied by a triangular waveform alternating between 0V and +5V and the cycle period is 1 second. The minimum current drawn is zero. Therefore the average current drawn is simply 100mA/2 = 50mA per second.

If the waveform is alternating between two other levels, a similar principle applies, but requires just a bit of extra calculation. Suppose, for example, that the waveform causes the current to alternate between 100mA maximum and 20mA minimum:

First take the difference between the two extremes: 100mA – 20mA = 80mA. The average of the current difference for this waveform is 80mA/2 = 40mA. But there is the "standing" current of 20mA, which has to be added to the average difference. Thus the overall average current drawn = 40mA + 20mA = 60mA.

What happens, though, if the waveform is evenly alternating between –6V and +6V, for example? Instinct might just suggest that if 100mA is drawn at +6V, then –100mA is drawn at –6V, thus the average current drawn is zero. *But*, you might wonder, *doesn't that mean the battery would never run down?* Sadly, not so . . .

It's certainly true to say that the average current or voltage value of a waveform which alternates symmetrically above and below a zero value will be zero if measured over a long enough period, although this does not mean that the *power* consumed is zero.

When it comes to expressing an *average* in relation to a triangular waveform *uniformly* alternating above and below a zero point, it is usually taken as the average over

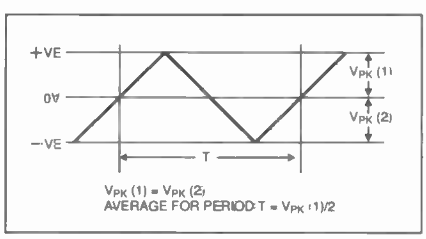


Fig.5.3. Relationships between upper and lower sections for a uniformly alternating waveform.

just *half* of a cycle, not over the *full* cycle. The half cycle can be either on the negative or positive side of the zero midway level. The effective answer is same. (See Fig.5.3.)

However, what we can say with respect to both sides of the waveform is that it has a *peak-to-peak* value twice that of its *peak* value. The peak value in the previous example is 100mA, therefore its peak-to-peak value is 200mA.

WAVING PROOF

If your computer has QuickBASIC or QBasic installed, you can prove for yourself that for a triangle wave the average voltage or current for one side of its ramp is half the peak value, using the following BASIC routine:

```
ramplength = 10: ' (seconds)
totalvolts = 0
FOR volts = 0 TO ramplength STEP 1
totalvolts = totalvolts + volts
NEXT volts
averagevolts = totalvolts / ramplength
PRINT averagevolts
```

You will get an answer of 5V.

Now do the same for a half a sine wave (having an angular change of 0° to 180°) and whose peak voltage is 1V. Remember that the sine of 0° is 0 and that the sine of 90° is 1.

```
CONST pi = 3.141592653589# / 180
volts = 1
totalvolts = 0
FOR angle = 0 TO 180
totalvolts = totalvolts + (SIN(angle *
        pi)* volts)
NEXT angle
averagevolts = totalvolts / 180
PRINT averagevolts
```

The answer now will be 0·6366036V (approx), say 0·636V.

SINE WAVES

Since sine waves are obviously subject to a different set of rules to triangle waves, let's examine them a bit more closely. From

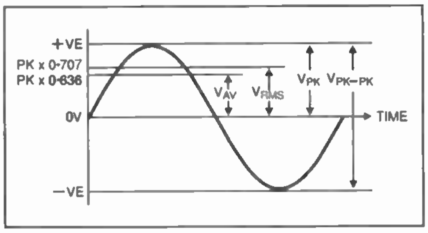


Fig.5.4 Definition of the four value relationships for a pure sine wave.

the main menu select Sine Wave Value Relationships. Photo 5.4 shows what you should see displayed.

The relationships we now discuss are specifically those with regard to *pure* sine waves. They do not apply to any other type of waveform. Furthermore, if you see any waveform relationships referred to anywhere and the shape of the waveform is not actually stated, then the relationships are assumed to refer to sinusoidal conditions.

Looking at your screen display (and Fig.5.4), you will see the representation of a pure sine wave swinging symmetrically above and below a zero level and plotted horizontally with respect to time.

Four vertical arrows indicate four major relationships exhibited by a sinusoidal voltage waveform:

- **Vpk** **peak voltage**
- **Vav** **average voltage**
- **Vpk-pk** **peak to peak voltage**
- **Vrms** **r.m.s. voltage**

Vpk – the peak voltage is that relating to just one half of the cycle. Since a sine wave is symmetrical above and below 0V, Vpk is the same whatever half (positive or negative) of the waveform is measured.

Vav – as said in the previous section, a sine wave's average voltage is that taken over one complete half-cycle. We showed that it has a value 0·636 times that of the peak voltage.

Vpk-pk – the peak-to-peak voltage is obviously twice that of the peak voltage (Vpk).

Vrms – well, first we had better explain the concept of r.m.s.:

R.M.S. VALUES

You have discovered in earlier parts that when a current flows through a resistance, power is dissipated. We went on say that heat is generated by that dissipation.

For a fixed resistance, and steady (d.c.) voltage or current, the heat generated is calculable – often expressed in watts (see Part 1). In the Ohm's Law section (Part 3) you saw that power can be calculated in several ways, such as $P = I^2 \times R$, $P = V^2/R$ and $P = I \times V$.

An r.m.s. (root of the mean square) value states the *effective* value of alternating current or voltage in terms of the heat that will be generated through a resistance. By definition, the value is that which will produce the same amount of heat in the resistance as would a direct voltage or current of the same magnitude.

Any waveform shape can be related to an r.m.s. value, but the value is really only meaningful when referred to a known shape. For a sinusoidal waveform the r.m.s. value is 1·414 times the peak value.

SINE WAVE RELATIONSHIP

The four sine wave units of measurement listed in the previous section have their relationships tabulated at the bottom of the main screen box displayed.

The screen display relationships are interactive (although the waveform itself is not). Each formula can be selected using the four keyboard arrows. Various values can also be set through the smaller left-hand box. Thus you can have the computer calculate relationship answers in respect of values of your choosing.

On entry to the screen you will see a highlight on Pk × 0·636, allowing you to find the average value (AV =) when the peak value is known. Referring to the values box, Pk is shown as 1V. At the top of the main box is shown the answer to the calculation, in this case the same answer that we illustrated earlier with the BASIC sine wave calculation example.

We suggest you experiment with the different formulae and values of your choice (the options vary depending on the formula). Try to memorise some of the formula (two useful ones are AV = Pk × 0·636 and Pk = r.m.s. × 1·414). The scaling of the values is changeable using <X>.

You will find this facility to be of enormous value when you design your own circuits in the future (or wish to analyse those of other designers).

SELF-TEST

Finally for this month's Tutorial – through the Self-Test option the computer randomly selects sine wave related questions. You are expected to use your calculator, and then compare your answer to the computer's, as displayed when you press <A>. You can cheat a bit if you want by changing the values offered by the computer!

And thinking of changing values, do read and take in our "measured observations" – in Panel 5.1 following the Experimental section.

EXPERIMENTAL

In this month's Experimental section we show you how to add another circuit to the interface board. This allows you to actually view on screen the various waveforms you've been generating with the variable mark-space oscillator of Fig.4.3 last month,

These include triangle, rising ramp, falling ramp, square wave and regular pulse. Sine waves, irregular pulses and complex waveforms we shall illustrate via your breadboard later in the *Teach-In* series.

NEXT MONTH

In Part 6 next month, we return to Binary Logic (briefly discussed when the Parallel Port Data Display/Set program was described). The discussion will include Digital Logic Gates – OR, NOR, XOR, XNOR, AND, NAND. As usual, the screen displays will be interactive.

TEACH-IN 2000 – Experimental 5

ANALOGUE-TO-DIGITAL CONVERTER

We are now going to describe a very simple circuit that you can assemble on your breadboard, and which will allow you to use your computer to view various analogue waveforms, such as the triangle and ramps discussed in this month's Tutorial. It is capable of displaying other waveforms as well.

However, we won't try to deceive you – the circuit is highly useful, but it's also very limited!

Commercial equipment such as oscilloscopes, or commercial software for computer-based *virtual* 'scopes will do far more than our simple demo software. The author's *Virtual Scope* project of *EPE* Jan-Feb '98 is also an extremely sophisticated item of computer-based test gear, but it has to be said that the construction of its complex printed circuit boards is not suited to novices.

The intention of the *Teach-In* analogue interface is basically to let you view the various waveforms that you create on your breadboard. However, it can be used not only with the demo circuits we describe throughout this *Teach-In* series, but it will be of use with some of your own future designs.

Should we have space later in the series, we'll describe the sort of facilities you should expect from a fully-fledged oscilloscope (and which need not be very expensive).

ANALOGUE INTERFACE

A very simple analogue-to-digital converter (ADC) integrated circuit (i.c.) is the only active component in this part of your interface assembly. The circuit diagram for its connections is shown in Fig.5.5.

We shall discuss the nature of the ADC (IC2) later on in this article. In the meantime, we want you to assemble the circuit on the breadboard and have a look at some waveforms on your screen.

The breadboard layout for the ADC (and the computer interface from last month) is shown in Fig.5.6. Assemble the components into the breadboard, following the latter's numbered holes.

The oscillator should be same as that referred to at the start of this month's Tutorial (i.e. with diodes D2 and D3 included). Use a 100μF capacitor for C1 and adjust preset VR1 to a midway position.

Connect the resistor/capacitor junction on the oscillator (IC1a pin 1) to the ADC at its input pin 2 (Signal Input as shown in the breadboard layout). Also connect the ADC's data output pin 6 (D OUT as shown in Fig.5.5) to IN1 on the computer interface part of the board. Crocodile-clipped links will do in both cases.

Power up the board and run the Analogue Input Waveform Display. On entry to the display, a yellow line should be seen traversing the screen from left to right, its vertical position moving up and down. Adjust VR1 (or change the value of C1) until the moving line begins to show several cycles of a triangular-like waveform, as you saw demonstrated in the simulation program Frequency and Time, see Photo 5.6.

Should the yellow line just be sitting towards the bottom of the screen, check that the Port register selected is still the correct one (as discussed in Part 4). Also

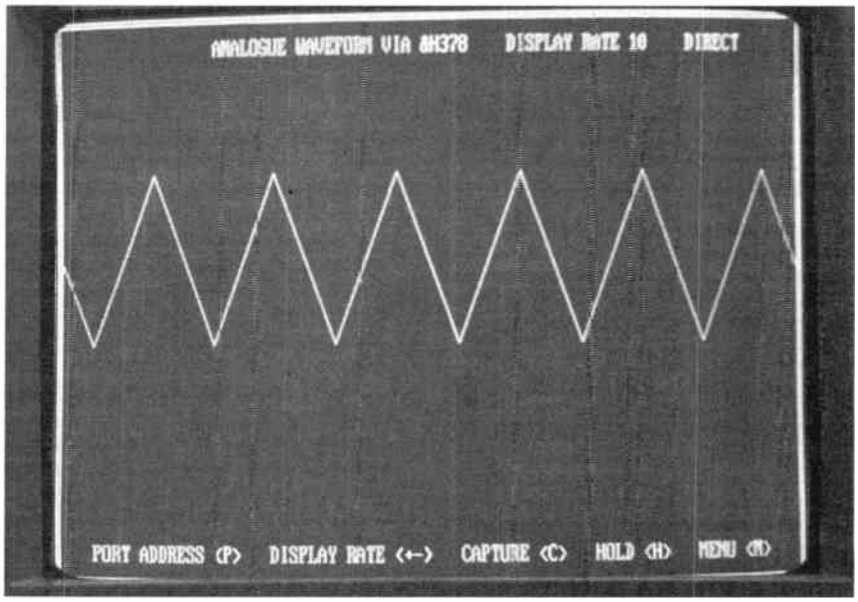


Photo 5.6. Typical analogue waveform as demonstrated using the complete interface circuit.

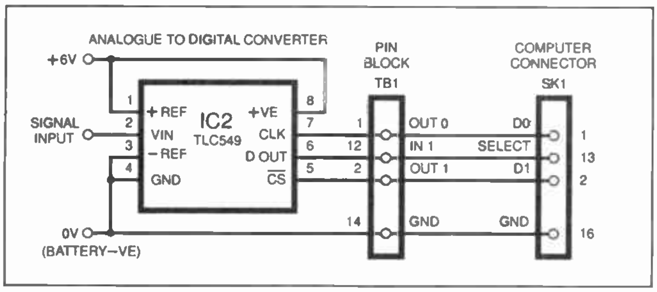


Fig.5.5. Circuit diagram for the serial analogue-to-digital converter interface.

