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MARCH 1995

INCORPORATING ELECTRONICS MONTHLY

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Free PROBABLY THE MOST USEFUL PCB EVER! *Worth £3*

Build any of these projects on the FREE pcb:

SOUND ACTIVATED SWITCH

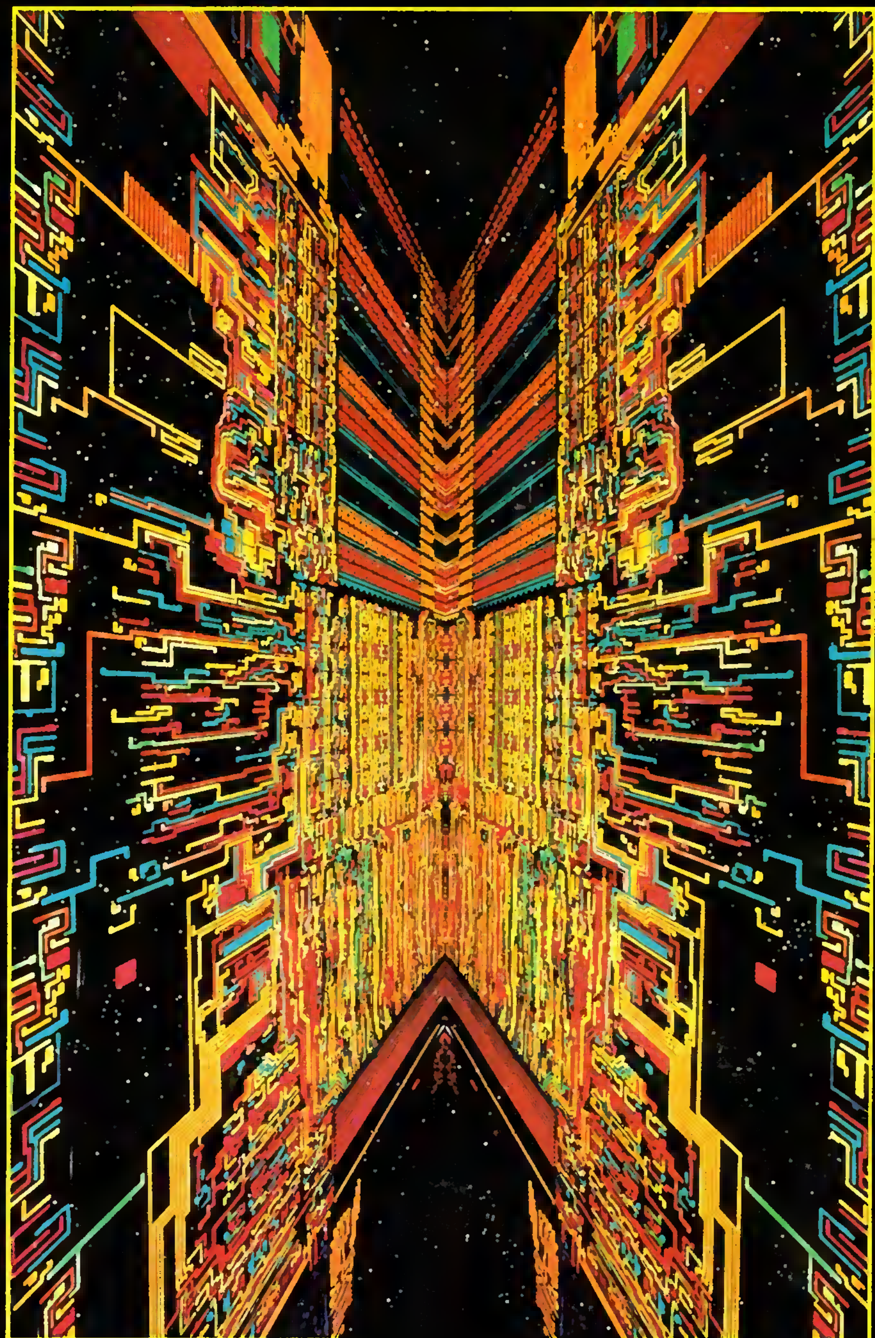
AUDIO AMPLIFIER

LIGHT BEAM COMMUNICATOR

Plus three more projects next month – details inside

Also UNDERSTANDING PIC MICROCONTROLLERS

Learn how to use these inexpensive, versatile chips



THE No. 1 INDEPENDENT MAGAZINE FOR ELECTRONICS, TECHNOLOGY & COMPUTER PROJECTS

03

9 770262 361065

A4 DTP MONITORS Brand new, 300 DPI. Complete with diagram but no interface details.(so you will have to work it out!) Bargain at just £12.99 each!!!!

OPD MONITORS 9" mono monitor, fully cased complete with rasterboard, switched mode psu etc. CGA/TTL input (15way D), IEC mains. £15.99 ref DEC23. Price including kit to convert to composite monitor for CCTV use etc is £21.99 ref DEC24

LOW COST LASER NIGHT SIGHT just £79!!! Cheaper version of our £245 Cyclops model, works ok in low light levels or in complete darkness with the built in Laser. ref 95/79 (please allow about 1 month delivery for these due to import difficulties)

PC CONTROLLED 4 CHANNEL TIMER Control (on/off times etc) up to 4 items (8A 240v each) with this kit. Complete with Software, relays, PCB etc. £25.99 Ref 95/26

LOW COST RADAR DETECTOR Built and tested pocket radar detector, ideal for picking up speed traps etc. Why pay £70 or more? ours is just £24.99 ref 95/25.

COMPLETE PC 300 WATT UPS SYSTEM Top of the range UPS system providing protection for your computer system and valuable software against mains power fluctuations and cuts New and boxed, UK made Provides up to 5 mins running time in the event of complete power failure to allow you to run your system down correctly. **SALE PRICE just £119.00.**

RACAL MODEM BONANZA! 1 Racal MPS1223 1200/75 modem, telephone lead, mains lead, manual and comms software, the cheapest way onto the net! all this for just £13 ref DEC13

HOW LOW ARE YOUR FLOPPIES? 3.5" (1.44) unbranded. We have sold 100,000+ so ok! Pack of 50 £24.99 ref DEC16

BRITISH TELECOMM MULTIMETERS SA9083 These are 'returns' so they may have faults but look ok. Complete with new leads and leather case. Price for two meters & 1 case is £10 ref DEC89.

5mw LASER POINTER. Supplied in kit form, complete with power adjuster, 1-5mw, and beam divergence adjuster. Runs on 2 AAA batteries. Produces thin red beam ideal for levels, gun sights, experiments etc. Cheapest in the UK! just £39.95 ref DEC49

SHOP WOBBLERS! Small assemblies designed to take D size batteries and 'wobble' cardboard model signs about in shop windows! £3.99 Ref SEP4P2

RADIO PAGERS Brand new, UK made pocket pagers clearance price is just £4.99 each 100x40x15mm packed with bits! Ref SEP5.

BULL TENS UNIT Fully built and tested TENS (Transcutaneous Electrical Nerve Stimulation) unit, complete with electrodes and full instructions. TENS is used for the relief of pain etc in up to 70% of sufferers. Drug free pain relief, safe and easy to use, can be used in conjunction with analgesics etc. £49 Ref TEN/1

STEREO MICROSCOPE 155X195MM, up to 600mm high, so items up to 10" will fit under lense. Rack and pinion focusing, 6 interchangeable rotating object lenses, interchangeable eye pieces, +scaled eyepiece for accurate measuring etc. Powerful low voltage illumination system with green filter and variable intensity, 100mm black/white + ground glass stage plate, 70mm swivel mirror, adjustable eyepieces (both focus and width). Magnification range 4.6-100.8, field of view 39-2.4mm). Price is £299 for complete setup. Ref 95/300.

3D 35MM CAMERA SYSTEM Complete kit to convert a standard 35mm camera into a 3D version!, enable you to take 3D colour slides with your own camera! Kit contains a prism assembly for the front of your existing lense, a sample 3D slide, a 3D slide viewer and 2 different lense mounts 49mm and 52mm, (other sizes available from photo shops at about £3 ea) all you need is standard slide film. Price for the complete kit is £29.99 ref 95/30

COMPUTER RS232 TERMINALS. (LIBERTY) Excellent quality modem units,(like wyse 50,s) 2xRS232, 20 function keys, 50 thro to 38,400 baud, menu driven port, screen, cursor, and keyboard setup menus (18 menu's). £29 REF NOV4

OMRON TEMPERATURE CONTROLLERS (E5C2). Brand new controllers, adjustable from -50 deg C to +1,200 deg C using graduated dial, 2% accuracy, thermocouple input, long life relay output .3A 240v o/p contacts. Perfect for exactly controlling a temperature. Normal trade £50+, ours £15. Ref E5C2.

ELECTRIC MOTOR BONANZA! 110x60mm. Brand new precision, cap start (or spin to start), virtually silent and features a moving outer case that acts as a fly wheel. Because of their unusual design we think that 2 of these in a tube with some homemade fan blades could form the basis for a wind tunnel etc. Clearance price is just £4.99 FOR A PAIR! (note-these will have to be wired in series for 240v operation Ref NOV1

MOTOR NO 2 BARGAIN 110x90mm. Similar to the above motor but more suitable for mounting vertically (ie turntable etc). Again you will have to wire 2 in series for 240v use. Bargain price is just £4.99 FOR A PAIR!! Ref NOV3.

OMRON ELECTRONIC INTERVAL TIMERS.
Minature adjustable timers, 4 pole c/o output 3A 240v,

HY1230S, 12vDC adjustable from 0-30 secs. £9.99
HY1210M, 12vDC adjustable from 0-10 mins. £9.99
HY1260M, 12vDC adjustable from 0-60 mins. £9.99
HY2460M, 24vAC adjustable from 0-60 mins. £5.99
HY241S, 24vAC adjustable from 0-1 secs. £5.99
HY2460S, 24vAC adjustable from 0-60 secs, £5.99
HY243H, 24vAC adjustable from 0-3 hours. £8.99
HY2401S, 240v adjustable from 0-1 secs. £9.99
HY2405S, 240v adjustable from 0-5 secs. £9.99
HY24060m, 240v adjustable from 0-60 mins. £12.99

PC PAL VGA TO TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware. £49.95. Ideal for laptops or a cheap upgrade.

EMERGENCY LIGHTING UNIT Complete unit with 2 double bulb floodlights, built in charger and auto switch. Fully cased. 6v 8AH lead acid req'd. (secondhand) £4 ref MAG4P11.

GUIDED MISSILE WIRE. 4,200 metre reel of ultra thin 4 core insulated cable, 28lbs breaking strain, less than 1mm thick! Ideal alarms, intercoms, fishing, dolls house's etc. £14.99 ref MAG15P5

300v PANEL METER 70X60X50MM, AC, 90 degree scale. Good quality meter. £5.99 ref MAG 6P14. Ideal for monitoring mains etc

ASTEC SWITCHED MODE PSU BM41012 Gives +5 @ 3.75A, +12@1.5A, -12@ 4A. 230/110, cased, BM41012 £5.99 ref AUG6P3

TORRODIAL TX 30-0-30 480VA. Perfect for Mosfet amplifiers etc. 120mm dia 55mm thick. £18.99 ref APR19

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. £9.99 ea ref AUG10P3.

FLOPPY DISCS DSDD Top quality 5.25" discs, these have been written to once and are unused. Pack of 20 is £4 ref AUG4P1.

ECLATRON FLASH TUBE As used in police car flashing lights etc, full spec supplied, 60-100 flashes a min. £9.99 ref APR10P5.

24v AC 96WATT Cased power supply. New. £13.99 ref APR14.

MILITARY SPEC GEIGER COUNTERS Unused anstraightfrom Her majesty's forces. £50 ref MAG 50P3

STETHOSCOPE Fully functioning stethoscope, ideal for listening to hearts, pipes, motors etc. £6 ref MAR6P6

OUTDOOR SOLAR PATH LIGHT Captures sunlight during the day and automatically switches on a built in lamp at dusk. Complete with sealed lead acid battery etc £19.99 ref MAR20P1

ALARM VERSION Of above unit comes with built in alarm and pir to deter intruders. Good value at just £24.99 ref MAR25P4

CARETAKER VOLUMETRIC Alarm, will cover the whole of the ground floor against forced entry. Includes mains power supply and integral battery backup. Powerful internal sounder, will take external bell if req'd. Retail £150+, ours? £49.99 ref MAR50P1.

TELEPHONE CABLE White 6 core 100m reel complete with a pack of 100 clips. Ideal 'phone extns etc. £7.99 ref MAR8P3.