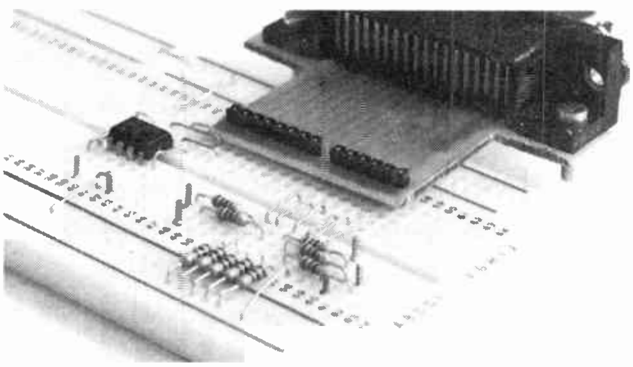


Photo 5.5. Detail of the interface board with the ADC included.

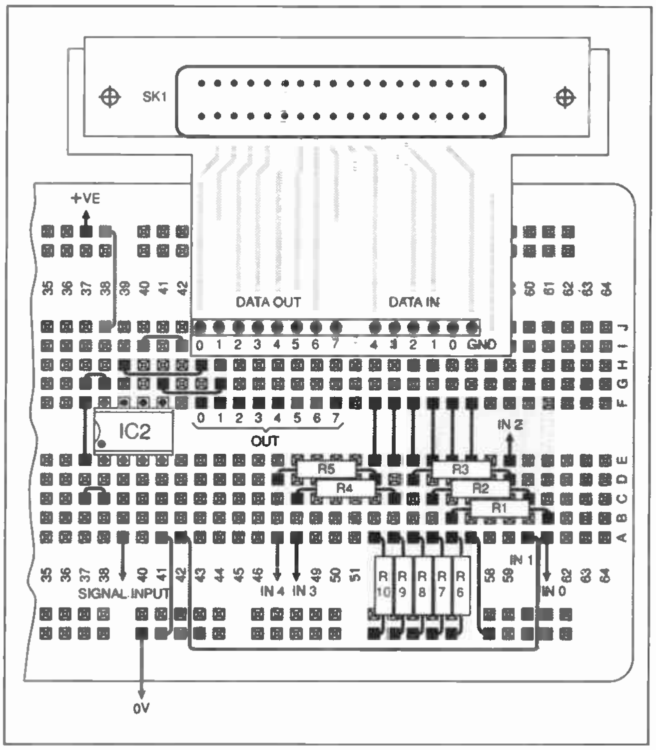


Fig.5.6. Component layout for the computer interface circuit with the ADC added.

double-check that your ADC's breadboard assembly corresponds to the connections shown in Fig.5.6, and that the oscillator is still correctly assembled.

Towards the top right of the screen is shown the Display Rate, 10 at the moment. Using the <+> and <–> keys, this can be set to any value between 1 and 10 and controls the rate at which the waveform line crosses the screen. The slower the rate, so more waveform cycles are shown.

Note that changing this rate also changes the rate at which data is acquired (sampled) from the ADC. We shall discuss analogue sampling in a moment.

Also at the top right of the screen is the single word DIRECT. This means that data is being sampled in real-time (here and now).

By pressing <C> the word CAPTURE appears instead. In this mode, the computer samples the data as fast as it can and temporarily stores it in memory. Once a full set of samples (640) has been received, the computer then plots them as a screened waveform.

This technique allows higher speed waveforms to be sampled than does the Direct method. The drawback is that there is a pause between each full screen change of data (computer speed dependent).

Experiment with different oscillator frequency rates and waveforms, using preset potentiometer VR1, and different values for capacitor C1. Also find out how Direct/Capture and Display Rate settings have their benefits. Note that each time the Display Rate is changed, the waveform line restarts from the left of the screen.

Also see whether you can replicate some of the stranger waveforms you have seen through the ADC-Demo program. (It has to be said that those of you with higher-speed computers will fair more easily since the waveforms will be traced faster on the screen.)

Just for interest, try connecting the oscillator's digital output (F OUT, IC1a pin 2) to the ADC instead of the analogue waveform.

SERIAL ADC DEVICE

As the Analogue-to-Digital Converter's name states, it allows an analogue signal (e.g. voltage waveform) to be input, and converts the voltages to equivalent binary numbers. You saw in Part 4 the representation of a number in both binary and decimal (Parallel Port Data Display/Set).

The ADC is capable of "reading" the voltage level at many thousand times per second and is controlled by logic level signals from the computer (or other device in other applications). The ADC used in this *Teach-In* demo is a *serial* ADC, which means that its output data is read one bit at a time.

Parallel ADCs also exist, in which the 8-bit data is read as a single 8-bit byte. Parallel ADCs are much faster to read than serial types, but require more computer control and data lines than we have (readily) available for your *Teach-In* breadboard.

To start each voltage level sampling and digital conversion, the computer sets the ADC's CS input (chip select) high via output data line D1. This action causes the ADC to "read" the voltage present on its signal input (Vin) at that moment.

The ADC has an internal high speed oscillator that then controls the data conversion process. (Incidentally, *chip* is a term frequently encountered in electronics and is colloquially used to mean any integrated circuit device.)

The result of the conversion is a binary number between 00000000 and 11111111 (decimal 0 to 255). A conversion value of zero results from an input voltage of zero. The maximum conversion value of 255 occurs (in this breadboard assembly) when the input is at the same voltage level as the ADC's power supply. This conversion range is determined by the voltage levels to which the ADC's +REF and –REF pins are connected (6V and 0V in this case).

In other applications, the pins may be connected to other reference voltages to provide a different conversion range. The reference voltages must lie at or between the power supply voltages. (Note that the maximum voltage at which this ADC can be powered safely is +6·5V.)

READING BITS

Once conversion is complete, the binary data can be read bit-by-bit by the computer. It is read in order of bit 7 to bit 0 of the binary conversion value. (In theory, about 40,000 conversion and data-read cycles per second can take place – but not with this *Teach-In* demo!)

To read each bit, the computer takes the ADC's CLK (clock) pin high via output line D0 (OUT0). The data is then read from the ADC's Dout pin via the breadboard's IN1 path – computer parallel port register bit 4.

The data on register bit 4 will either be at logic 1 or logic 0. As discussed when we described the data input process in Part 4, the value of the bit is isolated from the other register bits (using an AND command) and set into the rightmost (bit 0) position of the 8-bit binary value being assembled by the computer. Between each bit, the value is multiplied by two to shift all the bits left by one place.

The computer then sets the ADC's CLK line low, causing it to set the next bit of its binary conversion onto the output pin. Taking the CLK line high again allows the computer to now read this bit, and so on for all eight bits.

At this point, the computer does whatever it has been told to do with the data, in our case it either stores it or draws a screen line in relation to it. After which the next sample can be taken.

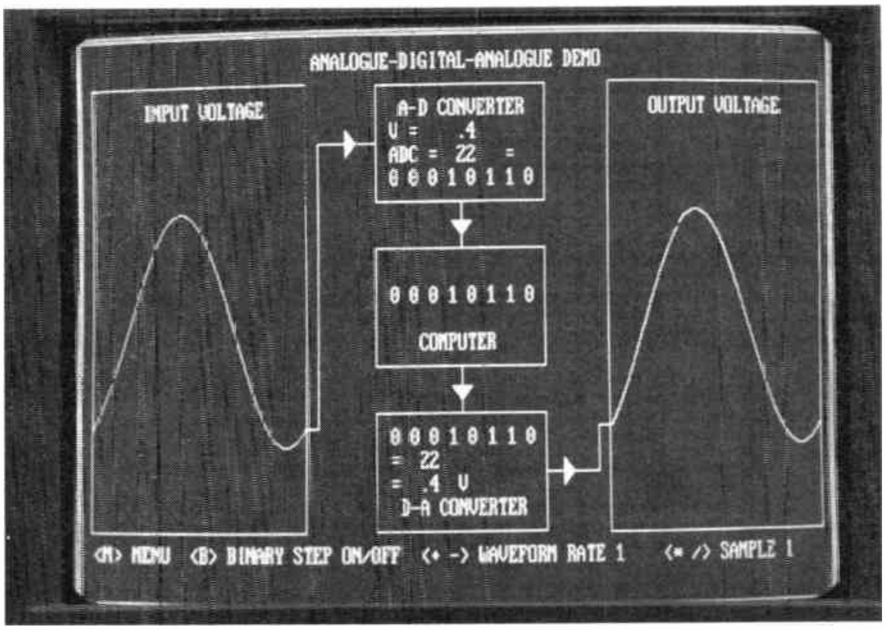


Photo 5.7. Analogue-digital-analogue demonstration screen. You can observe each bit being "assembled" to a binary number, and change the sampling step rate.

As an example of the computer's data acquisition routine, take the conversion value of binary 10010111 (decimal 151). The computer first sets its data storage value to 0 (00000000). The reading routine results in the following binary values of the chip and the assembled data storage:

STEP	ADC VALUE	ASSEMBLED VALUE
0	10010111	00000000
1	00101110	00000001
2	01011100	00000010
3	10111000	00000100
4	01110000	00001001
5	11100000	00010010
6	11000000	00100101
7	10000000	01001011
8	00000000	10010111

The computer's assembled value at step 8 is the same as that of the original ADC conversion value.

ADC DEMO

Run the Analogue-Digital-Analogue Demo program from the main menu to see the animated principle of how the ADC conversion is output from your breadboard to the computer (see Photo 5.7).

The left-hand box (Input) shows a single sine wave, cycling between 0V and +5V. It is shown feeding into the serial Analogue-to-Digital converter, where the present voltage level is given, together with the ADC conversion value in both decimal and binary. For the sake of this demo, the ADC is assumed to be referenced so as to generate an output of 0 for 0V and 255 for +5V.

The ADC is shown connected to the computer. At present, the immediate ADC binary value is repeated as the computer's received value. The computer then feeds this value into a Digital-to-Analogue Converter (DAC). DAC devices will be discussed another time – this one converts the 8-bit binary into an equivalent output voltage, in this example having the same scale as the ADC.

Also at present, the DAC shows the same values as the ADC, and the resulting waveform is displayed in the right-hand box (Output).

To see how the computer reads in the ADC's binary conversion value bit, press <B>.

Note how the left-hand ADC bit (bit 7) drops down and moves right to insert itself into bit 0 of the computer's storage value (which starts off at zero for each cycle of eight bits).

Note also how the ADC and storage values shift left by one binary place during the copying process, with the previous bit 7 being "lost". A zero value enters the ADC value at bit 0 at each shift left.

When all eight bits have been input to the computer, the final byte value is copied to the DAC, and the process starts again by the ADC taking another sample, with the Input waveform having shifted slightly to the right.

Please be aware that the process illustrated is not intended to represent the behaviour of any particular serial ADC device, it is a very generalised interpretation.

To terminate the bit-shifting process, press <B> again.

SAMPLING RATES

While discussing pulse frequency counting in Part 4, we referred to the problems of sampling data at rates slower than ideal. We can now illustrate one way in which the problem manifests itself.

With binary step sampling off, first note the shape of the two sine waves (Waveform Rate 1, Sample 1, as stated in the bottom text line).

Although you will notice that the waveforms have slightly rough edges, they are as close to sine waves as we can get with the program that creates the display you are watching. Just for background interest – the waveforms are plotted as 180 steps (pixels) across the screen, and 140 steps vertically between top and bottom waveform extremes.

For every step made by the input waveform, the output waveform makes the same step, i.e. the sampling rate is just right in order to replicate the original.

However, the output waveform will become an imperfect copy of the input if its sampling rate is reduced – press the <*>

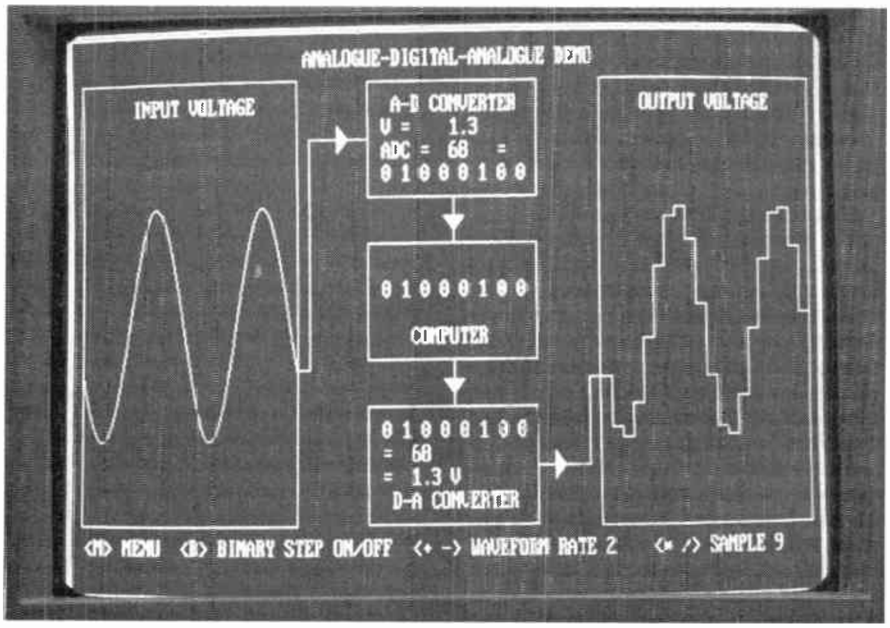
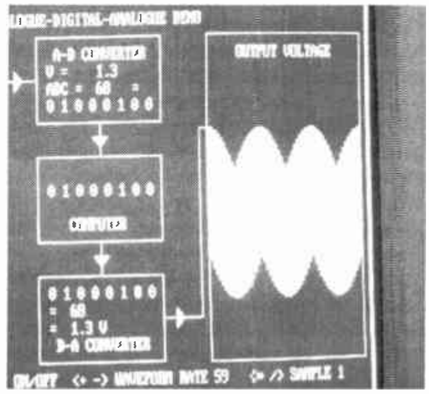
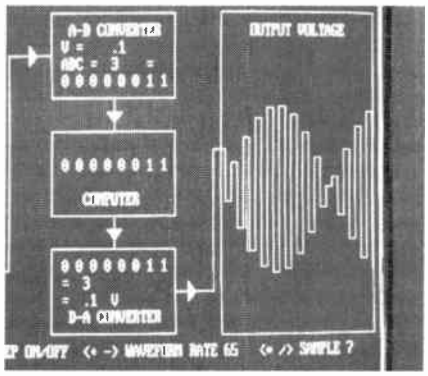


Photo 5.8. Another example of the ADA demo screen, this time showing (right) the result of using fewer sampling steps.



Photos 5.9 and 5.10. Examples of the screen demo set for different waveform and sample rates.



key once, to set a sampling rate to half that of what it was (Sample 2). Now observe the extra jaggedness of the output shape.

Press <*> a few more times and observe the increasing distortion.

What is happening is that the output waveform is being "traced" horizontally across the screen at a given rate. The movement represents the Time axis we discussed in the Resistor-Capacitor Charging Graph of Part 2, and in the waveform period timings discussion in this month's Tutorial.

The sampling rate, though, is not fast enough to keep pace with the trace, which continues to show the vertical value last sampled until the next one is taken. The steps become even more pronounced the more you press <*>, and the less recognisable the output waveform becomes.

RATEABLE LESSON

The lesson we hope you will take in from this is that when sampling an electronic signal, whether it's digital or analogue, the sampling rate should be carefully chosen to obtain the optimum results. Too slow a rate is obviously undesirable.

A further example of sampling is discussed next month when we illustrate Logic Gates (program Digital Sampling and Logic Demo is the one we shall discuss in this context – see the main menu).

Play around with other input Waveform Rates (<*> and </>) and Sample values (<+> or <–>) and see what you observe. You'll come across some quite remarkable output waveforms.

In some cases, especially at higher input waveform rates (25, 26, 44 and 59 for example – with Sample = 1), you will notice that another waveform appears to be superimposed on the top and bottom of the overall input screen display. This illustrates another by-product of how two frequencies can react with (modulate) each other.

The result is two new frequencies, one that is the sum of the originals and one that is the *difference* between them. The effect is known as *heterodyning* (Greek: *heteros* = other, and *dynamis* = strength).

Suppose, for example the two base frequencies are 2kHz and 3kHz, the sum of the frequencies is 5kHz, and the difference is 1kHz. These two new frequencies replace the original base frequencies.

It should be pointed out that the reason for the Input display also showing heterodyning is because it too is actually created through sampling, in this case in the computer simulation program, where the sine wave is calculated according to an angle count being incremented – small increments for slow waveforms, greater for higher rates.

Nonetheless, heterodyning is a very real effect; undesirable in some cases (audio sampling for example), but highly beneficial in others (e.g. radio reception).

The word *superhet* is derived from the term, although the full term in the radio reception context is actually *supersonic heterodyne* – a superhet receiver mixes the incoming radio frequency with a local oscillator frequency, to produce a specific (fixed) *intermediate frequency* (i.f.) from the which the desired signal can be more easily amplified and extracted.

DIVERSION END

After that diversion, and coming back to the ADC subject, you should now have a greater understanding of what it can achieve and what its failings can be.

In addition to the subjects listed at the end of the Tutorial, next month we shall examine Sampling in greater detail. Before then, see what you can discover for yourself about the subject with the aid of your digital and analogue waveform sampling displays.

Till next month, the author *waves* goodbye and exits screen-right!

CORRECTION

Part 4, Feb. '00, Fig.4.6. SK1 pin 23 should read pin 32. SK1 pin 16 should read pin 23. The p.c.b. is correct.

PANEL 5.1 – MEASURED OBSERVATIONS

You might think, perhaps, that in order to know the true state of affairs regarding component values, timings, voltages and currents etc., all you need to do is take some measurements. True, measurements of anything that happens in electronics can be taken, though for some of them extremely sophisticated equipment is needed.

But, and this is a big *But*, no measurement can be taken instantaneously, it's spread over a "window in time". Consequently, the measurement does not show the actual state of the condition being measured at a specific *point* in time, it simply shows an averaging-out of what might be numerous values occurring within the period of measurement.

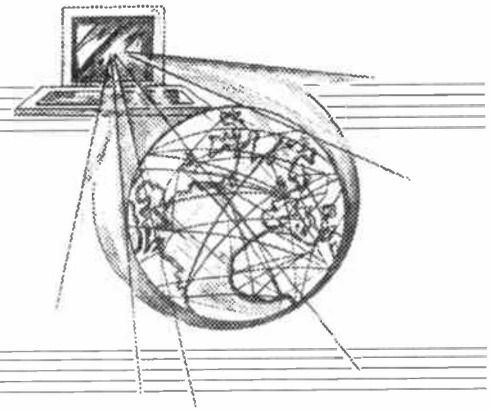
Furthermore, the value reading shown on the measuring instrument only reveals the value to within so many decimal places, or within an estimated fractional distance from a marker on a scale. Fortunately, in many electronic circumstances, only a close approximation to the actual value is needed, although there are instances when greater precision would be desirable.

There is a further important factor which affects the accuracy of measuring some aspects of electronic circuits – the measuring instrument itself can affect the characteristics of the circuit point being measured; significantly so in some instances, and sometimes it is necessary to take ingenious steps to try to circumvent the problem, but even then a degree of interference will still exist. Electronics is riddled with practical examples of the *Principle of Uncertainty!*

SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



Radio Bygones Message Board

WELCOME to our monthly column related to Internet issues. On our own web site at **www.epemag.wimborne.co.uk** you will find indexes listing the projects contained in issues dating back to 1996, and also further details, including colour photos, of the constructional projects which have appeared in *EPE* within the last 18 months or so. Some readers will also know from the *EPE Chat Zone* that a full redesign is now being considered, as the site has evolved over the past four years and is getting ready for a total rebuild. A shopping cart system is under trial, as well. We welcome your suggestions and feedback by E-mail regarding our Internet presence to **webmaster@epemag.demon.co.uk**.

We have also just opened a message board system for *Radio Bygones* readers – check in at (deep breath) **www.epemag.wimborne.co.uk/radiobygones/wwwboard** to leave messages or to follow up regarding antique radio sets or just share your nostalgic memories. Advertisements from the antique radio sector are also welcomed – and they're free!

Still on the subject of *Radio Bygones*, we can announce that we have now obtained the domain of **radiobygones.co.uk** and a web site related to our sister magazine will be open in the near future. You will be able to subscribe on-line using a secure server and generally see what the magazine is about. American and Canadian readers are welcome to have a look at **www.radiobygones.com** and an on-line version will hopefully be produced.

Search and you will find... an advert

If you type in the URL **www.altavista.digital.com** you will of course be redirected to the popular search engine of AltaVista, now at **www.altavista.com**. Apart from a web site refresh, the development of this interesting and important search engine has largely gone unnoticed by many UK users. For the benefit of newcomers, AltaVista was originally created by the computer manufacturer Digital Equipment Corp. (DEC) as a showcase for their Unix and NT mainframes and servers. Digital Equipment saw their powerful search engine as a good advert, to demonstrate the power of their Alpha processors and servers to search their enormous database of the world wide web, and to sally forth with the closest matches to a search enquiry. Indeed AltaVista has always been a personal favourite, partly because it offers Boolean command search options that come as second nature to many electronics enthusiasts (especially if you followed our series *Teach-In 98:* An Introduction to Digital Electronics).

AltaVista's powerful "spider" (a network search and retrieval program) would traverse the web in search of links which would then be catalogued and added to the enormous AltaVista database back home. You could also add your own URL manually just to be sure, and indeed the task of registering one's own URL into all the relevant search engines – there are some 1,500 or more of them – is now an important element when creating new web sites. (Apparently only I see the joke in AltaVista's "Add URL" confirmation message stating that "this URL was retrieved in 4.997 seconds and will be added in a day or two.")

In January 1998, Compaq (**www.compaq.com**) acquired DEC along with its Alpha microprocessor technology and the AltaVista engine, and nearly two years later in November 1999 Compaq announced a new line-up of "supercomputer" Alpha-based servers and workstations for 3D, CAD and Internet server applications. Compaq hadn't been idle with AltaVista though, and the trusty old search engine was destined for greater things. Very early last year Compaq announced the development of AltaVista as a separate company – and at about the same time it announced that it had purchased **shopping.com**, a very popular on-line retailer in the US.

Then in the middle of last year Compaq announced that it had sold a majority stakeholding in AltaVista to the Internet business development and management group CMGI (**www.cmgi.com**), formerly College Marketing Group Information Services. CMGI will develop AltaVista further into what they hope will become the world's largest portal.

Coupled with the fact that Compaq Internet-ready desktop PCs were to include a ready-made link to AltaVista, it became clear how Compaq was starting to embrace the commercial forces of the Internet and steer business the way of AltaVista. Compaq said that they would meld their consumer Presario Internet PCs with CMGI's Internet services, by providing keyboard and web browser access to AltaVista and other CMGI web offerings.

An updated AltaVista web site was mooted in June '99. The old logo and layout would be replaced by a fresh new number in cheerful yellow along with all the usual portal offerings of news, travel, shopping, jobs and so on. The **shopping.com** site would also be restructured and enhanced.

AltaVista has already grown into a key portal site, which was rated at the ninth largest domain on the entire Internet in early 1999, and conveniently accessible from Compaq desktop PCs. A quick look at the Compaq Presario web pages (**www.compaq.com/mypresario/internetservices/**) on "How to Search" takes you directly (surprise) to My AltaVista, where users are encouraged to configure a start-up page.

Disappearing URLs

One potential problem seems to be surfacing with AltaVista: users are complaining that their own web site seems to have disappeared from its listings, and this can be attributed to the rebuild at the end of last year. Webmasters should do a quick search for themselves (literally) on AltaVista and resubmit their URL. This option is buried in the Advanced Search page (Add/Remove a URL). Some users have quoted a period of up to six weeks before their URL appears again, which obviously means that they will lose traffic or business opportunities during that time.

For those of you wishing to ensure that your web pages receive a higher scoring in search engine listings, you should have a look at **www.searchenginewatch.com**. This provides details on most of the commonest engines and other tips.

It is interesting that there seems to be no objection to Compaq's eagerness to provide a direct link to AltaVista, which by Compaq's own admission is also intended, in turn, to route consumer Internet traffic to e-commerce sites (to the tune of several million hits over Christmas 1998 alone). Yet many PC users rebelled when Windows 95 included a direct and unwanted desktop link to MSN, its fledgling mail service and Internet Content Provider. This was immediately branded a prime example of Microsoft's own (failed) attempts at Internet empire-building.

Users and manufacturers complained even more when Microsoft's Internet Explorer browser was being foisted on them, to the alleged detriment of Netscape, yet they seem happy for consumers to be steered from their home desktops towards a portal site which, with a bit of luck, will ultimately entice them into breaking out their credit cards in a "seamless information and shopping experience" as Compaq calls it.

Nevertheless, AltaVista remains a firm favourite as a search engine, although on my own recently redesigned web site (**http://homepages.tcp.co.uk/~alanwin**) there is a Google search engine installed on my "Links" page. Google is tremendously fast and slick, with none of the portal padding of AltaVista.

You can contact me, as always, by email at **alan@epemag.demon.co.uk**.