MICRODRIVE STRIPPER Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. £2 each ref JUN2P3

SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor. Superb value kit just £5.99 REF: MAG6P8

SOLID STATE RELAYS Will switch 25A mains. Input 3.5-26v DC 57x43x21mm with terminal screws £3.99 REF MAG4P10

300DPI A4 DTP MONITOR Brand new but shop soiled so hence bargain price! TTL/ECL inputs, 15" landscape, 1200x1664 pixel complete with circuit diag to help you interface with your projects. JUST £14.99. REF JUN15P2.

BUGGING TAPE RECORDER Small voice activated recorder, uses microcassette complete with headphones £28.99 ref MAR29P1

ULTRAMINI BUG MIC 6mmx3.5mm made by AKG, .5-12v electret condenser. Cost £12 ea. Ours? just four for £9.99 REF MAG10P2

RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back anodised metal case. £79 each REF JUN79

ANSWER PHONES Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1. PSU £5 ref MAG5P12.

SWITCHED MODE PSU ex equip, 60w +5v @5A, -5v@.5A, +12v@2A,-12v@.5A 120/220v cased 245x88x55mm IEC input socket £6.99 REF MAG7P1

PLUG IN PSU 9V 200mA DC £2.99 each REF MAG3P9

PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

ACORN ARCHIMEDES PSU +5v @ 4.4A. on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2

GEIGER COUNTER KIT Low cost professional twin tube, complete with PCB and components. Now only £19 REF AUG19

9v DC POWER SUPPLY Standard plug in type 150ma 9v DC with lead and DC power plug. price for two is £2.99 ref AUG3P4

AA NICAD PACK encapsulated pack of 8 AA nicad batteries (tagged) ex equip, 55x32x32mm. £3 a pack. REF MAG3P11

13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3

PPC MODEM CARDS These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 REF: MAG5P1

INFRA RED REMOTE CONTROLLERS Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects. Our clearance price is just £2 REF: MAG2

200 WATT INVERTER Converts 10-15v DC into either 110v or 240v AC. Fully cased 115x36x156mm, complete with heavy duty power lead, cigar plug, AC outlet socket. Auto overload shutdown, auto short circuit shut down, auto input over voltage shutdown, auto input under voltage shut down (with audible alarm), auto temp control, unit shuts down if overheated and sounds audible alarm. Fused reversed polarity protected. output frequency within 2%, voltage within 10%. A extremely well built unit at an excellent price. Just £64.99 ref AUG65.

UNIVERSAL SPEED CONTROLLER KIT Designed by us for the C5 motor but ok for any 12v motor up to 30A. Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

MAINSCABLE Precut black 2 core 2 metre lengths ideal for repairs, projects etc. 50 metres for £1.99 ref AUG2P7

COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance. Complete kit £8.99.

MINI CYCLOPS PIR 52x62x40mm runs on PP3 battery complete with shrill sounder. Cheap protection at only £5.99 ref MAR6P4

ELECTRIC MOTOR KIT Comprehensive educational kit includes all you need to build an electric motor. £9.99 ref MAR10P4

VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

***FM CORDLESS MICROPHONE** Small hand held unit with a 500' range! 2 transmit power levels. Reqs PP3 9v battery. Tuneable to any FM receiver. Price is £15 REF: MAG15P1

LOW COST WALKIE TALKIES Pair of battery operated units with a range of about 200'. Ideal for garden use or as an educational toy. Price is £8 a pair. REF: MAG 8P1 2 x PP3 req'd

***MINATURE RADIO TRANSCEIVERS** A pair of walkie talkies with a range of up to 2km in open country. Units measure 22x52x155mm. Including cases and earp'ces. 2xPP3 req'd. £30.00 pr REF: MAG30

COMPOSITE VIDEO KIT. Converts composite video into separate H sync, V sync, and video. 12v DC. £8.00 REF: MAG8P2.

LQ3500 PRINTER ASSEMBLIES Made by Amstrad they are entire mechanical printer assemblies including printhead, stepper motors etc etc In fact everything bar the case and electronics, a good stripper! £5 REF: MAG5P3 or 2 for £8 REF: MAG8P3

LED PACK of 100 standard red 5m leds £5 REF MAG5P4

UNIVERSAL PC POWER SUPPLY complete with flyleads, switch, fan etc. Two types available 150w at £15 REF MAG15P2 (23x23x23mm) and 200w at £20 REF: MAG20P3 (23x23x23mm)

***FM TRANSMITTER** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £26 REF: MAG26 Transmits to any FM radio

***FM BUG KIT** New design with PCB embedded coil for extra stability. Works to any FM radio. 9v battery req'd. £5 REF: MAG5P5

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? Price is just £3 REF: MAG3P1

TOP QUALITY SPEAKERS Made for Hi Fi televisions these are 10 watt 4R Jap made 4" round with large shielded magnets. Good quality. £2 each REF: MAG2P4 or 4 for £6 REF: MAG6P2

TWEETERS 2" diameter good quality tweeter 140R (ok with the above speaker) 2 for £2 REF: MAG2P5 or 4 for £3 REF: MAG3P4

AT KEYBOARDS Made by Apricot these quality keyboards need just a small mod to run on any AT, they work perfectly but you will have to put up with 1 or 2 foreign keycaps! Price £6 REF: MAG6P3

HEADPHONES Ex Virgin Atlantic. 8 pairs for £2 **REF: MAG2P8**

DOS PACKS Microsoft version 3.3 or higher complete with all manuals or price just £5 REF: MAG5P8 Worth it just for the very comprehensive manual! 5.25" only

DOS PACK Microsoft version 5 Original software but no manuals hence only £5.99 3.5" only

PIR DETECTOR Made by famous UK alarm manufacturer these are hi spec, long range internal units. 12v operation. Slight marks on case and unboxed (although brand new) £8 REF: MAG8P5

MOBILE CAR PHONE £5.99 Well almost! complete in car phone excluding the box of electronics normally hidden under seat. Can be made to illuminate with 12v also has built in light sensor so display only illuminates when dark. Totally convincing! REF: MAG6P6

ALARM BEACONS Zenon strobe made to mount on an external bell box but could be used for caravans etc. 12v operation. Just connect up and it flashes regularly) £5 REF: MAG5P11

6"X12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. Bargain price just £5.99 ea REF MAG6P12

FIBRE OPTIC CABLE BUMPER PACK 10 metres for £4.99 ref MAG5P13 ideal for experimenters! 30 m for £12.99 ref MAG13P1

HEATSINKS (finned) TO220, designed to mount vertically on a pcb 50x40x25mm you can have a pack of 4 for £1 ref JUN1P11

INFRARED LASER NIGHT SCOPES

Image intensifier complete with hand grip attachment with built in adjustable laser lamp for zero light conditions. Supplied with Pentax 42mm camera mount and normal eye piece. 1.6kg, uses 1xPP3, 3xAA's. Please allow us about 1 month for delivery on this product due to import problems ! £245+Vat

NEW HIGH POWER LASERS

15mW, Helium neon, 3 switchable wavelengths .63um, 1.15um, 3.39um (2 of them are infrared) 500:1 polarizer built in so good for holography. Supplied complete with mains power supply 790x65mm. Use with EXTREME CAUTION AND QUALIFIED GUIDANCE. £349+Vat.

WE BUY SURPLUS STOCK FOR CASH

1995 100 PAGE CATALOGUE NOW AVAILABLE, 45P STAMP OR FREE WITH ORDER.

3FT X 1FT 10WATT SOLAR PANELS 14.5v/700mA £44.95

(PLUS £2.00 SPECIAL PACKAGING CHARGE)

TOP QUALITY **AMORPHOUS SILICON CELLS** HAVE ALMOST A TIMELESS LIFESPAN WITH AN INFINITE NUMBER OF POSSIBLE APPLICATIONS, SOME OF WHICH MAY BE CAR BATTERY CHARGING, FOR USE ON BOATS OR CARAVANS, OR ANYWHERE A PORTABLE 12V SUPPLY IS REQUIRED.

PORTABLE RADIATION DETECTOR WITH NEW COMPUTER INTERFACE.

£59.00

A Hand held personal Gamma and X Ray detector. This unit contains two Geiger Tubes, has a 4 digit LCD display with a Piezo speaker, giving an audio visual indication. The unit detects high energy electromagnetic quanta with an energy from 30K eV to over 1.2M eV and a measuring range of 5-9999 UR/h or 10-99990 Nr/h. Supplied complete with handbook. Ref. **NOV 18.**

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

BULL ELECTRICAL

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

MAIL ORDER TERMS: CASH PO OR CHEQUE WITH ORDER PLUS £3.00 POST PLUS VAT.

PLEASE ALLOW 7 - 10 DAYS FOR DELIVERY

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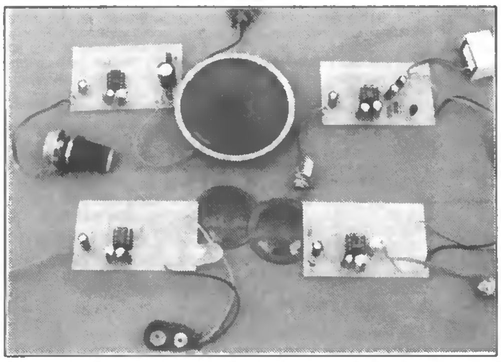
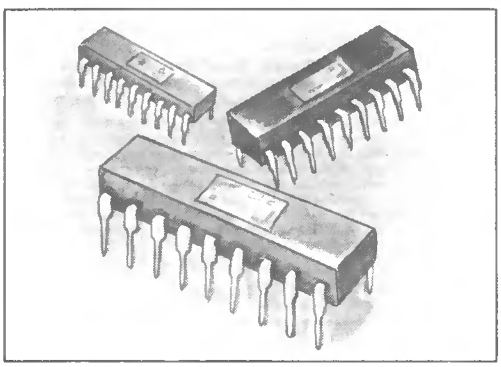




Projects

Series

Features

Our April '95 Issue will be published on Friday, 3 March 1995. See page 171 for details.

Surplus always wanted for cash!

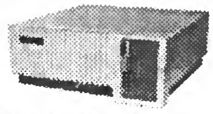
THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

LOW COST PC's - ALL EXPANDABLE - ALL PC COMPATIBLE

SPECIAL BUY AT 286

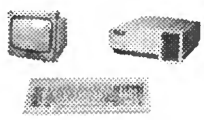


40Mb HD + 3Mb Ram

LIMITED QUANTITY only of these **12Mhz HI GRADE 286** systems Made in the USA to an industrial specification, the system was designed for *total reliability*. The compact case houses the mother-board, PSU and EGA video card with single **5¼" 1.2 Mb** floppy disk **drive & integral 40Mb hard disk drive** to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with **enhanced keyboard, 640k + 2Mb RAM, DOS 4.01 and 90 DAY Full Guarantee.** *Ready to Run !*
Order as HIGRADE 286 ***ONLY £149.00*** (E)
CALL FOR QTY DISCOUNTS

Optional Fitted extras: VGA graphics card	£29.00
1.4Mb 3½" floppy disk drive (instead of 1.2 Mb)	£32.95
NE2000 Ethernet (thick, thin or twisted) network card	£49.00

PC SCOOP COMPLETE COLOUR SYSTEM *ONLY £99.00*



A massive bulk purchase enables us to bring you a **COMPLETE ready to run colour PC system at an unheard of price! The Display Electronics PC99 system** comprises of fully compatible and expandable XT PC with 256k of RAM, 5¼" 360k floppy disk drive, **12" CGA colour monitor**, standard 84 key keyboard, MS DOS and all connecting cables - **just plug in and go !!** Ideal students, schools or anybody wishing to learn the world of PC's on an ultra low budget. **Don't miss this opportunity.** Fully guaranteed for 90 Days.
Order as PC99COL **£99.00** (E)

Optional Fitted extras: 640k RAM	£29.00
2nd floppy drive, specify 5¼" 360k or 3½" 720k	£29.95
Above prices for PC99 offer ONLY.	

SPECIAL OFFER

Computer Controlled Laser Video Disk Player

One of the most **amazing** surplus deals that we ever been able to offer you! The **Philips VP410** LaserVision player, in as new condition, unit features full computer control, Plays standard 12" LaserVision disks with **startling visual and audio quality** in two channel **stereo** or mono. When controlled by a computer, it may also be used as a versatile high quality storage / retrieval medium. It will play back either LaserVision CAV (active play) or CLV (Long Play) discs (which covers most types of commercially available video discs). Some of the many features of this incredible machine are:

RS-232 INTERFACE	**RGB / COMPOSITE VIDEO OUTPUT**
BNC+SCART INTERFACE	**PAL / RGB DECODER**
IR+WIRED REMOTE CONTROL	**FAST RANDOM ACCESS**

SPECIAL PURCHASE Only **£399.00** (F)

FLOPPY DISK DRIVES 3.5"- 8"

5.25" from £22.95 - 3.5" from £24.95

Massive purchases of standard 5.25" and 3.5" drives enables us to present prime product at industry beating low prices! All units (unless stated) are ***BRAND NEW*** or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. **All are IBM-PC compatible** (if 3.5" supported on your PC).