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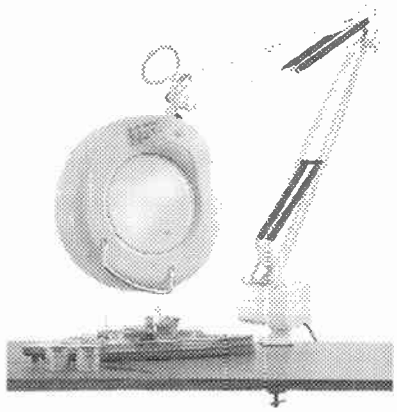

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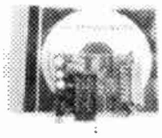

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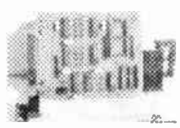

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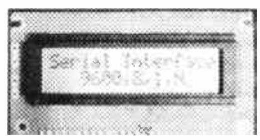

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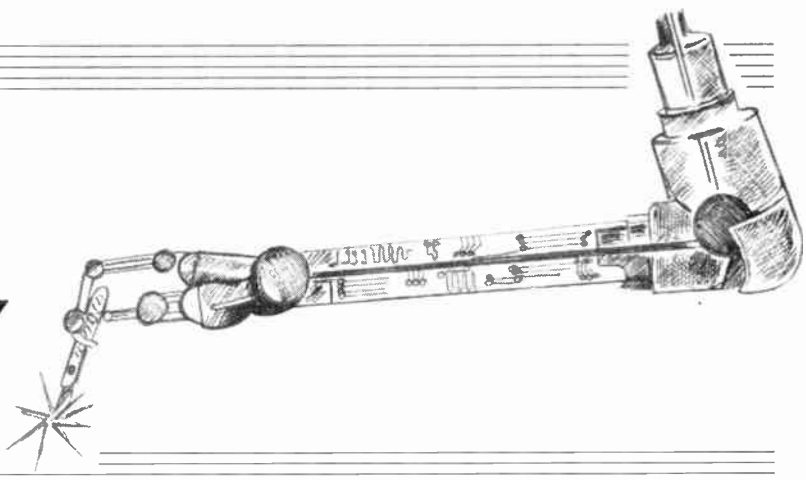


CIRCUIT SURGERY

ALAN WINSTANLEY and IAN BELL

Our Surgery writers continue their exploration of operational amplifiers, by delving into the innards of typical devices to explain basic op.amp principles of operation.

A FEW months ago now readers ***Mohab Refaat*** and ***Tony Soueid*** enquired about the use of one of the most fundamental building blocks of electronics, the operational amplifier or op.amp. Mohab asked about choosing op.amps and we explained all the major op.amp characteristics in the Dec '99 and Jan '00 issues.

We now go on to address Tony's main point: *"I don't know what is inside that 'black box'. . . it's based on a differential pair of transistors, but it's far from being that simple. Can you please supply me with some information?"*

This is a big topic, one that can and does fill whole textbooks, but we will try to give a brief overview of some important points.

Identical Twins

Tony is right to say that op.amps are based on the "differential pair", which we'll look at in detail in a moment, but first look at Fig.1 which shows a general block diagram of an op.amp.

The circuitry of an operational amplifier often comprises: a **differential input stage**, with voltage gain followed by one or more further, **single-ended voltage gain stages**, often with frequency compensation, and finally an **output buffer** providing power gain to drive external loads, but with no voltage gain. All of these stages are *direct-coupled*, which means they are connected without coupling capacitors. Direct coupling means that op.amps are able to amplify d.c. and very low frequency signals.

The circuit diagram for the basic differential pair is shown in Fig.2a. Notice the symmetry of this circuit – it is the key to its operation. The symmetry is so important that in order for this circuit to work well the two transistors must have exactly the same characteristics, i.e. they must be ***matched.***

These characteristics must remain matched all the time – something that, given the high temperature sensitivity of semiconductor devices, can only really be achieved if the two transistors are physically close together on the same piece of silicon. Also, integrated circuit designers use special layout techniques to make sure that transistors that should be matched do indeed have the same characteristics, despite temperature variations and any imperfections in the semiconductor manufacturing process.

This would seem to make life difficult for the hobbyist or student who is interested in experimenting with these circuits using individual components, however it is possible to purchase matched transistors (such as the National Semiconductor LM394 "Supermatch pair" in Fig.2b) and some transistor arrays also contain differential pairs (e.g. the CA3086 "*npn* array") just for this kind of role.

Single-minded

The basic differential pair (Fig.2a) has two inputs V_{i1} and V_{i2} and two outputs V_{o1} and V_{o2}. Each transistor has a collector resistor R_c as a load. Small differences in the input voltages cause relatively large changes in the output voltages, also in a differential manner (i.e. as one output voltage increases, the other will decrease by the same amount). We can, however, choose to use only one output (referred to as taking a "single-ended output").

Key points to understanding the circuit's operation are firstly that a transistor's collector and emitter current are very sensitive to changes in its base voltage, and secondly that the emitters are connected to a **constant current source.** The following discussion assumes that both transistors are switched on – that is, their base-emitter voltage is greater than about 0·6V.

The constant current source means that the sum of the two emitter currents must always be equal to I_E. If the two base voltages are equal, and the transistors are identical, then it follows that I_E will split equally between the two transistors, they will draw the same base current, and their collector currents will be equal. As the two collector resistors are equal, the voltages dropped across them will also be equal (assuming there is no output current).

If the two input voltages change together (this is known as a *common-mode input signal*) then the symmetry will not be disturbed and I_E will still split equally between the two transistors. You may think that changing the input voltage must change the collector and emitter currents, but it does not have to, because the

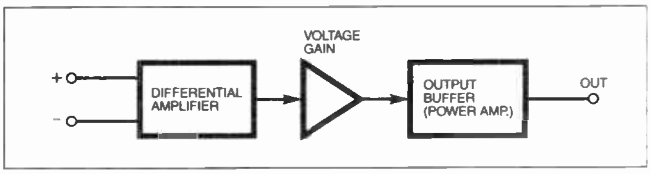


Fig.1. Typical op.amp block diagram.

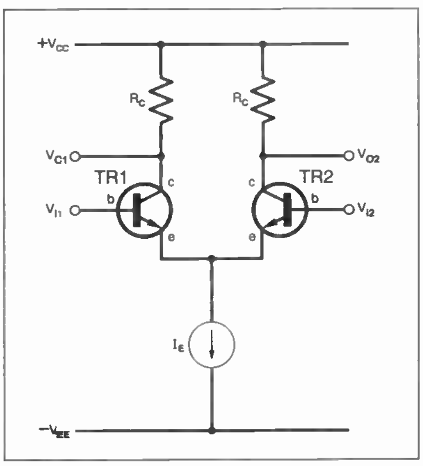


Fig.2a. Basic differential pair.

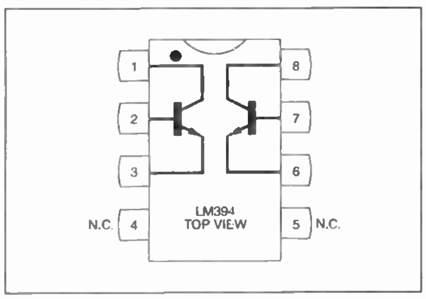


Fig.2b. Pinout details of the LM394 Supermatch pair (National Semiconductor).

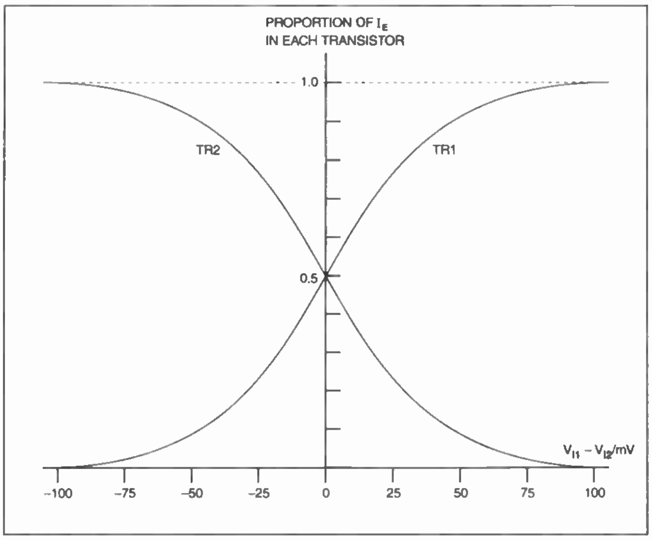


Fig.3. Typical characteristics of a basic differential pair.

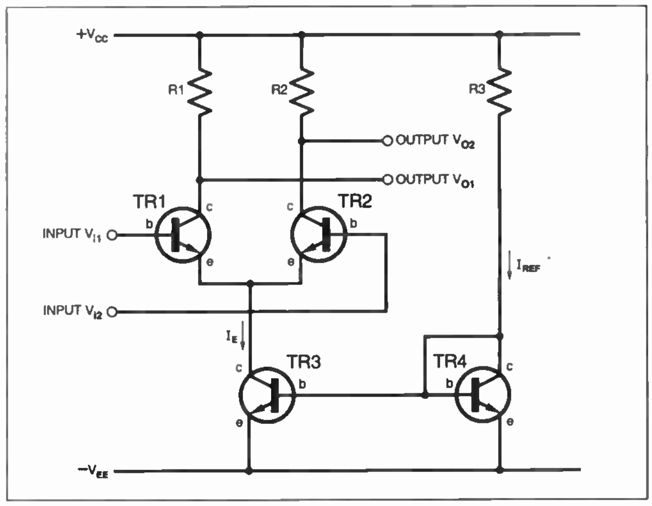


Fig.4. Basic differential pair, simple current mirror biasing.

emitter voltage is free to change whereas I_E is fixed by virtue of the constant current source.

The ability of the matched-transistor circuitry to reject signals which are the same on both inputs (common mode) is not only important because it gives us the function of a differential amplifier, but also because it makes the design of high-performance, high-gain d.c. amplifiers possible. For example, if the temperature of a single transistor amplifier changes then the bias currents change too, and so therefore do the circuit voltages.

In capacitively coupled (i.e. a.c.) circuits this does not matter because the temperature changes are slow and are below the cut-off frequency due to the coupling capacitor. However, if there is no capacitive coupling (as in an op.amp), any changes in voltages due to temperature (or other forms of "drift") are effectively indistinguishable from the required low frequency signals and will be amplified by subsequent stages.

However, if the temperature of a properly matched differential pair changes, both transistors are affected equally and there is no change in the output (the drift is a *common mode signal*). The worst place to get drift is in the first stage as the error is amplifier by all subsequent stages, so having a differential pair as the first stage is a good way of reducing drift.

If we change the (still equal) input voltages by a large enough amount then the circuit will cease to function as just described. For example, if we take the input voltages down to near V_{EE} then the current source may no longer function properly. This would determine the op.amp's common mode input range. Any lack of matching between the transistors would probably result in some shift in output voltage as the inputs varied together, which would manifest itself as a non-ideal common-mode rejection ratio (CMRR) for the op.amp.

Inverted View

The high sensitivity of the transistor's collector and emitter currents to base voltage comes in to play when we make the voltages at the two inputs slightly different. This breaks the symmetry and causes a larger proportion of I_E to flow in one transistor than the other.

For example, if we increase V_{i1} slightly and decrease V_{i2} by the same amount, then more of I_E will flow in transistor TR1 than in TR2. This will cause TR1's collector to fall lower than TR2's, so output V_{o1} will be lower than V_{o2}. Thus, if we take a single-ended output from the collector of TR2, V_{i1} will act as the **non-inverting** input (+) and V_{i2} will act as the **inverting** (–) input. This denotes what effect a signal on either input has on the polarity of the output: increase the non-inverting input and the output effectively increases too. Increasing the inverting input at V_{i2} will cause the output V_{o2} to fall (invert).

Note that differences over a few tens of millivolts (mV) result in most of I_E flowing in one or other of the two transistors. Over a large input difference range the response of the circuit is exponential (see Fig.3), but for just a few millivolts difference between the inputs the change in the output voltage difference is near-enough directly proportional to the input difference (the central part of Fig.3). So we have the linear differential amplifier that we require for an op.amp input stage.

To turn Fig.2a into a practical circuit we need a current source, this can also be achieved using a couple of matched transistors such as the Supermatch pair, although there are also more sophisticated current sources employing more transistors. For a more detailed discussion of current sources please refer to *Circuit Surgery* May and June 1999 in which we discussed these types of circuit in depth.

Mirror Current

A basic differential pair with current mirror biasing is shown in Fig.4, which will hopefully be familiar to regular readers. The emitter current can be set using $I_E = (V_{CC} - V_{EE} - V_{BE(TR4)}) / R3$, where V_{BE} will be typically 0·6V to 0·7V. To choose the R_C collector resistors (R1 and R2) for maximum swing, set the quiescent ("idle") output voltage to half the positive supply. Thus the quiescent voltage across the collector resistors is $V_{CC} / 2$.

Since we set I_E above and the collector current is approximately $I_E / 2$ then R_C for each transistor in the pair can be calculated using $R_C = (V_{CC} / 2) / (I_E / 2) = V_{CC} / I_E$. So if the supplies are ±9V and we chose a bias current of about I_E = 1mA then we get R3 = 18K and $R1 = R2$ = 9K.

For any given transistor $I_E / 2$ should be chosen to give optimal performance (transistor gain etc. varies with bias current). The supply current required may also be a consideration when choosing I_E. Although a device such as the LM394 Supermatch pair has a maximum collector current rating of 20mA, National guarantees most parameters over a range of 1μA to 1mA.

Op.amp Selector

Table 1 shows a comparison between a number of popular op.amps. It is by no means comprehensive, as thousands of op.amps are available, but it will at least enable you to compare the specifications of many well-established types. You can use the information we have provided in previous issues to decipher the meanings of the data: expressions such as "Open Loop Gain" and "Slew Rate" should now be readily understood (we hope).

The manufacturers' data must be consulted for more design information as needed, as our figures may often only apply under certain conditions (supply voltage, temperature etc.). The World Wide Web offers for the first time the possibility of readers fetching data directly from the manufacturer. It's usually in Adobe Acrobat PDF format, which needs the free Acrobat reader from **www.adobe.com**.

Next month we will look at how gain can be improved by using transistors instead of resistors as loads, and consider the problem of getting all the bias voltages right when you cannot isolate stages using coupling capacitors. *IMB.*

Hot Regulator

I built a 1A power supply with a 317-type variable regulator. The data says that it is a 2A regulator but when I draw 1A, the regulator gets very hot and the voltage slowly drops. Why?

So asked a reader in the *EPE Chat Zone* on our web site (**www.epemag.wimborne.co.uk**) recently.

Regulators are usually protected against excess current and thermal overload. It sounds as though you haven't heatsinked

Table 1: Op.Amp Selector

	Max. supply voltage	Differential input voltage	Maximum input voltage	Maximum power diss. (mW)	Supply current	Output voltage swing	Output short circuit current	Open loop gain V/mV	Input bias current	Input resistance	Input offset voltage drift μV/°C	Input offset voltage mV	CMRR dB	Slew rate V/μS	Bandwidth (GBW)	Supply voltage rejection ratio dB	
TL071	±18V	±30V	±15V	680	1·4mA	±13·5V	–	200	65pA	$10^{12}\Omega$	18·0	3·0	100	13·0	3MHz	100	Fast slew, j.f.e.t. input, low noise
TL081	±18V	±30V	±15V	680	1·4mA	±13·5V	–	200	30pA	$10^{12}\Omega$	18·0	3·0	86	13·0	3MHz	86	Low power, j.f.e.t. input
TLC27M2C	18V	$+V_{DD}$	–0·3 to $+V_{DD}$	725	285μA	–	–	275	0·7pA	–	2·1	1·1	94	0·62	635kHz	93	Dual, low voltage, precision
TLC27M7	18V	$+V_{DD}$	–0·3 to $+V_{DD}$	725	285μA	–	–	275	0·7pA	–	2·1	0·19	94	0·62	635kHz	93	Low offset, low power
LT1013AC	±22V	±30	V_{CC-} –5 to V_{CC+}	–	0·7mA	±14V	28mA	2500	–12nA	400MΩ	2·5	0·04	117	0·4	800kHz	120	Dual, single rail, high gain
OP07C	±22V	±30V	±22V	500	–	±13V	–	400	±1·8nA	33MΩ	0·5	60·0	120	0·3	600kHz	103	Low noise, bipolar input
OPA27GP	±22V	±0·7	$+V_{CC}$	500	3·3mA	±13·8V	–	1,500	15nA	2GΩ	0·4	0·025	122	1·9	8MHz	120	Low noise, low offset, low drift, precision instrumentation
OPA177GP	±22V	±30V	$\pm V_S$	–	1·3mA	±14V	–	12,000	0·5nA	45M	0·7	0·02	115	0·3	600kHz	115	Precision. bipolar, instruments
OPA544T	70V	–	V+ +0·7 to V– –0·7	–	12mA	–	4·0A	–	15pA	$10^{12}\Omega$	–	1·0	106	8·0	1·4MHz	–	High voltage, high current, TO220
AD711JN	±18V	V_S	±18V	500	2·5mA	–	25mA	400	20pA	$3 \times 10^{12}\Omega$	7·0	0·3	88	20·0	4·0MHz	95	Precision, high speed, low offset
AD744JN	±18V	V_S	±18V	500	3·5mA	–	25mA	400	30pA	$3 \times 10^{12}\Omega$	5·0	0·3	88	75·0	13·0MHz	95	Precision, f.e.t. input
741	±18V	±30V	±15V	500	1·7mA	±14V	25mA	200	80nA	2M	15	1·0	90	0·5	1·5MHz	96	Obsolete G.P. bipolar
LM10	45V	±40	–	–	270μA	–	–	400	10nA	500k	2·0	0·3	102	–	–	96	Low voltage, reference output
LM308	±18V	–	±15V	500	150μA	±14V	–	300	10nA	40M	6·0	10·0	100	–	–	96	Low voltage, battery op., precision
LF411	±18V	±30V	±15V	670	1·8mA	±13·5V	–	200	50pA	$10^{12}\Omega$	7·0	0·8	100	15	4·0MHz	100	Low offset, j.f.e.t. input
LF441	±18V	±30V	±15V	670	150μA	±13V	–	100	10pA	$10^{12}\Omega$	10·0	1·0	95	1·0	1·0MHz	90	Low power, j.f.e.t. input
LMC6001-AIN	–0·3 to +16V	$\pm V_S$	–	–	750μA	14·6V	±30mA	1400	25fA	>1TΩ	10·0	0·35	75	0·8	1·3MHz	80	Ultra-low input, instrumentation
LMC6081	15V	V_S	–	–	450μA	14·5V	–	1400	10fA	>10TΩ	1·0	0·35	85	–	1·3MHz	94	Precision, low offset CMOS
EL2044	±18V	±10V	V_S	–	5·2mA	±13·6V	75mA	1·5kV/V	2·8μA	15M	10	0·5	90	325	60MHz	80	Low power, low voltage
EL2001	±18V	–	±15V	–	1·3mA	±11V	±100mA	998	1·0μA	8M	–	2·0	–	2000	70MHz	75	High slew rate, high speed buffer
NE5534	±22V	0·5	$+V_S$	1,150	4·0mA	<±16V	38mA	100	400nA	100k	5·0	0·5	100	13·0	10MHz	–	Low noise, audio, instrumentation
CA3130	16V	8·0	+V +8 to –V – 0·5	–	300μA	<15V	20mA	100	5pA	1·5TΩ	10·0	8·0	90	<30·0	4MHz	74	MOSFET input, rail-to-rail output
CA3140	36V	8·0	"	–	1·6mA	13V	+40mA	100	2pA	1·0TΩ	6·0	5·0	90	7·0	3·7MHz	80	MOSFET input, bipolar output
CA3420	22V	15·0	"	9·0	150μA	–	2·6mA	100	0·05pA	150TΩ	4·0	5·0	80	0·5	0·5MHz	90	Low voltage, portable instruments

the device properly (if at all). It's imperative that the regulator is allowed to dissipate any power efficiently, to prevent the chip from overheating.

Fortunately, the LM317 – like many other three terminal regulators – will suffer no immediate damage from inadequate heatsinking, because it will simply current-limit and gradually shut itself down. As you saw, the output voltage slowly falls during this shut-down process. However, any repeated cycling like this can stress a device over time, ultimately leading to some lasting damage. Simply bolt it to a generously-sized heatsink and it will perform fine. Proper thermal resistance calculations are the best way of determining what size heatsink to use. *ARW.*

Conventional Current

Do you know why the plate of a valve (vacuum tube) is called an anode whilst the plate on a semiconductor diode is called a cathode? Most confusing. ***E.J. Bibby.***

When I first started reading up on electronics in the early 1970's, my very first text book started with valves (but hey, I'm not *that* old!). Their operation was described in terms of real electron flow, i.e. what actually happened in terms of the physics of the electron. The simplest vacuum tube is the diode, consisting of a cathode (which is a piece of metal warmed up by a heating element) together with an anode "plate".

Electrons boil off the hot cathode and, being negatively charged, are attracted towards the anode, which when positively biased will "accept" these negative electrons. The current of electrons which flows through the valve in this way is called the **anode current.**

By placing an electrode between the cathode and anode and applying a grid bias voltage to it, the anode current can be controlled – thus a triode valve is created which can be used as an amplifier. This, together with my scant knowledge of Nuffield Physics (as my schoolteacher of the time would testify), meant that I started out in electronics knowing that electric current flowed towards the most positive electrode. It all made sense.

The trouble is, in modern semiconductor electronics we talk in terms of *"conventional current flow"*. We all do this without thinking, but it's extremely bizarre to anyone coming into electronics from other sciences (notably physics and chemistry). Under this convention, electric current is deemed to flow from positive to negative, although in real life it flows in the other direction.

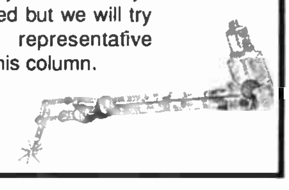
More than one Physics teacher has torn a strip off me for apparently not knowing which way current flows in a circuit: my apologies to Physics teachers everywhere but unfortunately the convention is now so well entrenched around the world that it will never change. (Can you imagine the chaos if it did? Which way round would you connect your multimeter?)

In a semiconductor diode, conventional current flows in the direction of the arrowhead symbol – from *anode to cathode*. In a silicon diode, the anode (a) must be 0·7V more positive than the cathode (k) for a "forward current" to flow from anode to cathode. However, the anode (electron) current in a vacuum tube flows from *cathode to anode*.

I'm afraid that we have history to blame for this conundrum, but in practice everything works fine. After all, we know what we mean, don't we? *ARW.*

CIRCUIT THERAPY

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



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ELECTRONIC MODULES AND SYSTEMS FOR BEGINNERS
Owen Bishop

This book describes over 60 modular electronic circuits, how they work, how to build them, and how to use them. The modules may be wired together to make hundreds of different electronic systems, both analogue and digital. To show the reader how to begin building systems from modules, a selection of over 25 electronic systems are described in detail, covering such widely differing applications as timing, home security, measurement, audio (including a simple radio receiver), games and remote control.

200 pages **Temporarily out of print**

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages **Order code BP53** **£4.99**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order to your door. Full ordering details are given on the last book page.

FOR ANOTHER SELECTION OF BOOKS SEE THE NEXT TWO MONTH'S ISSUES.

Note our UK postage costs just £1.50 no matter how many books you order!

3a

Computing

WINDOWS 95 EXPLAINED
P. R. M. Oliver and N. Kantaris

If you would like to get up and running, as soon as possible, with the new Windows 95 operating system, then this is the book for you.

The book was written with the non-expert, busy person in mind. It explains the hardware that you need in order to run Windows 95 successfully, and how to install and optimize your system's resources. It presents an overview of the Windows 95 environment.

Later chapters cover how to work with programs, folders and documents; how to control Windows 95 and use the many accessories that come with it; how to use DOS programs and, if necessary, DOS commands and how to communicate with the rest of the electronic world.

170 pages **Order code BP400** **£5.95**

EASY PC INTERFACING
R. A. Penfold

Although the internal expansion slots of a PC provide full access to the computer's buses, and are suitable for user add-ons, making your own expansion cards requires a fair amount of expertise and equipment. The built-in ports provide what is often a much easier and hassle-free way of interfacing your own circuits to a PC. In particular, a PC printer port plus a small amount of external hardware provides a surprisingly versatile input/output port. The PC "games" port is less useful for general interfacing purposes, but it can be useful in some applications.

This book provides a number of useful PC add-on circuits including the following: Digital input/output ports; Analogue-to-digital converter; Digital-to-Analogue Converter; Voltage and Current measurement circuits; Resistance meter; Capacitance meter; Temperature measurement interface; Biofeedback monitor; Constant voltage model train controller; Pulsed model train controllers; Position sensor (optical, Hall effect, etc.); Stepper motor interface; Relay and LED drivers; Triac mains switching interface.