3.5" **Panasonic** JU363/4 720K or equivalent	£24.95(B)
3.5" **Mitsubishi** MF355C-L. 1.4 Meg. Laptops only *	£36.95(B)
3.5" **Mitsubishi** MF355C-D. 1.4 Meg. Non laptop	£29.95(B)
5.25" **Teac** FD-55GFR 1.2 Meg	£29.95(B)
5.25" **BRAND NEW Mitsubishi** MF501B 360K	£22.95(B)
* Data cable included in price.	
Shugart 800/801 8" SS refurbished & tested	£195.00(E)
Shugart 851 8" double sided refurbished & tested	£250.00(E)
Mitsubishi M2894-63 8" double sided *NEW*	£275.00(E)
Mitsubishi M2896-63-02U 8" DS slimline *NEW*	£285.00(E)
Dual 8" drives with 2 mbyte capacity housed in a smart case with built in power supply. Ideal as exterior drives!	£499.00(F)

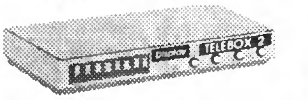
HARD DISK DRIVES

End of line purchase scoop! Brand new **NEC D2246** 8" 85 Mbyte of hard disk storage! Full **Industry standard SMD interface**. Ultra hi speed data transfer and access time, replaces Fujitsu equivalent model, complete with manual. Only £299.00(E)

3.5" **FUJI** FK-309-26 20mb MFM I/F RFE	£59.95(C)
3.5" **CONNER** CP3024 20 mb IDE I/F (or equiv)RFE	£69.95(C)
3.5" **CONNER** CP3044 40mb IDE I/F (or equiv.)RFE	£89.00(C)
3.5" **RODIME** RO3057S 45mb SCSI I/F (Mac & Acorn)	£99.00(C)
5.25" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	£49.95(C)
5.25" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	£69.95(C)
5.25" **CDC** 94205-51 40mb HH MFM I/F RFE tested	£69.95(C)
8" **FUJITSU** M2322K 160Mb SMD I/F RFE tested	£195.00(E)
Hard disc controllers for MFM , IDE, SCSI, RLL etc. **from £16.95**	

THE AMAZING TELEBOX

Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND & VIDEO TUNER!

The **TELEBOX** consists of an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as **MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD** etc. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers* (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. **TELEBOX MB** covers virtually all television frequencies VHF and UHF **including the HYPERBAND as used by most cable TV operators.** A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard.

TELEBOX ST for composite video input type monitors	£34.95
TELEBOX STL as ST but with integral speaker	£37.50
TELEBOX MB Multiband VHF-UHF-Cable- Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6mhz sound specification.
*For cable / hyperband reception Telebox MB should be connected to cable type service. Shipping code on all Teleboxes is (B)

FANS & BLOWERS

MITSUBISHI MMF-D6D12DL 60 x 25 mm 12v DC	£4.95	10 / £42
MITSUBISHI MMF-09B12DH 92 x 25 mm 12v DC	£5.95	10 / £53
PANCAKE 12-3.5 92 x 18 mm 12v DC	£7.95	10 / £69
EX-EQUIP 120 x 38mm AC fans - tested specify 110 or 240 v	£6.95	
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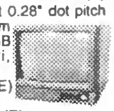

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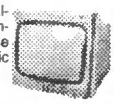

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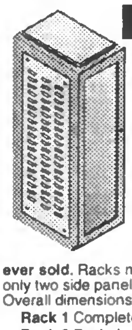
19" RACK CABINETS



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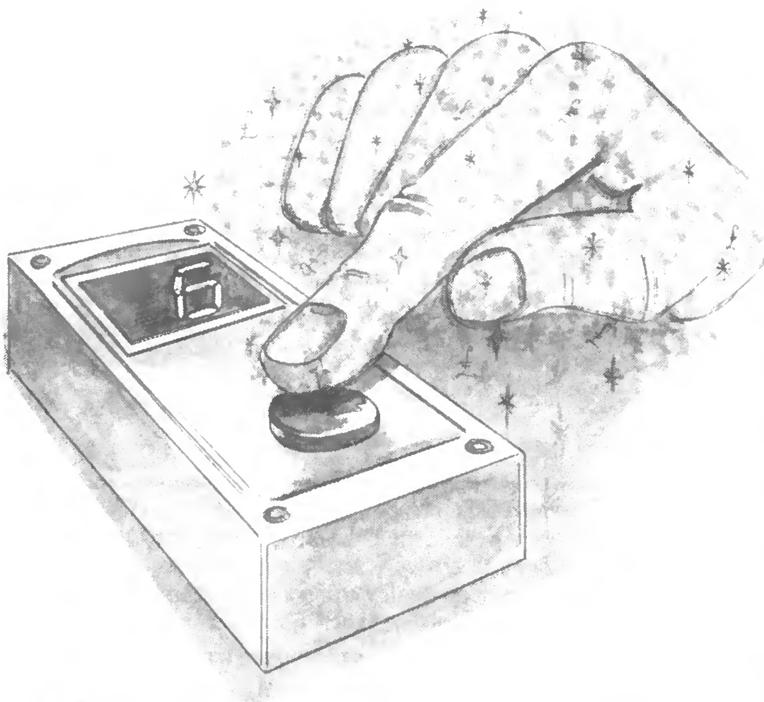
NATIONAL LOTTERY PREDICTOR



We know that if you win the lottery it will not change your life and you will keep reading **EPE**! *So it is without hesitation that we bring you the* **National Lottery Predictor.** *It employs a PIC Microcontroller to produce numbers for your lottery entry.*

This high tech. piece of equipment comes with a cast iron guarantee that it will not enhance your chances of winning! It also provides an example of PIC programming that will reinforce the lessons in this month's **Understanding PIC Microcontrollers** *article.*

Plus *Three more projects that can be built on this months Free P.C.B. These are: a* **Continuity Tester,** *a* **Timer** *and a* **Light Activated Switch.**

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4.7	–	–	£0.05	£0.08	–
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22	£0.05	£0.05	£0.09	–	–
47	£0.06	£0.06	£0.11	–	–
100	£0.06	£0.09	£0.11	–	–
220	£0.09	£0.12	£0.31	–	–
470	£0.15	£0.19	£0.57	–	–
1000	£0.22	£0.29	–	–	–
2200	£0.37	£0.57	–	–	–
4700	–	£1.11	–	–	–

ELECTROLYTIC AXIAL CAPACITORS

µF	16V	25V	63V	100V	450V
0.47	–	–	–	£0.15	–
1.0	–	–	£0.10	£0.10	£0.19
2.2	–	–	£0.10	£0.10	£0.22
4.7	–	£0.09	£0.10	£0.10	£0.34
10	–	£0.12	£0.12	£0.12	£0.48
22	–	£0.09	£0.13	£0.17	£1.06
47	£0.10	£0.11	£0.16	£0.20	–
100	£0.10	£0.13	£0.21	–	–
220	£0.13	£0.18	£0.42	–	–
470	£0.21	£0.24	£0.69	–	–
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FREE P.C.B.

It is many years since we last gave away any form of circuit board with the magazine and in the past these have been "universal" wiring boards, e.g. stripboard or plain perforated boards. It has not been our policy to give away a p.c.b. which is only suitable for one project as we believe this limits its value to a large proportion of readers.

This issue carries three projects which use the cover mounted Free p.c.b., next month there will be another three – see page 171 for details – and in the Autumn we will publish a further six projects and give away the same p.c.b. again. So, if you are not interested in any of the projects this time around, save your p.c.b. for the Autumn. Alternatively, you will find the board can be used to build almost any circuit which is designed around a single op.amp – things like the Guitar Treble Booster in our *Ingenuity Unlimited* section should go on the Free p.c.b.

MORE!

Because the board is so adaptable it will also be very useful to those who are building projects for various examinations, particularly for GCSE Electronics or Technology students. We can supply extra boards if you need them – see page 247 – alternatively, you can get another one by buying another issue; it will then cost £2.25 instead of £3. If you do this can we ask that you pass the spare issue to a friend or school, etc., so that someone can make use of it. The same thing applies to the p.c.b., if you don't want it why not pass it on to someone who might be able to put it to good use?

COVER PRICE

As you may have noticed the cover price of this issue has been increased by 10p. Let me assure you that this has not been done to cover the cost of the gift. Unfortunately we are faced with massive paper price increases over which we have absolutely no control. We have no wish to reduce the number of pages we publish and have, therefore, been forced to increase the cover price. Note that the price of annual subscription has presently been held at £24 (UK) – see below.

We will continue to make sure that our pages are packed with information and that each issue covers a wide range of subjects and projects, thus providing what we believe to be the best value for money publication for the electronics enthusiast. The rise in the price of paper is due to a worldwide shortage and this is now starting to affect *all* publishers.

Mike Kenward

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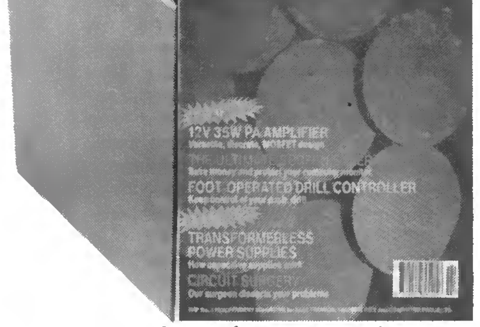

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

COMPONENT SUPPLIES

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We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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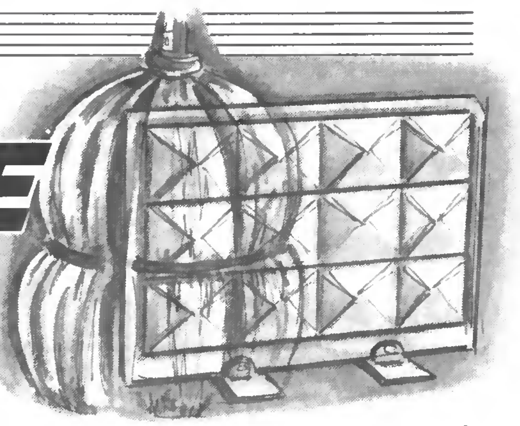
Constructional Project



MULTI-PURPOSE THERMOSTAT

ALAN WINSTANLEY

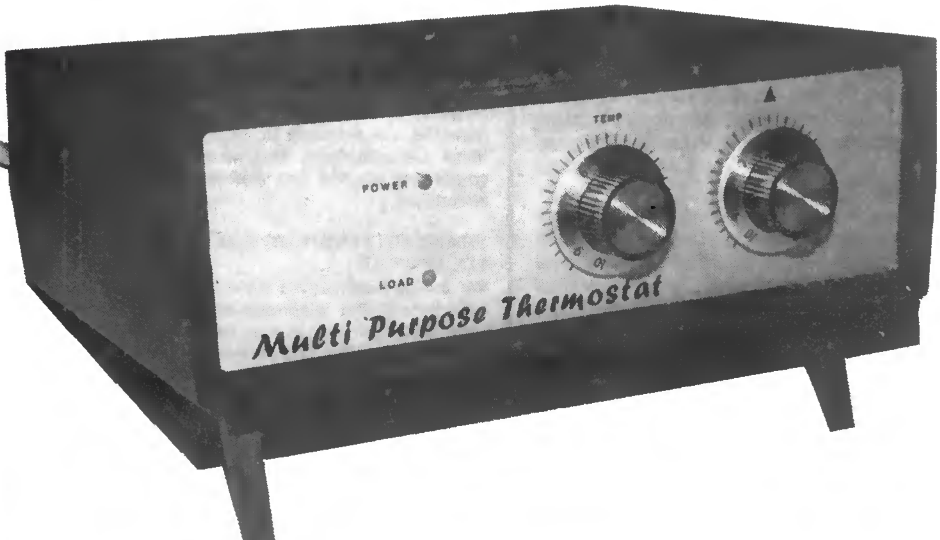
An adaptable design for precise control of electric heaters. Useful in domestic, horticultural, photographic, aquatic applications and more. Full 13A 250V rating.

TEMPERATURE control is just one area where electronics excels over its electromechanical counterparts. Mechanical bi-metallic strips are often used in heating systems not requiring a particularly fine degree of temperature control, for instance in tropical aquaria an immersible bi-metallic strip thermostat is the usual means of sensing the water temperature since it is cheap to implement and is reasonably reliable. The initial setting up, however, is often a matter of trial and error because these devices are generally completely uncalibrated and the only way to know whether you've got it right is to try it and see – and hope that the fish agree!

In other domestic applications a bi-metallic strip may find its way into a typical central heating thermostat, and refrigerator or electric fire temperature controls. In the case of a fan or convector heater thermostat, for instance, the control may be calibrated with just an arbitrary scale and secondly, there is almost always a proportion of "overshoot" where the temperature has to reach a peak before the bi-metallic strip will switch off the heater.

Then the temperature may have to fall to an undesirably low level before the heater switches in again. Therefore the control might well be set with the minimum required temperature in mind, paying scant attention to the unnecessary temperature peaks and surges which may occur before the bi-metallic thermostat turns the fire off. Hence, you either freeze or fry!

Another problem with electromechanical thermostats is their tendency to "waver" at the desired setting, resulting in a second or two of buzzing and contact arcing as the bi-metallic strip trips over. Sometimes a magnet is included on the strip to help guard against this, to accelerate the movement of the contacts when they switch over.



APPLICATIONS

It's a simple matter to overcome all of these disadvantages with an electronic thermostat such as the one to be described here. This general purpose unit can be adapted to suit the reader's specific requirements. It was designed to be safe and reliable to construct, whilst keeping a keen eye on cost.

It has a full 13A 250V rating which enables it to control a load of up to 3kW (3,000 watts).

By fitting a temperature sensor of suitable design, it can be used to detect both air and liquid ambient temperatures. This makes it useful for:

- General domestic applications (electric fires, space heating etc.).
- Horticultural use (greenhouse heating, propagator and nursery bench temperature control).
- Photography (dish warming, developer process control).
- Printed circuit board (p.c.b.) production – etchant temperature control.
- Tropical aquaria – fishtank heating.
- Homebrewing – fermentation control.

An extra feature of this design is the inclusion of an optional "hysteresis" control. This permits the user to adjust the difference between the high and low temperature switching points, which then allows further control over the temperature accuracy.

This means that the operating band of the thermostat can be narrowed or widened somewhat, which may help to compensate for the thermal "inertia" of the heating system: a larger inertia means more stored warmth in the heater, producing a temperature overshoot even after the heater has switched off. The hysteresis control feature could, however, be omitted if necessary.

CIRCUIT DESCRIPTION

The complete circuit diagram of the Multi-Purpose Thermostat is shown in Fig. 1. This is a straightforward design centred around an operational amplifier i.c. IC3, configured as a Schmitt trigger. It is powered from a mains-derived regulated 12V d.c. rail. A high-stability adjustable shunt regulator (IC2) is set to provide an accurate reference voltage for the op.amp, which compares a temperature-dependent signal against this reference and operates a heavy duty relay to turn the mains load on and off accordingly.

A thermally-sensitive resistor or thermistor R9 forms the temperature sensor for this unit. In order to economise, a readily available bead thermistor was selected rather than a glass bead type, which although more accurate is both more expensive and quite delicate to handle.

The thermistor has a negative temperature co-efficient (n.t.c.) which implies that its resistance falls when its temperature increases. It's usual to specify the thermistor resistance at a given temperature: a 4k7 at 25°C bead is used.

This is located remotely from the main thermostat and is connected by a 3·5mm jack plug and socket, PL1/SK2. Capacitor C4 helps reduce any noise picked up on the connecting cable. By suitably mounting the thermistor, it can be adapted to sense either liquids or ambient air temperatures, see later.

Along with Temperature control potentiometer VR1 and resistor R5, the thermistor forms a potential divider which is connected to the non-inverting (+) input, pin 3, of the op.amp IC3, which has a high impedance MOSFET input. When the thermistor's temperature increases, its resistance falls and so the non-inverting input voltage falls also.

The op.amp amplifies the difference between the voltages of the non-inverting and inverting input (pins 3 and 2 respectively). If the + input is greater than the – input then the output swings "high". Conversely, should the – input be greater than the + input then the output will move negatively "low".

Because a single rail supply is used here rather than a split supply, the output pin can only switch either to the positive rail or to 0V, depending on the polarity of the two input voltages. In this mode the op.amp is actually operating as a comparator.

REFERENCE VOLTAGE

The inverting (–) input is firmly clamped at a fixed reference voltage. This is set for precisely 6V d.c. (half the rail voltage) and is generated by IC2, a TL431 adjustable shunt regulator.

This is quite a handy device to become acquainted with, and its basic principle of operation is shown in Fig. 2. The device

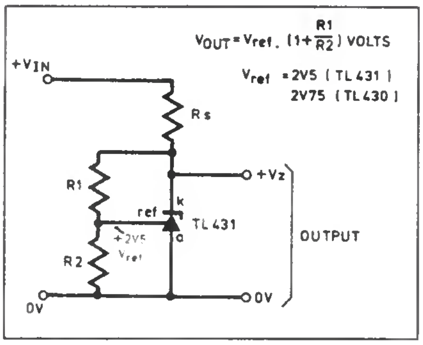


Fig. 2. Operation of the high stability TL431 adjustable shunt regulator.

has three pins, namely anode (a), cathode (k) and a third "reference" (ref) terminal. The TL431 has its own temperature-compensated "bandgap" reference which is highly stable and contributes to the great accuracy of the component – important in a thermostat application where the reference voltage should not drift unduly with temperature.

The TL431 reference voltage is 2·5V which appears between the anode and reference pins as shown. A potential divider consisting of resistors R1 and R2 is used to determine the output voltage of the device. It's preferable to allow a 1mA current to flow through the potential divider and the designer allowed a further 5mA forward current to flow through the TL431 itself.

The formula is:

$$V_z = V_{ref}\left[1 + \frac{R1}{R2}\right]$$

To generate a 6V "Zener" output voltage, a little equation solving produced values of 4k7 and 3k3 for R1 and R2 respectively. Happily, these values are readily available in the E12 series thus no special precision resistors are needed.

A series current limiting resistor Rs is also needed which is calculated in the same way as that for an ordinary Zener diode. If we assume a supply rail of 12V d.c., and a Zener output of 6V, then with a total of 6mA (1mA + 5mA) flowing through the series resistor, a 1k value is fine.

DYNAMIC RESISTANCE

This reference circuit has several key advantages over an ordinary Zener diode. Apart from the fact that the output voltage can be controlled precisely with external resistors, it has a much greater temperature stability (typically 50 parts per million per degree C.) and also has a much lower internal resistance.

The "dynamic" resistance of a standard Zener diode could be some 40 ohms or more, which produces an unwanted error voltage when the Zener current increases (the resistance causing an undesirable "internal" voltage drop within the Zener diode). Even the dynamic or "slope" resistance of a 1N821 temperature compensated Zener is 15 ohms, for instance. The dynamic resistance of the TL431 is only 0·2 ohms, so the reference output is largely independent of the current flowing through the component.

The result is a highly stable reference voltage which is used to clamp the inverting input of the op.amp IC3 at 6V. Hence, whenever the voltage at pin 3 is greater than 6V, the op.amp output switches high. This turns on the transistor switch TR1 and completes the circuit to the power relay RLA, also the l.e.d. D7 will illuminate whenever the relay is switched on. Diode D6, as usual, guards against back e.m.f. from the coil when the relay switches out.

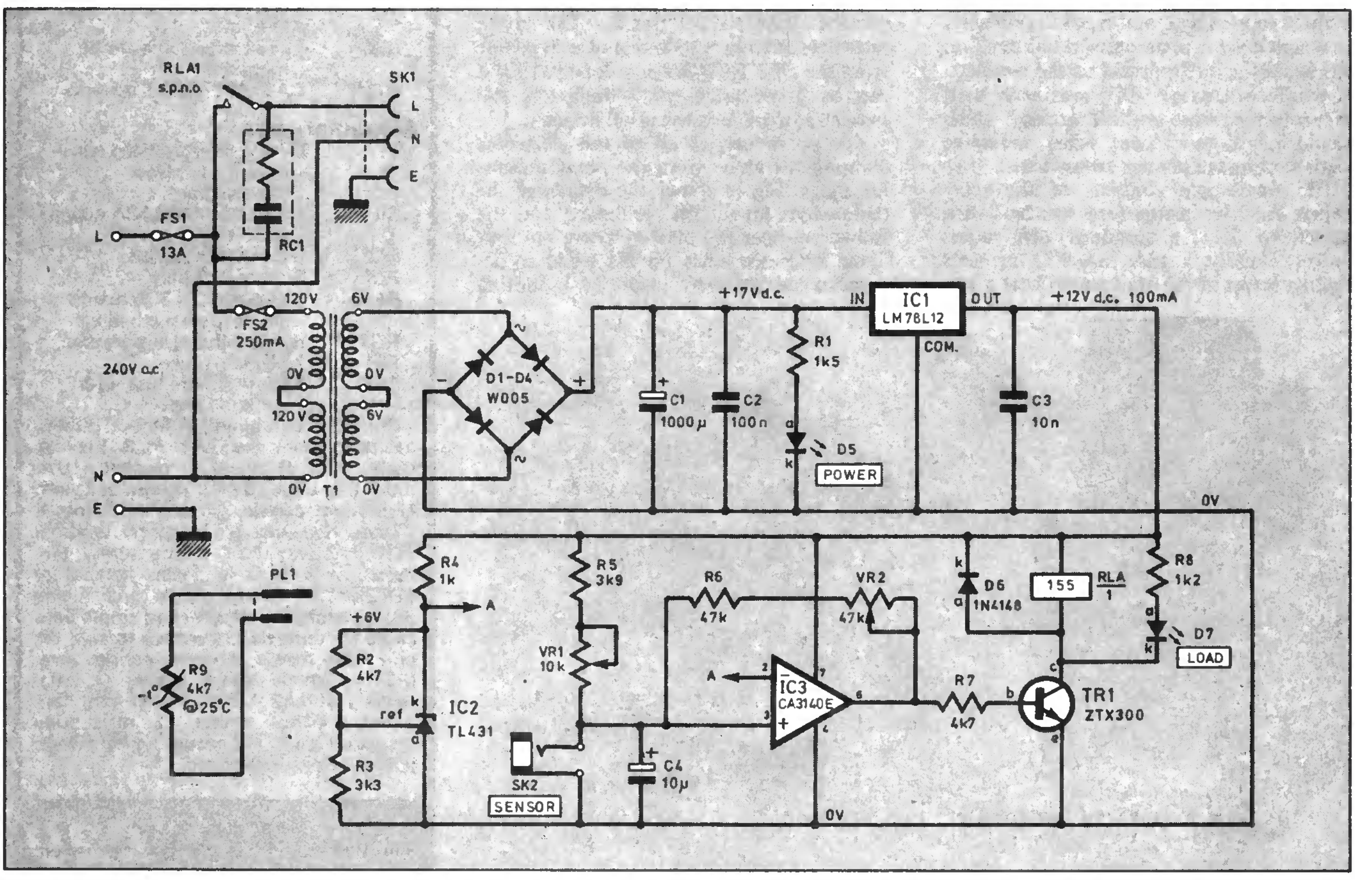


Fig. 1. Circuit diagram for the Multi-Purpose Thermostat.

HYSTERESIS

A potential drawback with this arrangement is that it is very sensitive, and the op.amp will amplify the tiniest difference between its two inputs and switch the output high or low. With an input signal which is relatively slow-moving, there are often occasions when the circuit may seem to "jitter" just on the switching point. This can be very undesirable when switching mains loads, and can be overcome by converting the circuit into a clean "snap action" Schmitt trigger.

To do this, a feedback arrangement is introduced with VR2 and R6. This effectively causes the switching point to have two levels – a higher and a lower set point with a small difference in between called the "hysteresis."

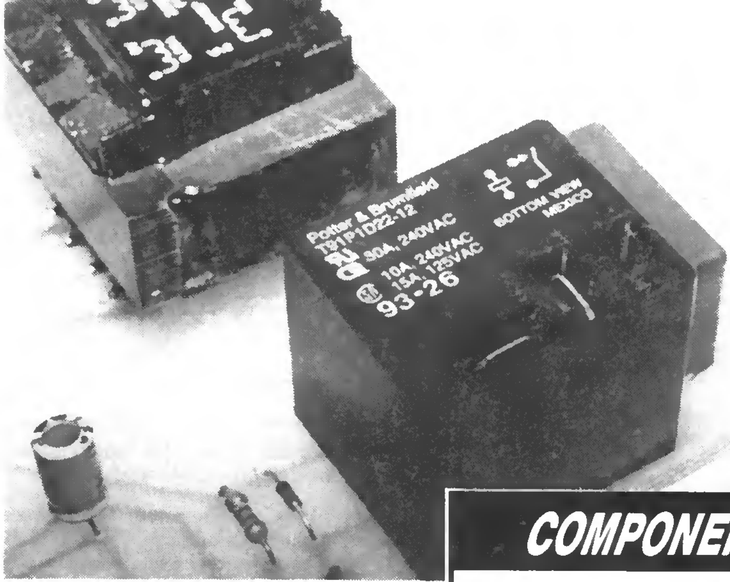
Now the circuit is no longer able to "jitter" at the set point: instead, the temperature must reach a particular level to switch the heater off, and then it must fall to a lesser temperature before the heater can switch on again. By making this hysteresis variable, it's possible to adjust the operating characteristics of the thermostat so that you can compensate for any temperature overshoots. This feature could be left out if desired, see later.