179 pages **Order code BP385** **£4.99**

INTRODUCTION TO MICROPROCESSORS
John Crisp

If you are, or soon will be, involved in the use of microprocessors, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors, assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern microprocessors.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

Contents: The world changed in 1971; Microprocessors don't have ten fingers; More counting; Mathematical micros; It's all a matter of logic; Registers and memories; A microprocessor based system; A typical 8-bit microprocessor; Programming, High level languages; Micros are getting bigger and faster; The pentium; The PowerPC; The Alpha 21164 microprocessor; Interfacing; Test equipment and fault finding.

222 pages **Order code NE31** **£16.99**

Theory and Reference

Bebop To The Boolean Boogie

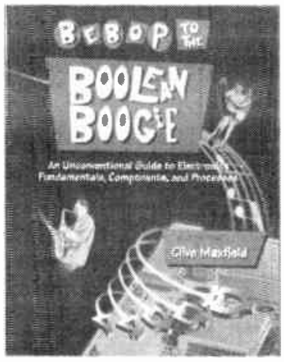
By Clive (call me Max) Maxfield

ORDER CODE BEB1

£24.95

470 pages. Large format

Specially imported by EPE – Excellent value



An Unconventional Guide to Electronics Fundamentals, Components and Processes

This book gives the "big picture" of digital electronics. This in-depth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean algebra and Karnaugh maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!). Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day....

470 pages – large format **Order code BEB1** **£24.95**

DIGITAL ELECTRONICS – A PRACTICAL APPROACH

FREE SOFTWARE

With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsar (Limited Functionality)

Richard Monk

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchronous and synchronous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer-aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and printed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages **Order code NE28** **£16.99**

DIGITAL GATES AND FLIP-FLOPS

Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

200 pages **Order code PC106** **£8.95**

Bebop Bytes Back

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By Clive "Max" Maxfield and Alvin Brown

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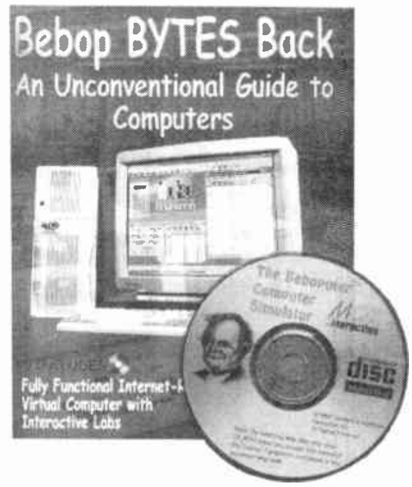

An Unconventional Guide To Computers

Plus **FREE CD-ROM** which includes: Fully Functional Internet-Ready Virtual Computer with Interactive Labs

This follow-on to *Bebop To The Boolean Boogie* is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this one!

Over 500 pages – large format **Order code BEB2** **£29.95**

NEWNES INTERACTIVE ELECTRONIC CIRCUITS CD-ROM

CD-ROM

Edited by Owen Bishop

An expert adviser, an encyclopedia, an analytical tool and a source of real design data, all in one CD-ROM. Written by leading electronics experts, the collected wisdom of the electronics world is at your fingertips. The simple and attractive Circuits Environment (TM) is designed to allow you to find the circuit or advice notes of your choice quickly and easily using the search facility. The text is written by leading experts as if they were explaining the points to you face to face. Over 1,000 circuit diagrams are presented in a standardised form, and you are given the option to analyse them by clicking on the Action icon. The circuit groups covered are: Amplifiers, Oscillators, Power, Sensing, Signal Processing, Filters, Measurement, Timing, Logic Circuits, Telecommunications.

The analysis tool chosen is SpiceAge for Windows, a powerful and intuitive application, a simple version of which automatically bursts into action when selected.

Newnes Interactive Electronic Circuits allows you to: analyse circuits using top simulation program SpiceAge; test your design skills on a selection of problem circuits; clip comments to any page and define bookmarks; modify component values within the circuits; call up and display useful formulae which remain on screen; look up over 100 electronic terms in the glossary; print and export netlists.

System Requirements: PC running Windows 3.x, 95 or NT on a 386 or better processor. 4MB RAM, 8MB disk space.

CD-ROM **Order code NE-CD1** **£49.99**

Audio and Music

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN

V. Capel

This book explores the various features, good points and snags of speaker designs. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even design loudspeaker enclosures for him – or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the *Kapellmeister* loudspeaker enclosure.

148 pages **Order code BP256** **£3.99**

PREAMPLIFIER AND FILTER CIRCUITS

R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases). The preamplifier circuits featured include: Microphone preamplifiers (low impedance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A. equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls.

92 pages **Order code BP309** **£3.99**

HIGH POWER AUDIO AMPLIFIER CONSTRUCTION

R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

96 pages **Order code BP277** **£3.99**

ACOUSTIC FEEDBACK – HOW TO AVOID IT

V. Capel

Feedback is the bane of all public address systems. While feedback cannot be completely eliminated, many things can be done to reduce it to a level at which it is no longer a problem.

Much of the trouble is often the hall itself, not the equipment, but there is a simple and practical way of greatly improving acoustics. Some microphones are prone to feedback while others are not. Certain loudspeaker systems are much better than others, and the way the units are positioned can produce a reduced feedback. All these matters are fully explored as well as electronic aids such as equalizers, frequency-shifters and notch filters.

The special requirements of live group concerts are considered, and also the related problem of instability that is sometimes encountered with large set-ups. We even take a look at some unsuccessful attempts to cure feedback so as to save readers wasted time and effort duplicating them.

Also included is the circuit and layout of an inexpensive but highly successful twin-notch filter, and details on how to operate it.

92 pages **Temporarily out of print**

Testing, Theory, Data and Reference

SCROGGIE'S FOUNDATIONS OF WIRELESS AND ELECTRONICS – ELEVENTH EDITION
S. W. Amos and Roger Amos
Scroggie's Foundations is a classic text for anyone working with electronics, who needs to know the art and craft of the subject. It covers both the theory and practical aspects of a huge range of topics from valve and tube technology, and the application of cathode ray tubes to radar, to digital tape systems and optical recording techniques.

Since *Foundations of Wireless* was first published over 60 years ago, it has helped many thousands of readers to become familiar with the principles of radio and electronics. The original author Sowerby was succeeded by Scroggie in the 1940s, whose name became synonymous with this classic primer for practitioners and students alike. Stan Amos, one of the fathers of modern electronics and the author of many well-known books in the area, took over the revision of this book in the 1980s and it is he, with his son, who have produced this latest version.
400 pages **Order code NE27** **£19.99**

ELECTRONICS MADE SIMPLE
Ian Sinclair
Assuming no prior knowledge, *Electronics Made Simple* presents an outline of modern electronics with an emphasis on understanding how systems work rather than on details of circuit diagrams and calculations. It is ideal for students on a range of courses in electronics, including GCSE, C&G and GNVQ, and for students of other subjects who will be using electronic instruments and methods.

Contents: waves and pulses, passive components, active components and ICs, linear circuits, block and circuit diagrams, how radio works, disc and tape recording, elements of TV and radar, digital signals, gating and logic circuits, counting and correcting, microprocessors, calculators and computers, miscellaneous systems.
Page 199 (large format) **Order code NE23** **£12.99**

TRANSISTOR DATA TABLES
Hans-Günther Steidle
The tables in this book contain information about the package shape, pin connections and basic electrical data for each of the many thousands of transistors listed. The data includes maximum reverse voltage, forward current and power dissipation, current gain and forward transadmittance and resistance, cut-off frequency and details of applications.

A book of this size is of necessity restricted in its scope, and the individual transistor types cannot therefore be described in the sort of detail that maybe found in some larger and considerably more expensive data books. However, the list of manufacturers' addresses will make it easier for the prospective user to obtain further information, if necessary.

Lists over 8,000 different transistors, including f.e.t.s.
200 pages **Order code BP401** **£5.95**

MORE ADVANCED USES OF THE MULTIMETER
R. A. Penfold

This book is primarily intended as a follow-up to BP239, (see below), and should also be of value to anyone who already understands the basics of voltage testing and simple component testing. By using the techniques described in Chapter 1 you can test and analyse the performance of a range of components with just a multimeter (plus a very few inexpensive components in some cases). Some useful quick check methods are also covered.

While a multimeter is supremely versatile, it does have its limitations. The simple add-ons described in Chapter 2 extended the capabilities of a multimeter to make it even more useful.
84 pages **Order code BP265** **£2.95**

ELECTRONIC TEST EQUIPMENT HANDBOOK
Steve Money
The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bridges, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of the instruments are also examined.

Everything from Oscillators, through R, C & L measurements (and much more) to Waveform Generators and testing Zeners.
206 pages **Order code PC109** **£8.95**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.
96 pages **Order code BP239** **£2.95**

NEWNES ELECTRONICS TOOLKIT– SECOND EDITION
Geoff Phillips
The author has used his 30 years experience in industry to draw together the basic information that is constantly demanded. Facts, formulae, data and charts are presented to help the engineer when designing, developing, evaluating, fault finding and repairing electronic circuits. The result is this handy workmate volume: a memory aid, tutor and reference source which is recommended to all electronics engineers, students and technicians.

Have you ever wished for a concise and comprehensive guide to electronics concepts and rules of thumb? Have you ever been unable to source a component, or choose between two alternatives for a particular application? How much time do you spend searching for basic facts or manufacturer's specifications? This book is the answer, it covers resistors, capacitors, inductors, semiconductors, logic circuits, EMC, audio, electronics and music, telephones, electronics in lighting, thermal considerations, connections, reference data.
158 pages **Order code NE20** **£12.99**

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
This is not a book of theory. It is a book of practical tips, hints, and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialized.

The book covers: **Basics** – Voltage, current and resistance; Capacitance, inductance and impedance; Diodes and transistors; Op-amps and negative feedback; **Fault finding** – Analogue fault finding, Digital fault finding; Memory; Binary and hexadecimal; Addressing; Discrete logic; Microprocessor action; I/O control; CRT control; Dynamic RAM; Fault finding digital systems; Dual trace oscilloscope; IC replacement.
274 pages **Order code NE22** **£18.99**

AN INTRODUCTION TO LIGHT IN ELECTRONICS
F. A. Wilson
This book is not for the expert but neither is it for the completely uninitiated. It is assumed the reader has some basic knowledge of electronics. After dealing with subjects like Fundamentals, Waves and Particles and The Nature of Light such things as Emitters, Detectors and Displays are discussed. Chapter 7 details four different types of Lasers before concluding with a chapter on Fibre Optics.
161 pages **Order code BP359** **£4.95**

UNDERSTANDING DIGITAL TECHNOLOGY
F. A. Wilson C.G.I.A., C.Eng., F.I.E.E., F.I. Mgt.
This book examines what digital technology has to offer and then considers its arithmetic and how it can be arranged for making decisions in so many processes. It then looks at the part digital has to play in the ever expanding Information Technology, especially in modern transmission systems and television. It avoids getting deeply involved in mathematics.

Various chapters cover: Digital Arithmetic, Electronic Logic, Conversions between Analogue and Digital Structures, Transmission Systems. Several Appendices explain some of the concepts more fully and a glossary of terms is included.
183 pages **Order code BP376** **£4.95**

Project Building

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.
135 pages **Order code BP392** **£4.95**

45 SIMPLE ELECTRONIC TERMINAL BLOCK PROJECTS
R. Bebbington
Contains 45 easy-to-build electronic projects that can be constructed, by an absolute beginner, on terminal blocks using only a screwdriver and other simple hand tools. No soldering is needed.

Most of the projects can be simply screwed together, by following the layout diagrams, in a matter of minutes and readily unscrewed if desired to make new circuits. A theoretical circuit diagram is also included with each project to help broaden the constructor's knowledge.

The projects included in this book cover a wide range of interests under the chapter headings: Connections and Components, Sound and Music, Entertainment, Security Devices, Communication, Test and Measuring.
163 pages **Order code BP378** **£4.95**

30 SIMPLE IC TERMINAL BLOCK PROJECTS
R. Bebbington
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HOW TO DESIGN AND MAKE YOUR OWN P.C.B.S
R. A. Penfold
Deals with the simple methods of copying printed circuit board designs from magazines and books and covers all aspects of simple p.c.b. construction including photographic methods and designing your own p.c.b.s.
80 pages **Order code BP121** **£3.99**

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VIDEOS ON ELECTRONICS

A range of videos selected by *EPE* and designed to provide instruction on electronics theory. Each video gives a sound introduction and grounding in a specialised area of the subject. The tapes make learning both easier and more enjoyable than pure textbook or magazine study. They have proved particularly useful in schools, colleges, training departments and electronics clubs as well as to general hobbyists and those following distance learning courses etc

BASICS

VT201 to VT206 is a basic electronics course and is designed to be used as a complete series, if required.