Turning to the power supply section, mains voltage is stepped down by transformer T1 to 12V a.c. which is then rectified and smoothed by bridge rectifier D1-D4 and capacitor C1, to produce approximately 17V d.c. This is fed to a standard three terminal 12V 100mA fixed voltage regulator IC1 and forms the power rail for the electronics. An l.e.d. D5 placed before the regulator, lights as a "Power On" indicator.

RELAY

The specified relay has an important constructional feature in that it is very heavy duty (rated up to 30A) but is extremely economical, and most importantly although it is p.c.b. mounted it has push-on terminals for direct access to the contacts. A snubber network RC1 was also used to protect against contact arcing, which would be more evident when inductive loads such as fan heaters are switched.

The single-pole contacts of the relay switch the Live mains feed which is then passed to SK1, a standard 13A mains socket. Finally, a 13A fuse FS1 protects against faults in the load and FS2 is a low current quick blow fuse to protect against transformer faults etc. No mains on/off switch was included but guidance notes are given at the end should you wish to fit one.



Close-up of the power relay showing the push-on "spade" terminals accessible from the top.

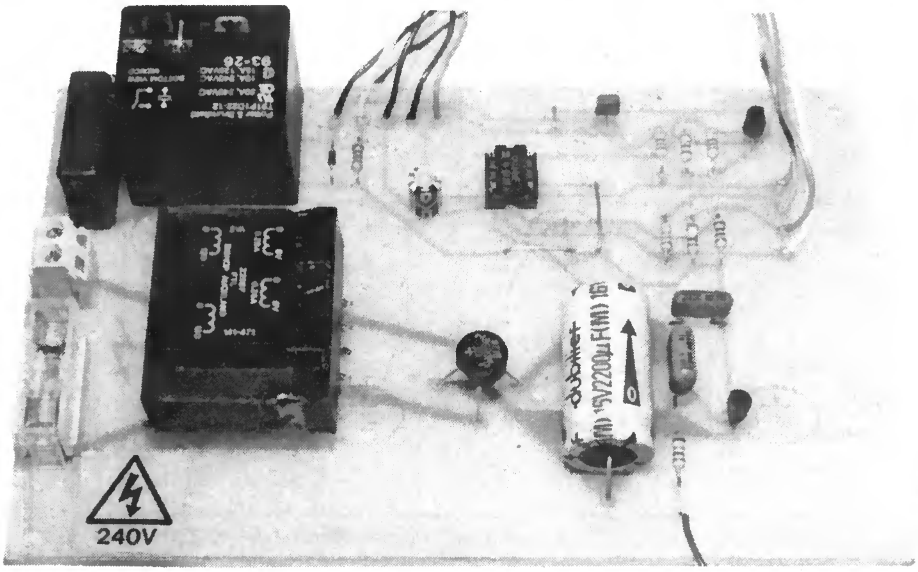
CONSTRUCTION

This project contains a mixture of both mains a.c. and low d.c. voltages. The unit was designed to ensure that construction was kept as simple and as safe as possible. If you are an inexperienced constructor then you must follow the details closely or seek help from a qualified person.

Do not substitute components but use those recommended in the Components List and you should have no difficulty in producing a safe and trouble free project. The use of an ELCB/RCD is strongly recommended during the initial testing and calibration stages.

In order to simplify construction, the circuit was constructed on a single-sided printed circuit board (p.c.b.). The board measures 160mm × 100mm and is available from the *EPE PCB Service*, code 931, or it can be home-made using the p.c.b. foil pattern as a guide in the usual manner.

The p.c.b. carries all of the electronic components apart from the panel mounting parts. Fig. 3 shows the details of the component layout on the board and the full size copper foil master. There are four 3mm clearance holes on the p.c.b. to accommodate the fully insulated mounting



Layout of components on the completed printed circuit board.

COMPONENTS

See SHOP TALK Page

Resistors

R1	1k5
R2, R7	4k7 (2 off)
R3	3k3
R4	1k
R5	3k9
R6	47k
R8	1k2
R9	bead thermistor, 4k7 at 25°C

All 0·25W 5% carbon film, except R9

Potentiometers

VR1	10k rotary carbon, lin. 0·4W
VR2	47k rotary carbon, lin. 0·4W

Capacitors

C1	1000µ axial elect. 25V
C2	100n polyester
C3	10n polyester
C4	10µ radial elect. 16V

Semiconductors

D1-D4	W005 50V PIV 1A bridge rectifier
D5	3mm red l.e.d.
D6	1N4148 signal diode
D7	3mm green l.e.d.
TR1	ZTX300 *npn* transistor
IC1	LM78L12ACZ, 12V 100mA regulator
IC2	TL431 adjustable shunt regulator
IC3	CA3140E CMOS op.amp

Miscellaneous

T1	0V-6V, 0V-6V 3VA p.c.b. mounting mains transformer
SK1	panel mounting 13A mains socket
SK2	3·5mm jack socket
PL1	3·5mm jack plug
RLA	155 ohm 12V 30A mains single-pole p.c.b relay
RC1	mains contact suppressor
FS1	13A mains fuse
FS2	250mA 20mm fuse with p.c.b. holder

Printed circuit board, 100mmx160mm, available from the *EPE PCB Service*, code 931; 8-pin d.i.l. socket; l.e.d. mounting clips (2 off); plastic box with aluminium panels 231mm x 181mm x 77mm; two-way p.c.b. screw terminal (TB1); 3-way 13A mains screw terminal, with built-in 1¼in. fuseholder (TB2); 13A 3-core cable and mains plug, materials and screened single core cable for temperature sensor to suit, 6A and 13A mains interconnecting wire; 0·25in. female crimp blades (2 off); cable restraint; 10mm crimp ring terminal; control knobs (2 off); fully insulated p.c.b. M3 mounting hardware; solder, hook-up wire etc.

Approx cost guidance only **£29** excluding case

MULTI-PURPOSE THERMOSTAT

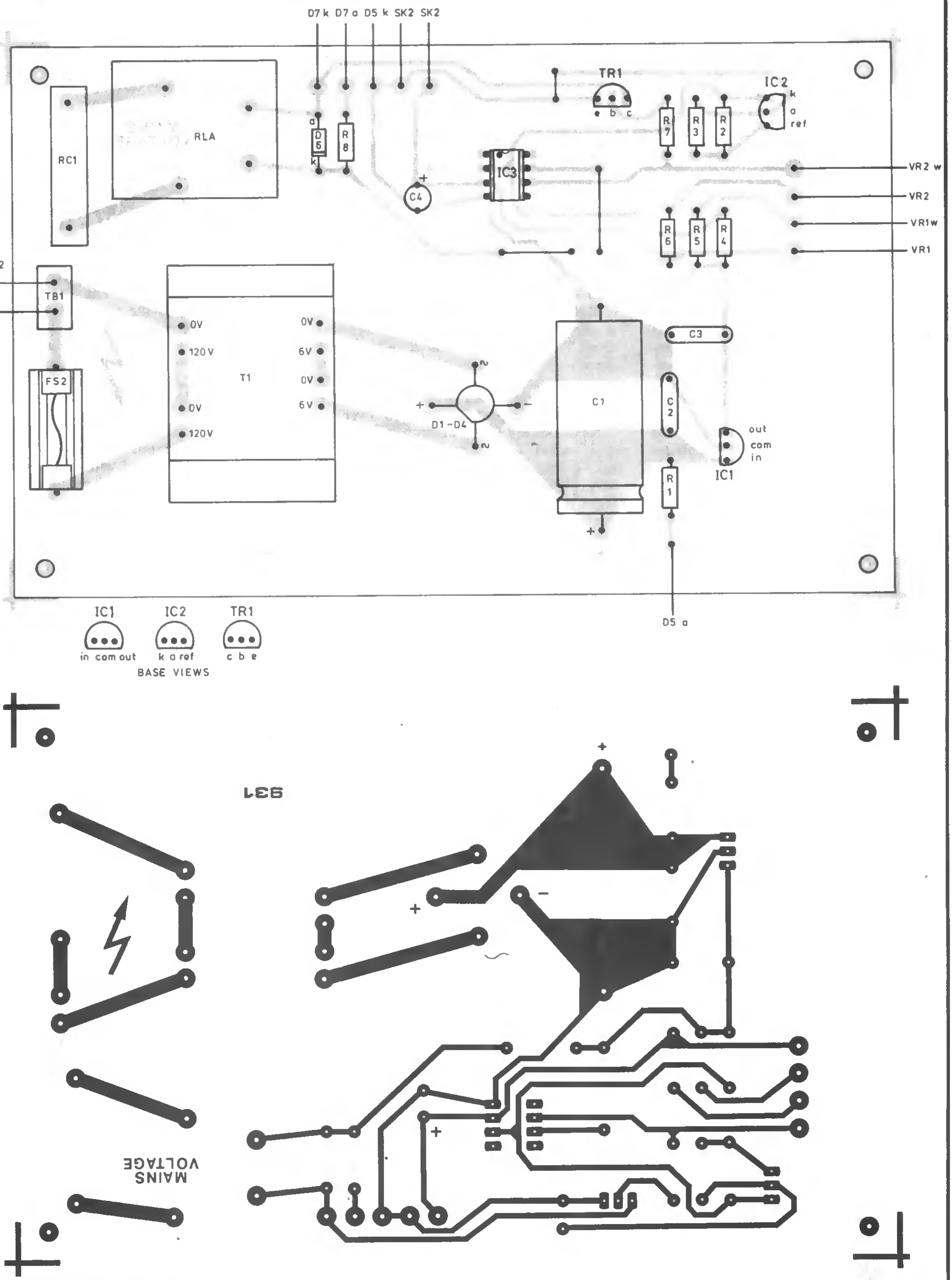


Fig. 3. Thermostat printed circuit board component layout and full size underside copper foil master pattern. Also shown are the pinout details for IC1, IC2 and transistor TR1.

Front panel layout and lettering.

hardware. The empty p.c.b. can be used as a template to mark out the drilling centres on the chosen case.

For convenience it is best to commence assembly by fitting the smallest and fiddliest parts first, finishing with the heaviest and largest components. There is plenty of space on the board, so start by soldering into place the three tinned copper link wires, then continue with the discrete components.

An 8-pin d.i.l. socket may be used for IC3, but do not fit the static-sensitive op.amp into position yet. Continue with the power supply section, noting that the polarities of the bridge rectifier D1-D4 and the smoothing capacitor C1 are absolutely ***critical***.

Also you must observe the polarity of the semiconductor devices carefully as these are likely to be damaged if their connections are reversed (it's one of the few ways you can destroy an overload-protected i.c. such as a regulator). Pinout connections are shown separately for the TL431,12V regulator and transistor, and must be followed closely.

RELAY

As explained earlier, the relay RLA is an interesting choice (see Components List) because although it is a p.c.b. mounting type, it has heavy duty contact terminals accessible on top, as well as via the p.c.b. This means that it is not necessary for the p.c.b. to carry a full 13A load, instead the load is routed to the relay directly through heavy gauge connecting wire.

In fact, only the relay *coil* is driven through the p.c.b. foil pattern and separate 13A wire will be used for the load connections which are taken straight off the relay housing (see photos) via 0·25in. blades – a very neat solution to an age-old problem. Whilst the main contacts also have solder pins, these are soldered to the board just to make the mounting of the relay more secure, and to connect the snubber RC1.

Mains input to the printed circuit board is effected via a two-way screw terminal block TB1 but this only carries a moderate current for the thermostat circuit. It does not carry the heater load current. Fuse FS2 is a p.c.b. mounting type which on the prototype has a protective clip-on cover.

Next, quickly fit the op.amp IC3 into its d.i.l. socket, using Fig. 3 as a guide, and taking any anti-static precautions necessary: it's safest to discharge any static away from your body through an Earthed point prior to handling the chip.

Finish off by soldering the mains transformer into place. It will only fit one way round but ensure that it is flush against the p.c.b. before soldering.

Having fitted all parts to the board, check the soldering very carefully, looking for signs of dry or incomplete joints, or stray whiskers of solder shorting adjacent copper pads. You may wish to finish off by spraying the copper foil with a coat of p.c.b. lacquer. Normally this can be through-soldered when connecting the flying leads.

HOUSING

These days, the enclosure is often amongst the most expensive of a project's components and it pays to compare sizes and shop around; alternatively you might consider saving money by producing a box yourself from suitable materials. The prototype was constructed in a plastic housing which had attractive front and rear aluminium panels coupled together with pressed steel members. It appeared to be the most competitively priced box for the required size.

The dimensions are primarily determined by the size of the mains socket which is fitted to the rear panel, also the "footprint" of the box must accommodate the p.c.b. together with a heavy duty 3-way terminal block (see photographs).

After some consideration the prototype used a plastic case no. BIM 3503 measuring 231 × 181 × 77mm, sourced from ElectroValue. This box was (only) just high enough to carry the mains socket as shown in the photographs.

Ventilation slots are also formed into the rear panel and plastic base though these are superfluous in this design. It also had tilt feet as a finishing touch. Any other suitable case of appropriate dimensions could be used but one with metal panels will facilitate good earthing, and aluminium is a more easy to work than steel.

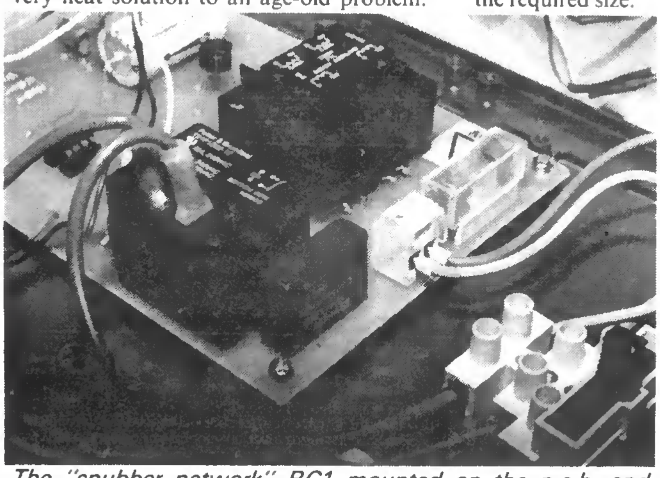
The base needs preparing to accept the p.c.b. mounting hardware if you haven't already done so earlier. The front panel is punched to carry the two potentiometers and two light emitting diodes (l.e.d.s): a 10mm or 3/8in Q-Max chassis punch will make light work of the pot. mounting holes whilst the l.e.d.s can be supported with plastic lens-clips or similar, of appropriate size. The prototype used 3mm l.e.d.s in transparent clips for an attractive finish.

After carrying out the metalwork, the panel can be enhanced with rub-down lettering which is now widely available in the High Street in many typefaces. If desired, the two rotary controls can also be embellished with rub-down "scales" such as those provided by Alfac (their part no. EC802). These vastly simplify the accurate marking out of the dials. Finally, spray on several coats of protective lacquer before turning to the rear panel.

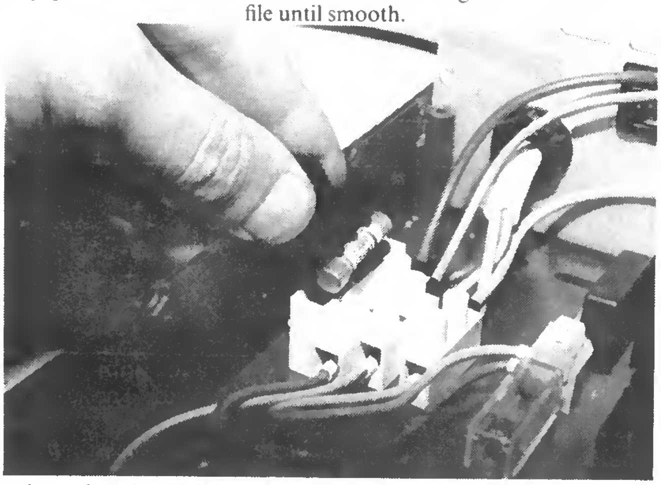
REAR PANEL

The panel at the back of the case needs punching to accept the 13A mains socket SK1 together with the 3·5mm jack socket SK2 and the mains cable inlet. The actual layout depends on the type of box used, and due care must be taken to ensure that when all parts are in place, nothing will interfere with any other parts or cause an obstruction which would prevent the box from being closed together properly.

A Q-Max punch is the best way to machine out the socket opening, however at 50mm diameter for the specified socket such a punch is a luxury. As an alternative, you could drill a ring of holes just inside the diameter of the proposed cut-out, and join them together with an Abrafile or similar, then file the edges with a half round file until smooth.



The "snubber network" RC1 mounted on the p.c.b. and heavy duty connections to the relay.



Inserting the 13A fuse into the fused mains terminal block.

Another approach would be to use a surface mounting socket, this will cover any cut-outs in the panel and perhaps avoid some of the need for neat metalworking. The case dimensions may need reviewing if a different socket is used. Use the mains socket as a template or mark out the two mounting holes for the fixing screws.

The mains cable inlet on the prototype consisted of a plastic cable gland capable of gripping the 8mm diameter 13A cable. This cushions the cable insulation and prevents it from wearing on the aluminium chassis, and also acts as a strain relief to ensure that the cable cannot be pulled out – an essential safety feature.

The other normally-accepted method of cable retention is to utilise a PVC grommet of 10mm internal diameter together with a nylon "P" clip. A suitable hole is also drilled in the rear panel to take the jack socket.

INTERWIRING

The final aspect of construction is the interwiring. ***It is imperative that due attention is paid to the current rating of certain wires; those which may potentially carry a full load MUST be rated at a full 13A.***

The complete interwiring diagram for the Multi-Purpose Thermostat is shown in Fig. 4. The mains inlet was fed, on the prototype, to a 16A 3-way fused screw terminal block TB2. This obviated the need for a separate fuseholder, and also the terminal block mounting screw (supplied) is automatically Earthed.

This connection block is strongly recommended (see Components List) but an ordinary 13A terminal block with a separate chassis mounting fuseholder could be used instead – in which case a one inch or 1¼in fuseholder is needed. As a further precaution against stray short circuits, crimp-on ferrules were utilised to terminate the stripped wires neatly prior to inserting into the terminal blocks. Continue with the interwiring as follows.

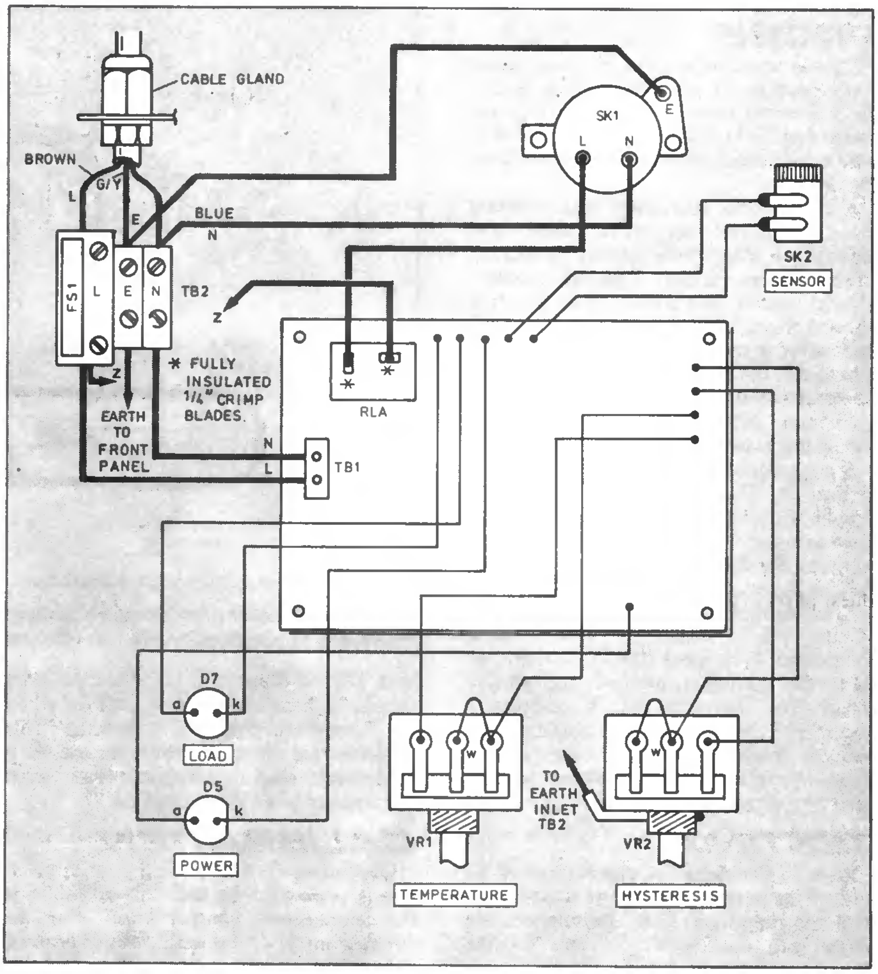
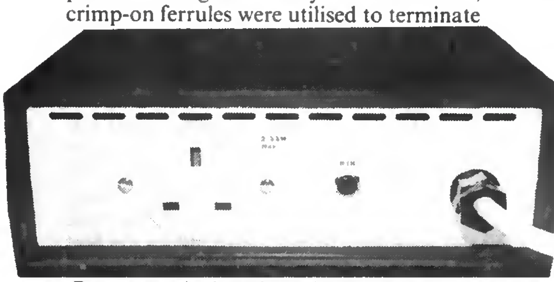


Fig. 4. Interwiring between off-board components and the circuit board. The "thick" leads are rated at 13A mains, except the two leads to TB1 which are rated at 6A.



Rear panel showing the mains outlet socket.

The p.c.b. mains input to the two-way block TB1 can be connected with 6A mains wire. The heavy load-bearing cables carry current between the mains inlet, via the relay to the mains socket. Use 13A rated mains cable to interconnect the relay and mains socket in accordance with Fig. 4.

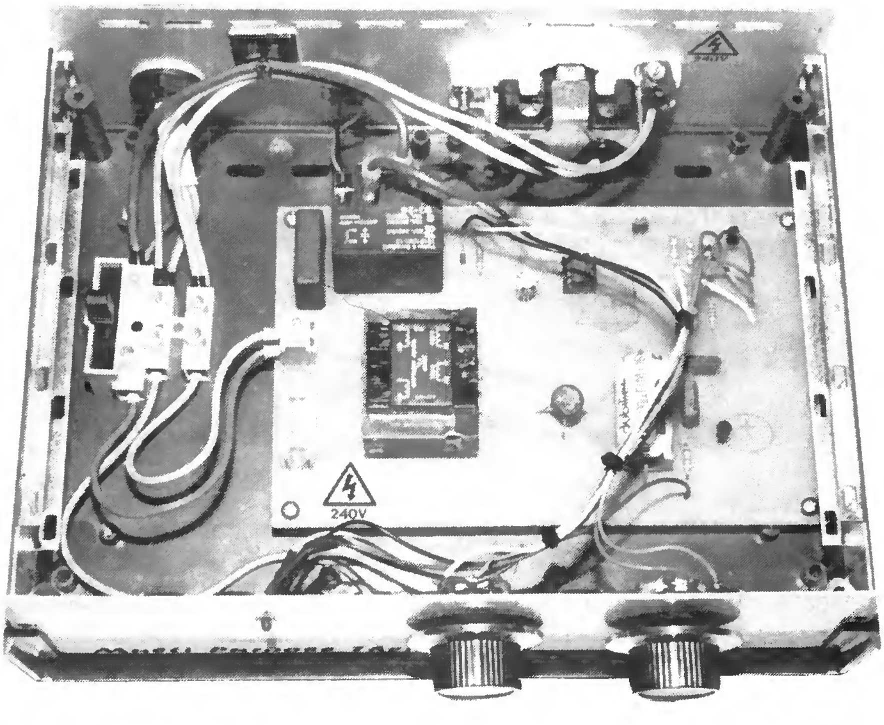
The specified relay is equipped with 0·25in shrouded male blades whilst the relay coil's power is derived from the p.c.b. Terminate the relay connecting wires with crimp automotive-type female connectors, preferably fully insulating them with heat-shrink sleeve or expanding insulation tubing (see close-up photographs). It is desirable to use the mains colour code for the live (brown) and neutral (blue) wiring.

FRONT PANEL

The front panel components can be hooked up via flying leads with standard multi-stranded interconnecting wire, using several different colours to simplify the checking process later on. The polarity of the l.e.d.s is as shown in Fig. 4.

Precautions must be taken to ensure that all the metalwork of the case is earthed soundly. A large size (10mm internal diameter) crimp ring terminal was used on the prototype, being placed under one of the potentiometer mounting bushes to form an electrical contact with the aluminium. (Note that the rear panel is automatically earthed through the mains socket mounting screws which effectively connect to the panel.)

After connecting all flying leads in accordance with Fig. 4., the printed circuit board can be fitted to the base of the housing, and **it is essential that fully insulated hardware is used here.** Typically, p.v.c. spacers with short self tapping screws at each end can be utilised. Finally, fit a plug fused at 13A to the mains inlet lead.



PROBE

Choose which type of probe you require – it's possible to adapt the probe design for measuring free air temperature or for immersing in liquids. The prototype of a simple air temperature probe is shown in Fig. 5a.