VT201 54 minutes. Part One; **D.C. Circuits.** This video is an absolute must for the beginner. Series circuits, parallel circuits, Ohms law, how to use the digital multimeter and much more. **Order Code VT201**

VT202 62 minutes. Part Two; **A.C. Circuits.** This is your next step in understanding the basics of electronics. You will learn about how coils, transformers, capacitors, etc are used in common circuits. **Order Code VT202**

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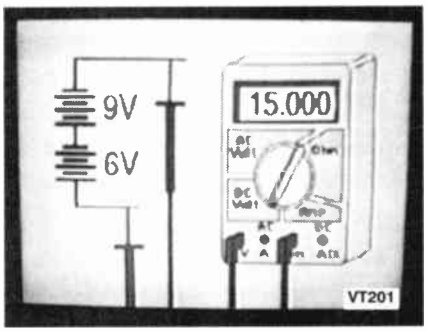

VT204 56 minutes. Part Four; **Power Supplies.** Guides you step-by-step through different sections of a power supply.
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VT206 54 minutes. Part Six; **Oscillators.** Oscillators are found in both linear and digital circuits. Gives a good basic background in oscillator circuits. **Order Code VT206**

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Order Code VT102

VT103 35 minutes: A step-by-step easy to follow procedure for professionally cleaning the tape path and replacing many of the belts in most VHS VCR's. The viewer will also become familiar with the various parts found in the tape path.
Order Code VT103

DIGITAL

Now for the digital series of six videos. This series is designed to provide a good grounding in digital and computer technology.

VT301 54 minutes. Digital One; **Gates** begins with the basics as you learn about seven of the most common gates which are used in almost every digital circuit, plus Binary notation. **Order Code VT301**

VT302 55 minutes. Digital Two; **Flip Flops** will further enhance your knowledge of digital basics. You will learn about Octal and Hexadecimal notation groups, flip-flops, counters, etc. **Order Code VT302**

VT303 54 minutes. Digital Three; **Registers and Displays** is your next step in obtaining a solid understanding of the basic circuits found in today's digital designs. Gets into multiplexers, registers, display devices, etc.
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VT304 59 minutes. Digital Four; **DAC and ADC** shows you how the computer is able to communicate with the real world. You will learn about digital-to-analogue and analogue-to-digital converter circuits.
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VT305 56 minutes. Digital Five; **Memory Devices** introduces you to the technology used in many of today's memory devices. You will learn all about ROM devices and then proceed into PROM, EPROM, EEPROM, SRAM, DRAM, and MBM devices.
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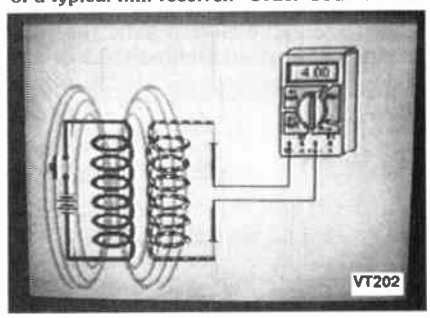

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MISCELLANEOUS

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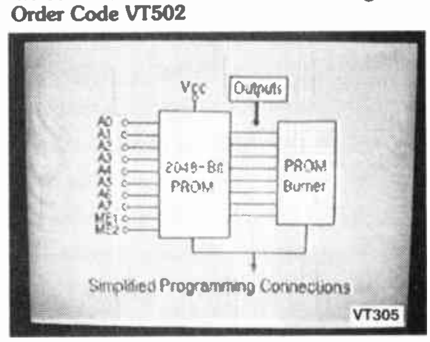

Each video uses a mixture of animated current flow in circuits plus text, plus cartoon instruction etc., and a very full commentary to get the points across. The tapes are imported by us and originate from VCR Educational Products Co, an American supplier. We are the worldwide distributors of the PAL and SECAM versions of these tapes. (All videos are to the UK PAL standard on VHS tapes unless you specifically request SECAM versions.)

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PRACTICALLY SPEAKING

Robert Penfold looks at the Techniques of Actually Doing It!

IN A previous *Practically Speaking* article we considered the subject of capacitors, and this month we move on to that other humble component – the *resistor*.

At a guess, in most projects about half the components are resistors, so beginners have to get to grips with resistors right from the start.

The basic unit of resistance is the ***Ohm***, but this is a small unit of measurement. Hence the resistors used in electronic circuits often have values of thousands or even millions of ohms.

The usual abbreviation for ohm is the Greek letter omega (Ω), but these days an upper case letter "R" is sometimes used instead. *(In EPE we use the omega symbol up to 999 ohms)*. Large values are expressed in either kilohms (kΩ or just k) or megohms (MΩ or just M). A kilohm is equal to 1,000 ohms, and a megohm is 1,000,000 ohms.

Colour Bar

One immediate problem facing the beginner is that most resistors are not marked with values using normal text characters. Instead a system of "colour coding" is used, and there are four or five coloured bands marked around the body of each component.

This may seem to be an unnecessarily awkward way of handling things, but you have to bear in mind that the average resistor is an extremely small component. You will often be dealing with resistors that are no more than about one millimetre in diameter.

Any lettering on a component this small would have to be minute, and would also be easily obliterated. Colour codes are relatively easy to read, and even if they become damaged it should still be possible to read the values of components correctly.

The normal resistor colour code has four bands, with three bands grouped together. It is these three that indicate the value of the component while the other one shows the tolerance rating of the component. The tolerance is simply the maximum deviation from the marked value given as a percentage. Thus, if a 100 ohm resistor has a tolerance rating of five per cent, its actual value would be between 95 and 105 ohms.

The group of three bands indicates the first two digits of the value and the multiplier. Fig.1 shows the function of each band. Table 1 shows the meaning of each colour when it appears in each band.

As an example, suppose that a resistor has *red–violet–orange–gold* as its colour code. The first two bands indicate the first two digits of the value, and in this case red and violet respectively indicate that these are two and seven. The third band is orange, which means that the first two digits must be multiplied by one thousand in order to give the value in ohms.

This gives 27 x 1000 and an answer of 27000 ohms (27 kilohms (27k)). The colour of the fourth band is gold, and the resistor therefore has a tolerance rating of five per cent.

Preferred Values

Resistors are normally available in what is called the "E24" series of values. The basic E24 series of values is listed in Table 2, but values ten times higher, a hundred times higher, etc. are also available, up to a normal maximum of 10 megohms (10M). Values one tenth and one hundredth of the basic values are also available, but are relatively difficult to obtain.

This range of values might look rather random at first glance, but each value is roughly ten percent higher than the previous value in the series. Together with the inclusion of the same values in various decades, this means that one of these "preferred" values will always be close to the required value for a resistor. In fact the ideal value calculated by a circuit designer should never be more than about five per cent away from a preferred value.

Most resistors are available in the full E24 series, but some are only available in the E12 series, which is every other value in the E24 series (1·0, 1·2, 1·5, etc.). Most electronic projects only use resistors having values from the E12 series.

Bunch of Fives

Rather unhelpfully, many of the resistors now sold to amateur users have five band codes. These operate in the manner shown in Fig.2. The first of these is quite easy to use because the first four bands give the value and tolerance rating in the normal way. The additional fifth band shows the temperature coefficient of the component, which is not something that is normally of any relevance. If the fifth band is ignored, the other four give the value and tolerance rating in the usual fashion.

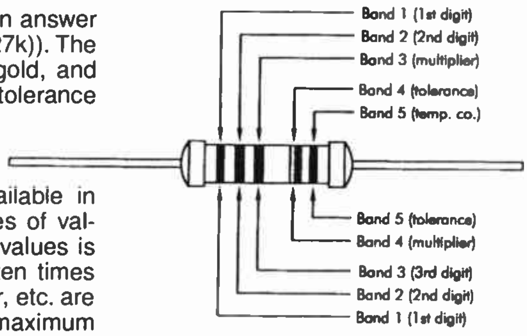

Fig.2. Two methods of five-band resistor colour coding.

Table 2

1·0	1·1	1·2	1·3	1·5	1·6
1·8	2·0	2·2	2·4	2·7	3·0
3·3	3·6	3·9	4·3	4·7	5·1
5·6	6·2	6·8	7·5	8·2	9·1

Fig.1. The normal method of colour coding resistors uses four coloured bands.

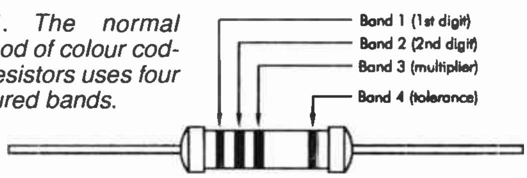

Table 1: Resistor Colour Code

Colour	*Band 1*	*Band 2*	*Band 3*	*Band 4*
Black	0	0	x1	–
Brown	1	1	x10	1%
Red	2	2	x100	2%
Orange	3	3	x1000	–
Yellow	4	4	x10000	–
Green	5	5	x100000	0·5%
Blue	6	6	x1000000	0·25%
Violet	7	7	–	0·1%
Grey	8	8	–	–
White	9	9	–	–
Gold	–	–	x0·1	5%
Silver	–	–	x0·01	10%
None	–	–	–	20%

The second form of five band coding is probably the more common one, and is slightly more difficult to deal with. Again, it is not that far removed from the four-band method.

The first two bands indicate the first two digits of the value, and the last two bands provide the multiplier and the tolerance rating. The difference is that an additional middle band is used to indicate the third digit of the value.

This method of coding can handle non-standard values such as 26·7k, but as these are not used in amateur electronics this is irrelevant to the electronics enthusiast. The normal four-band method of coding is all that is needed.

Nevertheless, this form of five band coding does seem to be used on the resistors sold to amateur users. When applied to normal E24 values the third digit is always zero, and the third coloured band is therefore black.

To compensate for this extra zero the multiplier value is reduced by a factor of ten. Taking our earlier 27k example, this would become red–violet–black–red–gold. This gives 270 x 100 = 27000 ohms.

Composition

In component catalogues you will find resistors described as "carbon film" and "metal film" or "metal oxide". The simplest resistors are the carbon composition type, which are basically just pieces of carbon with an electrode attached to each end.

These have now been replaced by carbon film resistors, which consist of a former made from an insulating material having an electrode at each end. A film of carbon is deposited on the former, and the resistance value obtained depends on the thickness and the exact composition of the film. Carbon film resistors are adequate for most applications, and are the type normally specified in components lists.

Metal film resistors are the usual choice for more demanding applications. They are similar in construction to carbon film resistors, but the film is based on a metal oxide instead of carbon. Resistors of this type normally have close tolerances of two percent or better, and generate less electrical noise than any form of carbon resistor. Their values are also affected less by temperature changes and ageing.

Metal oxide resistors are needed for some demanding applications, such as in critical stages of test equipment and in low noise audio preamplifiers. They can be used in place of carbon resistors for general use, but it makes sense to use cheaper carbon resistors in any application where they will suffice.

High Power

Some resistors do actually have the values written on the body using ordinary text characters, but in recent years this is something I have only encountered on higher power resistors. Most of the resistors used in electronic circuits have to dissipate very low power levels, and small resistors having ratings of about 0·25 watts are perfectly adequate.

Some circuits have the odd resistor or two that has to handle higher power ratings. Components lists normally indicate a suitable power rating for all the resistors anyway, but a suitable rating should certainly be given for any high power types.

It is very unusual for resistors having power ratings of more than about one watt (1W) to have the value marked using coloured bands. The larger physical size of these resistors makes it possible to mark the value using text characters of reasonable size.

The value is invariably marked on the resistor in the same form that it appears on a circuit diagram. In other words, the letter used to indicate the unit of measurement is also used to denote the position of the decimal point. A value of 2·7k would be marked as "2k7" and a value of 0·47 ohms would be marked as "0Ω47" (or "OR47").

There will usually be other marks as well, some of which might simply be the makers name, a batch number or something of this type. Of more use, there will probably be a wattage rating and a letter to indicate the tolerance rating of the component. Table 3 shows the corresponding tolerance rating for each of the code letters used.

Table 3

Letter	*Tolerance*
F	1%
G	2%
J	5%
K	10%
M	20%

High power resistors have various compositions, but the *wirewound* variety is by far the most common. This consists of a coil of resistance wire wound around what is usually a ceramic former.

One slight problem with wirewound resistors is that the coil of wire also acts as an inductor, although most components of this type are constructed in a fashion that minimises this problem. Even so, wirewound resistors are less than ideal for some applications, and if a different type is indicated in the components list it is advisable to use the specified type.

Very high power resistors have metal fins to help conduct heat from the component into the surrounding air (Fig.3). Many of these resistors also have to be mounted on a substantial piece of metal, which acts as a heatsink and provides further cooling. With resistors such as this, the article should give guidance on using the resistors, and this must be followed "to the letter".