A cheap bead thermistor was soldered to a piece of tag strip which was mounted in a small plastic box measuring 70mm × 49mm × 25mm. This has a pattern of large holes drilled into the front (finished off with a countersinking bit) to allow the thermistor to monitor ambient air; connection to the main unit was performed with a screened lead one metre long, terminated in a 3·5mm plug, but a much longer connecting lead could be used in practice.

A suggestion for a liquid probe is given in Fig. 5b. This time a small glass phial may be used, such as an aftershave or perfume sampler. Leads could be soldered directly to the thermistor, ensuring they are fully insulated with sleeving.

After positioning the bead in the bottom of the phial, embed it with potting compound or silicone rubber sealant, or leave the container unfilled and simply ensure that the cable exit is completely waterproof. Note that some potting compounds contain hazardous components (cyanide, actually) and the instructions must be followed very carefully.

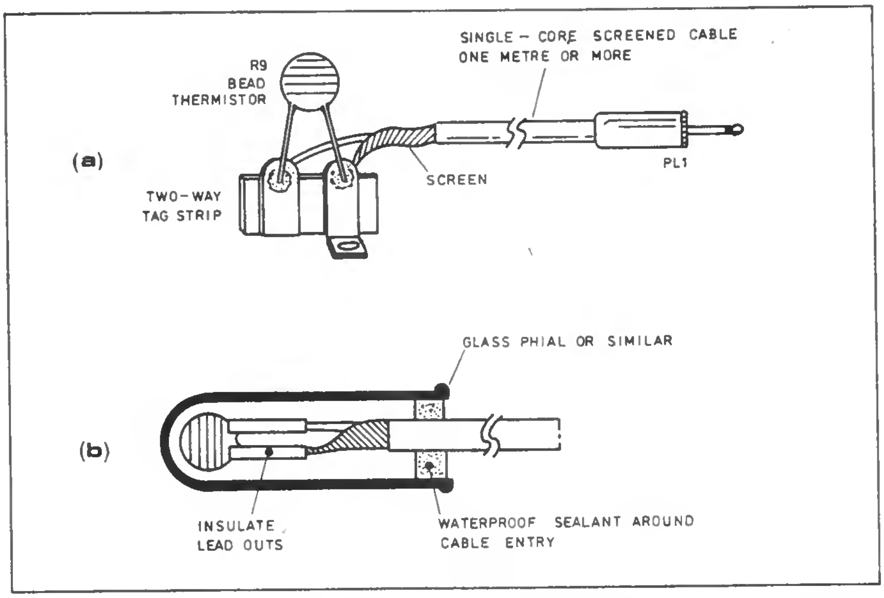


Fig. 5. (a) Ambient temperature sensor for mounting in a small box, with ventilation holes and (b) suggestion for an immersible probe for liquids.

TESTING

Prior to switching on, check through all interwiring carefully to ensure it conforms with the diagrams. Plug the temperature probe into the thermostat and set the potentiometers to mid-way.

Probably the best way to proceed after construction is to bench test the unit with a d.c. bench power supply. If available, clip a 15V to 17V d.c. (approximately) supply across the smoothing capacitor, observing polarity. There is no need to plug any heater load into the mains outlet.

Correct operation can be confirmed with a couple of quick voltmeter readings, measured with reference to 0V: the +12V regulator output was +12·09V and the reference voltage at IC3 pin 2 was +5·98V, as noted on the prototype. Check that rotating the potentiometer(s) causes the relay to switch in and out.

Warming the thermistor with a hairdryer should encourage the relay to switch out. Freezer aerosol will help cool it, if available (though the one the author used ruined the plastic finish of the prototype sensor!).

Before proceeding further, close up the case to avoid accidental electric shock and plug the unit into the mains, using an ELCB/RCD (Powerbreaker) if available. Upon powering up at the mains, the power l.e.d. D5 will illuminate, and then the relay should be heard to click on and off when the Temperature control is rotated. This indicates that the unit is ready for use. As a final check, plug in a suitable load which will operate when the relay is on.

CALIBRATION

Depending on how critical your application is, it may not be necessary to calibrate the temperature control knob. For the simple control of domestic electric heaters, for example, it may be perfectly acceptable to simply mark the dial 1 to 10 and then set the control from experience. If you do need to calibrate the control knob then it is necessary to refer the thermistor against a known temperature.

If the immersible probe is used, then possibly insert it into a bowl of iced water along with a thermometer and then compare the temperature readings against the control knob settings.

Rotate the control until the relay clicks off: read off the thermometer and calibrate the dial accordingly. Repeat this at a variety of temperatures. The Hysteresis control is best disconnected for this initial setting up, by temporarily unsoldering a flying lead on VR2.

If you have assembled the thermistor to measure air temperature, as per the prototype, then it's possible to simulate various temperatures using a cool box filled with ice packs, with the probe inside and a thermometer alongside it. Let the temperature drop down to near freezing point and then remove the ice box lid – allow the temperature to climb gradually and calibrate the setting of the control knob when the relay clicks, against the readings of the thermometer.

Again it is best to unhook the hysteresis control during setting up, to avoid any misleading errors. A digital thermometer was used against the prototype and the general range of the design was shown to be approximately +2 to +30 degrees Celsius. The Multi-Purpose Thermostat is then complete and ready for use.

FURTHER NOTES

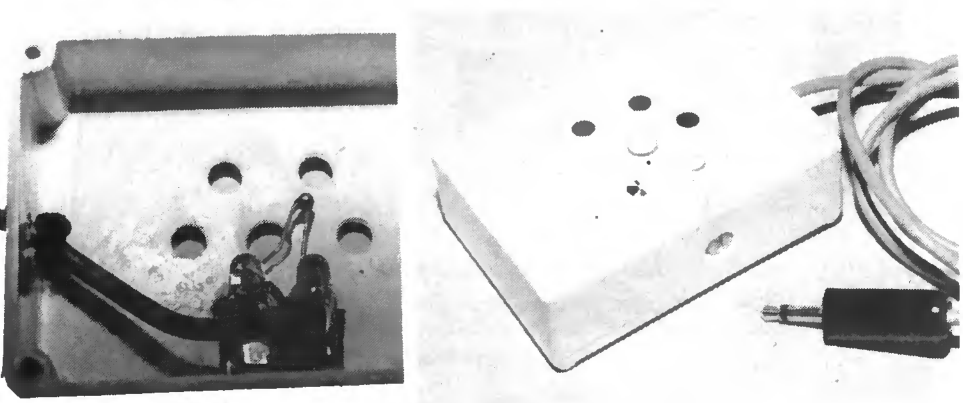
When setting up the Thermostat in its intended application, it is worth experimenting with the thermistor position to obtain the best overall effect. Obviously hot air rises and if the Multi-Purpose Thermostat is being used to sense room temperatures, then if the thermistor is placed too low down it may be "fooled" by the lower temperatures – or if it is too high or too close to the heater the thermostat may switch off prematurely. Some initial trial and error may be needed to obtain the best results, and the Hysteresis control may help to compensate as explained earlier.

Although the prototype design did not include a mains on/off switch, one can easily be incorporated into the reader's own version if desired. A double-pole rocker or toggle switch, capable of carrying the FULL mains load current, can be inserted into the circuit by connecting the mains Live and Neutral mains inputs to the poles of the switch, and then connect the wipers of the switch to the mains inlet terminal block.

Furthermore, a "bypass switch" can easily be incorporated by adding a single-pole mains rated switch in parallel with the relay contacts, then the heater can be forced to operate full-time independently of the thermostatic control.

If you wish to omit the Hysteresis control VR2, it is still best to include a degree or two of feedback in the op.amp circuit to avoid jitter. Change resistor R6 for a value of roughly 220 kilohms and then link the two adjacent take-off points for VR2 together on the p.c.b. with a jumper wire. In effect, this shorts out VR2 and places a 220 kilohm resistor in the feedback loop.

You will find that the Multi-Purpose Thermostat can be readily adapted for many temperature control applications. □



Suggested construction for the "air temperature" probes.

New Technology Update

Ian Poole investigates new, and old, materials being used to manufacture printed circuit boards and a tough new family of semiconductors.

PRINTED circuit boards are at the very heart of today's electronics manufacturing. As a method of construction the p.c.b. has been so successful that virtually 100 per cent of all electronic assemblies use them.

Introduced about 40 years ago, they were initially used to improve reliability and ease of production. During their lifetime they were initially used with valves, then transistors and now with i.c.s. Many other new technologies also use the basic idea of printing circuits onto a flat substrate, so it is likely that printed circuits and their derivatives will be around for many years to come.

There are a number of types of printed circuit boards. For applications where cost is of paramount importance, materials like s.r.b.p. are used. Glass fibre boards are also in widespread use.

Where r.f. performance is of critical importance p.t.f.e. is used because it offers much lower levels of loss and a far greater consistency of dielectric constant. This is particularly important when coils and transmission lines are printed onto the board.

Whilst existing materials are satisfactory in many respects they do have a number of shortcomings in certain applications. To help overcome them, IBM researchers at the Watson Research Centre in New York have developed a new resin which will offer some significant improvements in board materials.

Cyanate-esters

The new material, called CYTUF, took many months to develop to a point where its capabilities enable it to compete in the market place against epoxy resin based products. The new material is based around a group of compounds known as cyanate-esters.

Initially their brittle nature meant that they could not be used. However, by using a specialised additive the strength was retained without the tendency to crack.

Now fully developed CYTUF offers many advantages in terms of thermal stability, low moisture absorption, flame retardancy, and high strength. It also allows copper to be securely bonded to it. This is very important as many home constructors will know only too well.

Most of today's materials allow the copper to be bonded sufficiently well for manufacture. However, it is often very easy to lift pads and tracks when carrying out any rework or repair on the board. This is becoming even more important as track and pad sizes are being reduced as components become smaller and component densities rise.

Another of the advantages is that the new material is very heat resistant, and this allows monolithic i.c.s to be bonded directly onto the board. This gives the possibility of removing a level of packaging and thereby reducing the cost of the product. As such it is an ideal substrate for multi-chip modules (m.c.m.s) which are appearing in certain sectors of the market.

As the material is inherently fire resistant no further additives are required. Many existing types of board require the addition of fire retardant chemicals which tend not to be environmentally friendly.

As the material has a high degree of dimensional stability, and it is strong, it is also ideal for use as a base for printed antennas. This may prove to be a major use for the material because aerials for direct broadcast satellite television reception lend themselves to this type of approach. There is also a wide variety of other microwave aerials which can use printed aerials.

Silicon Carbide Semiconductors

For many years germanium and silicon have been the mainstay of the semiconductor industry. Now gallium arsenide is also being used more widely. However for i.c. manufacture silicon is still used far more than any other substance.

With developments taking place all the time, new semiconductor materials are being found and used. One of these is silicon carbide. Being the hardest material known to man next to diamond, it is usually used for drills and in various grinders. However it is also a very useful semiconductor.

The advantages of using silicon carbide for semiconductor applications have been known for some time, but it has taken until now for the first i.c.s to be manufactured using the material.

One of the main advantages of silicon carbide for use in electronic circuits is its resilience to heat. Normal commercial i.c.s have a temperature range extending up to 70°C, and those for extended temperature operation may be quoted up to 125°C.

Despite this it is always good practice to ensure that the operating temperatures are kept well down and do not approach the maximum limits. Operating any device close to its limits will reduce its reliability. In many applications where reliability is of paramount importance temperatures must be kept to a minimum.

As most designers known this is not always easy. If the equipment is to operate in a hot environment, the outside of the equipment may keep within the specifications, but temperature rises within the unit can cause the internal temperatures to exceed the limits.

As a result temperature considerations always have to be kept in mind. Designing circuits for very hostile environments is difficult. Where it is absolutely necessary to be able to measure or detect anything in one of these environments a very simple sensor has to be used and any processing applied at a point away from the sensor where the temperature can be kept within reasonable limits.

Running a Temperature

Now with silicon carbide semiconductor technology, more sophisticated sensors with in-built electronics are a possibility. General Electric, at their research centre in New York have now fabricated an i.c. capable of running in temperatures of over 450°C, significantly above that of any other silicon based circuits.

The first i.c. to be made using the new material is a monolithic operational amplifier. It is expected that it will be used mainly in conjunction with complex sensors in engines.

By using them it is expected that the general running and efficiency will be able to be improved by electronically controlling the conditions for the engine. It will also help in the design of new power plants, as it will be possible to measure aspects of the engine's performance more accurately.

Silicon carbide is similar to silicon in many respects, exhibiting the basic semiconductor characteristics. Naturally there are a few differences which enable the silicon carbide to perform differently to basic silicon. The major one is that it has a much wider bandgap. It is this aspect of its operation which enables it to perform at very much higher temperatures.