Potentiometers

The terms "potentiometer" and "variable resistor" tend to cause a certain amount of confusion. A potentiometer ("pot") has three terminals, and between two of these there is a fixed resistance. There is a variable resistance between these terminals and the third one.

A potentiometer consists of a track of carbon with a terminal at each end of the track. The third terminal connects to a wiper that can be moved along the track by means of a spindle.

There are also preset potentiometers that have no spindle, but can be adjusted using a screwdriver. With an open construction preset potentiometer the track, wiper, and terminals are all clearly visible (see Fig.4). The greater the amount of track between the wiper and one of the fixed terminals, the greater the resistance between them as well.

The normal way of using a potentiometer is with an input voltage across the track, and a variable output voltage is then available from the wiper (moving contact) and one of the track terminals. Strictly speaking, the components you buy are always potentiometers having three terminals, but in some applications it is a variable resistance that is required. It is then only necessary to use the wiper terminal and one of the track connections.

Potentiometers are available in three types, which are the linear (*lin*), logarithmic (*log*) and anti-logarithmic varieties. A linear potentiometer gives approximately equal resistance between the wiper and the two track terminals when it is at a central setting, as one would expect.

A logarithmic potentiometer produces vastly different resistances under the same conditions. So does an anti-logarithmic potentiometer, but with the high and low values the other way around.

When used as a volume control a linear potentiometer gives an odd control characteristic, with the volume seeming to jump to a high level when it is advanced slightly from zero. Further advancement then seems to have little effect. This is due to the way we perceive sound rather than a problem with the potentiometer.

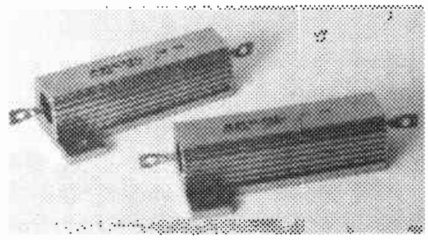

Fig.3. High power wirewound resistor in an aluminium heat dissipator.

When used as a volume control, a logarithmic potentiometer gives a much better control characteristic. Logarithmic potentiometers are used for little other than volume controls. Anti-logarithmic controls are difficult to obtain and are only needed for a few specialist applications. If you use a potentiometer of the wrong type the circuit will still work, but the control will be awkward to use.

Table 4

Letter	*Potentiometer Type*
A	Linear
B	Logarithmic
C	Anti-logarithmic

As Easy As ABC

The values of potentiometers are marked using text characters, together with the type "log", "lin" or "anti"). These days many potentiometers are marked with a code letter to indicate the type.

This works in the manner shown in Table 4. Note that potentiometers are only produced in a very limited range of values.

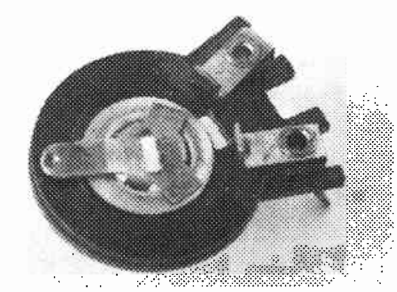

Fig.4. "Open-track" preset potentiometer.

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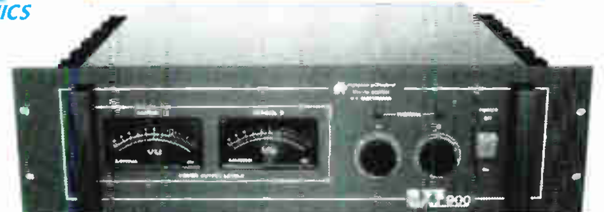

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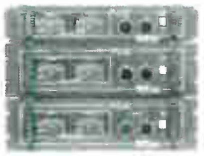

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PRICE:- £125.00 EACH

SPECIALIST CARRIER DEL:- £12.50 per pair, Wedge Monitor £7.00 each

Optional Metal Stands PRICE:- £49.00 per pair Delivery:- £6.00

OMP XO3-S STEREO 3 WAY ACTIVE CROSS OVER SWITCHABLE 2-WAY

BASS / MID / TOP — CONFIGURED 3 WAY
BASS/MID / TOP — 2 WAY BASS/MID COMBINED
BASS / MID/TOP — 2 WAY MID/TOP COMBINED

FEATURES:
Advanced 3 Way Stereo Active Cross Over (switchable two way), housed in a 19" x 1U case. Each channel has three level controls Bass Mid & Top. The removable front fascia allows access to the programmable DIL switches to adjust the cross over frequency. Bass-Mid 125/250/500Hz, Mid Top 1.8/3.5Hz all at 24dB per octave. The 2/3 way selector switches are also accessed by removing the front fascia. Each stereo channel can be configured separately. Bass Invert Switches are incorporated on each channel. Nominal 775mV input/output. Fully compatible with OMP Rack Amplifier and Modules

PRICE:- £117.44 + £5.00 P&P

FANE COLOSSUS POWER
VERY HIGH POWER LOUDSPEAKERS

THE COLOSSUS RANGE OF LOUDSPEAKERS ARE DESIGNED FOR USE IN SUPERIOR HIGH POWER OUTPUT SYSTEMS. *ALL MODELS ARE 8 OHM*

COLOSSUS 12MB:-* 12 INCH * 450WATT R.M.S. * 900 WATTS PEAK * Sens 98 dB.* Res Freq.55 Hz. * Frequency Range 40 Hz 3.5KHz PRICE £129.00

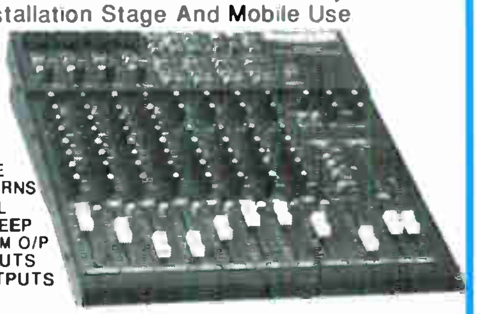
COLOSSUS 15XB:-* 15 INCH * 600WATTS R.M.S. * 1200 WATTS PEAK * Sens 99 dB * Res Freq.35 Hz. * Frequency Range 30 Hz-1.0KHz PRICE £159.00

COLOSSUS 18XB:-* 18 INCH * 600WATTS R.M.S. * 1200 WATTS PEAK *Sens 100dB.* Res Freq.30 Hz. * Frequency Range 27 Hz-1.0Kz PRICE £183.00

ALL MODELS ARE DELIVERED CARRIAGE FREE(UK ONLY)

SoundLAB SPM 12 AND 16 CH.MIXERS

The 12 and 16 Channel SPM Series Of Studio Quality Mixers Are Ideal For Fixed Installation Stage And Mobile Use



* 48v PHANTOM POWER
* BUILT IN POWER SUPPLY
* 230V AC/50Hz
* PEAK INPUT LEVEL LEDS
* PRE FADE LISTEN (PFL)
* SUB MASTER OUTPUT
* COMBINED XLR/¼ JACK
* 60mm FADERS * CH.MUTE
* 2 STEREO AUX.SEND/RETURNS
* CONSTANT PAN CONTROL
* 3 BAND EQ WITH MID SWEEP
* HEADPHONE/CONTROL ROOM O/P
* CD/TAPE INPUTS & OUTPUTS
* BALANCED INPUTS & OUTPUTS
* BUS ASSIGN SWITCH
* MONITOR SEND

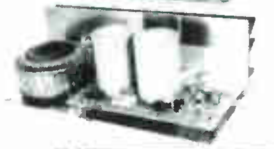
PRICES SPM1202 4MONO MIC/LINE.4STEREO INPUTS £299.00 FREE
SPM1602 8MONO MIC/LINE.4STEREO INPUTS £399.00 UK P&P

OMP MOS FET POWER AMPLIFIER MODULES
SUPPLIED READY BUILT AND TESTED

These modules now enjoy a world wide reputation for quality, reliability and performance at a realistic price. Four models are available to suit the needs of the professional and hobby market i.e. Industry, Leisure, Instrumental and Hi Fi etc. When comparing prices NOTE that all models include toroidal power supply, integral heat sink, glass fibre P.C.B. and drive circuits to power a compatible Vu meter. All models are open and short circuit proof

THOUSANDS OF MODULES PURCHASED BY PROFESSIONAL USERS

OMP/MF 100 Mos-Fet Output power 110 watts R.M.S into 4 ohms, frequency response 1Hz 100KHz 3dB, Damping Factor >300, Slew Rate 45V/uS, T.H.D typical 0.002%, Input Sensitivity 500mV, S.N.R. 110dB Size 300 x 123 x 60mm.
PRICE:- £42.85 + £4.00 P&P



OMP/MF 200 Mos-Fet Output power 200 watts R.M.S into 4 ohms, frequency response 1Hz 100KHz 3dB, Damping Factor >300, Slew Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. 110dB. Size 300 x 155 x 100mm.
PRICE:- £66.35 + £4.00 P&P

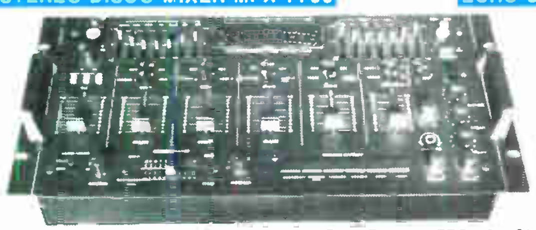
OMP/MF 300 Mos-Fet Output power 300 watts R.M.S. into 4 ohms, frequency response 1Hz 100KHz 3dB, Damping Factor >300, Slew Rate 60V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. 110dB. Size 330 x 175 x 100mm.
PRICE:- £83.75 + £5.00 P&P

OMP/MF 450 Mos-Fet Output power 450 watts R.M.S. into 4 ohms, frequency response 1Hz 100KHz 3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. 110dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 385 x 210 x 105mm.
PRICE:- £135.85 +£6.00 P&P

OMP/MF 1000 Mos-Fet Output power 1000 watts R.M.S. into 2 ohms, 725 watts R.M.S. into 4 ohms frequency response 1Hz 100KHz 3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R. 110dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti Thump Delay. Size 422 x 300 x 125mm.
PRICE:- £261.00 + £12.00 P&P

NOTE: MOS FET MODULES ARE AVAILABLE IN TWO VERSIONS: STANDARD INPUT SENS 500mV, BAND WIDTH 100KHz. OR PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) INPUT SENS 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC

STEREO DISCO MIXER MPX-7700 — ECHO & SOUND EFFECTS



* 4 STEREO INPUT CHANNELS
* 2 DJ MIC INPUT CHANNELS
* 2X7 BAND GRAPHIC EQUALISERS
* HEADPHONE MONITOR WITH PFL
* ASSIGNABLE CROSSFADE
* DIGITAL ECHO

STEREO DISCO MIXER WITH:- *2X7 GRAPHIC EQUALISERS *2 MONO MIC INPUTS *DJ MIC WITH FADER, TALKOVER AND VOICE CHANGER *4 STEREO CHANNELS WITH INDIVIDUAL FADERS AND ASSIGNABLE CROSSFADE *CHANNELS SWITCHABLE, TURNTABLE (MAG CARTRIDGE), CD, LINE, TAPE, ETC *ECHO WITH BALANCE, REPEAT AND DELAY *HEADPHONE MONITOR WITH PREFADE LISTEN *CHOICE OF 6 SOUND EFFECTS *STEREO MONO SWITCH *2 X LED VU METERS *MASTER FADER *OUTPUT 775mV *SIZE: 482X240X115mm *POWER 230V AC 50/60Hz **PRICE:- £169.00 + £5.00 P&P**

RADIO MICROPHONE CYBERWAVE FMM 1000

* IDEAL FOR: LIVE BANDS, PUBLIC ADDRESS & KARAOKE ETC.
* ON/STANDBY/OFF SWITCH MOUNTED ON MIC BARREL FOR EASE OF USE
* 100 HOURS BATTERY RUNNING TIME. 1 PP3 (NOT SUPPLIED)
* SINGLE CHANNEL RF MICROPHONE 174.23 OR 174.56MHz
* MAINS ADAPTOR FOR RECEIVER SUPPLIED * FM LOCK INDICATOR & VOL CONTROL ON RECEIVER. **PRICE:- £119.99 FREE UK P&P**

Access

DELIVERY CHARGES. PLEASE INCLUDE AS ABOVE,TO A MAXIMUM AMOUNT £30.00. OFFICIAL ORDERS FROM SCHOOL,COLLEGES, GOVT. BODIES,PLCs ETC. PRICES INCLUSIVE OF V.A.T. SALES COUNTER.CREDIT CARD ODERS ACCEPTED BY POST PHONE OR FAX

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