Although the first uses for the new i.c.s are expected to be with sensors, it is also anticipated that they will find uses in many other areas. Silicon carbide exhibits advantages over standard silicon in a number of other respects.

It has a higher breakdown voltage, better thermal conductivity, and also a high electron mobility. These make it an ideal candidate for uses in r.f. applications. Once sub-micron technology has been developed and refined for the material, it should be able to easily outperform silicon, and find widespread use.

Another distinct advantage is that silicon carbide technology does not differ greatly from its silicon counterpart during manufacture. This means that very few changes will be needed to any fabrication processes to enable silicon carbide components to be made. This is a major advantage in its favour, and it should mean that silicon carbide i.c.s become relatively common before too long.

Innovations

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

YOUTH SHOWS THE WAY

Schoolgirls take hi-tech awards – by Hazel Cavendish

AN ingenious electronic invention designed to help the blind has been developed by three British schoolgirls studying at St Swithuns School in Winchester, under the guidance of Technology master Vaughan Clarke. A shuttlecock which can be heard as it travels through the air is a triumph of miniaturisation in its electronic parts, fitted to enable totally blind people to play badminton.

Claire Dally and Elizabeth Kershaw, both aged 15, and 14-year-old Sara Haddows won the team project for *Young Engineers* in the countrywide competition sponsored by the Engineering Council last autumn, taking the much-coveted prize from 1,000 young inventors from all over Britain.

"The three girls conceived the idea themselves, but the difficulty they experienced was fitting the electronics into the space provided," said Vaughan Clarke. "Basically, it is achieved by using a 555 astable multivibrator which operates at a frequency of 2·1kHz – the optimum frequency for the human ear – to obtain the highest volume with the lowest amount of power, so that the smallest batteries can be used.

They fitted 3V Lithium batteries that were both thin and light, and a tiny solid-state resonator as a loudspeaker. Finally the circuit board itself was reduced to 0·4 grams and the whole circuit with resonator and battery only weighs about four grams. Reducing their invention to fit into the shuttlecock took them two school terms to achieve – an excellent lesson in attaining the miniaturisation which is essential in today's fast-moving electronic world.

"We travelled to the Bracknell Sports Centre to try the invention on some blind people who wanted to learn badminton. Our trials were very encouraging. The players were able to track the shuttlecock with their sharply developed hearing powers, and were soon beginning to play like normal people. We are now producing a dozen shuttlecocks for the trainer of the blind at Stoke Mandeville Hospital."

Best Electronics entry in the Southern Counties finals of the *Young Engineers for Britain* was won by Anniina Salonen, aged 16. A pupil at St Swithuns School, she invented an ultrasonic height calculator for use by District Nurses when measuring childrens' height. She incorporated a unit taken from a Polariod camera's ranging system in a portable device 50cm x 25cm x 4cm which can be rested on a child's head and by sending a sonar signal to the ground, gives an instant height reading.

The three girls from St Swithuns School, Winchester show off their award-winning shuttlecock design.

Claire Dally, from West Meon in Hampshire, described by Vaughan Clarke as "a very gifted girl with great potential" was a member of another three-girl team from the school which won one of five first prizes in last summer's *Duracell Science and Technology UK Schools Competition* for their invention of a Toddler Alarm, which the judges described as displaying "outstanding creativity and innovation". Claire, Anna Hadfield and Stephanie Biden won an all-expenses-paid trip to the United States, where they visited the Massachusetts Institute of Technology.

The three girls thought up the principle of a toddler alarm when they studied a radio-controlled toy car borrowed from a little brother, which had both a transmitter and a receiver. They worked out a package which could be used by a mother wearing a receiver and the child a small transmitter, with an alarm which went off if a child wandered more than 20 metres from the mother.

Originally conceived by them to enable mothers to find small children who wandered off in shopping centres, they decided to go ahead with the project after reading about the James Bulgar abduction and murder case. A frequency of 27MHz was used for the transmitter and receiver, and the package was eventually reduced to 5cm x 7cm x 2cm in size.

The team is now working on a batch of toddler alarms intended for British theme parks. They hope their product may prove suitable for park owners to hire out to families with small children for day use, designed on a coded system so that units do not react with one another.

Professor Ian Fells of Newcastle University has welcomed the numbers of girls who are not only entering technology competitions, but winning them and featuring in all the prize lists as well. "It is very encouraging for the future of science and technology", he said when making the awards at the Royal Institution.

SHARP AND LARGE LCDS

Until recently, the world's largest colour LCD display has been a 17-inch (43cm on the diagonal) high-resolution TFT LCD developed by Sharp in 1992. The company have now introduced an even larger one!

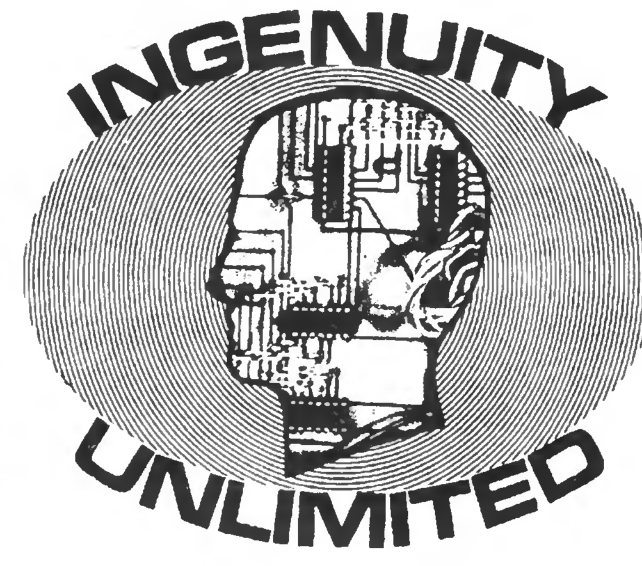
The new display features an effective screen area 1.5 times larger, and with a thickness of a mere 2.7cm (1.06 inch), it promises to open up new possibilities for direct-view wall-mount colour TVs and monitors with screen sizes exceeding 20 inches.

Several other LCDs have also been introduced by Sharp, some could revolutionise car dashboard display systems. They also have potential applications in other transportation areas.

Ranging from 10cm to 14cm (4 to 5.6 inch), these LCDs incorporate advances made over the last two years which enable such displays to be used in the relatively hostile environments of cars.

The technology is now maturing and embodies both NTSC and PAL formats as well as the facility to superimpose graphics. The displays exhibit resistance to high temperatures, shock and vibration, and also have improved viewing-angle characteristics.

For further information contact: Sharp Electronics (Europe) GmbH, MED London Office, Centennial Court, Easthampstead Road, Bracknell, Berks, RG12 1JA. Tel: +44-(0)344-869922.



Our regular round-up of readers' own circuits. We pay between £10-£50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas must be the reader's own work and **not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description showing all relevant component values. Please draw all circuit schematics as clearly as possible.

Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF. They could earn you some real cash!

Truly Simple TENS Unit

– helps provide pain relief

Following on from the *EPE Simple TENS Unit* (May 1994 issue), I wish to submit my own *truly* simple design which uses only five components. My father who was suffering intense leg pain through diabetes, found instant relief through the use of this device, and permanent relief after several months. The device will give at least one month of all-night service from an alkaline PP3 9V battery.

It is based around a UJT (unijunction transistor) oscillator, see Fig. 1. The frequency of operation is determined by resistor R1 and capacitor C1, whose charging action results in a pulse passing through the primary winding of the transformer T1. This is a mains to 6V step-down transformer used in reverse "step up" mode. With R2 having the value shown, the pulse on the primary is barely perceptible.

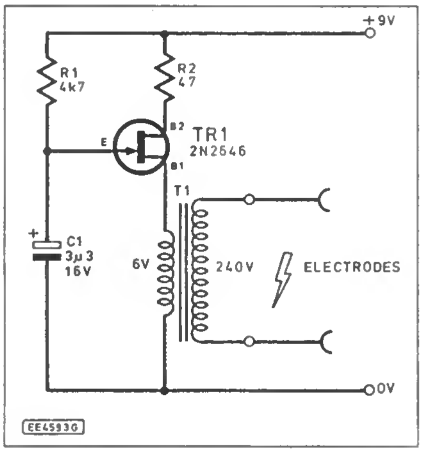


Fig. 1. Circuit diagram for a Truly Simple TENS Unit.

This unit was found to be most helpful when the electrodes (the transformer primary connections) were applied to either side of the painful area, between a toe and the knee.

Rev. Thomas O. Scarborough,
Cape Town 8001,
South Africa.

(Readers are STRONGLY RECOMMENDED to read and follow Andy Flind's recommendations concerning usage and the SAFETY precautions needed when considering using a TENS device. These were clearly highlighted in Andy's original article in the May 1994 issue. A.R.W.)

Auto Level Control for Car Radios

– for "easier listening"

This experimental circuit, Fig. 2, automatically increases the volume of a car radio when the vehicle's speed (and consequent road and wind noise) rises, returning the volume to a pleasant level at lower speeds. This relieves the driver of the distracting chore of continually fiddling with the radio's Volume control.

In Fig. 2, a special tachometer i.c. type LM2917 takes its input from the ignition system's contact breaker points and converts this into a voltage which is directly proportional to engine speed. This voltage will always be in the range of 0V to 5V and is used to illuminate a miniature filament lamp LP1. *(The LM2917 device has a sink source rating of 50mA typically - A.R.W.)*

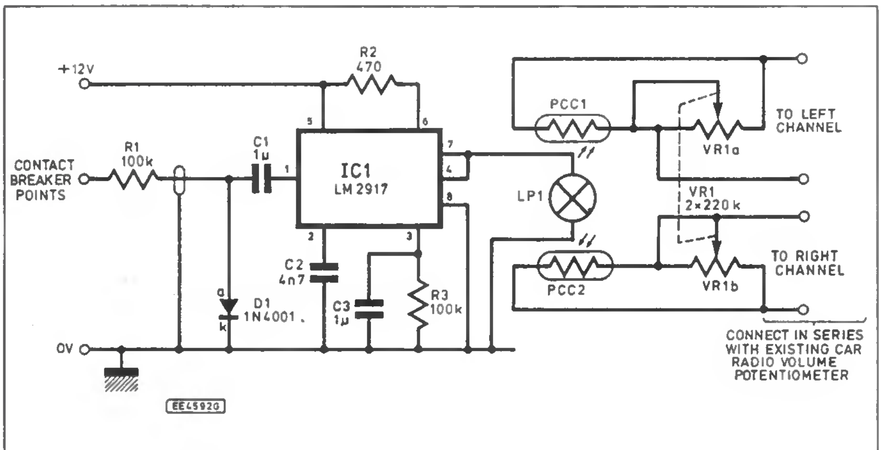


Fig. 2. Circuit diagram for the Auto Level Control for Car Radios.

Either side of this lamp are mounted a pair of light-dependent resistors (l.d.r.s) which are connected in series with the wipers of the radio's Volume control potentiometers. A ganged pot. across each of the l.d.r.s sets the minimum volume level, the radio's own volume being used for the high level.

The value of capacitor C2 determines the rev. range over which the unit will function satisfactorily. A suggested value of 4n7 would be a suitable starting point for further experimentation – it proved ideal for my car.

The complete circuit can be constructed onto a square inch of stripboard and mounted inside the radio itself, ensuring steps are taken to make the l.d.r./lamp assembly lightproof. Power to the unit can be derived from the switched live side of the radio, and the remaining leads can be fed through a convenient hole in the radio casing, perhaps using 4-core flat ribbon for the ganged potentiometer.

The 100 kilohm input resistor (R1) should be placed as near as possible to the ignition coil end to prevent RFI (radio frequency interference) and to ensure the contact breakers points are not shorted out should the wire short to earth (chassis) for any reason.

Martin Campbell,
Bradford, Yorkshire.

Electric Guitar Treble Booster – restores "muddy" sound

All electric guitars work on the same principle: the signal is produced in a coil and fed to the amplifier through a screened cable. Every cable has a certain capacitance which, combined with the impedance of the pick-up coil, will produce a low pass (treble cut) filter. This explains why some guitars sound "muddy" when fed directly to an amplifier.

The circuit diagram shown in Fig. 3 was designed to increase the treble content of an electric guitar's output. It boosts frequencies above 1kHz and helps to restore any higher frequency losses. IC1 is a TL071 op.amp connected as a non-inverting amplifier which is connected in line between the guitar and main amplifier.

Potentiometer VR1 determines the level of Treble Boost applied and, with the values of components shown, will give between 3dB to 20dB. Resistor R6 and the potentiometer VR1 could be replaced by a fixed resistor if required.

The actual boost frequency is set by the values of resistor R4 and capacitor C2. With switch S1 open, the circuit acts as a voltage follower with no effect on the guitar signal. Closing S1 grounds C2 to the 0V line, which introduces the boost.

Resistor R5 holds the "earthy" end of C2 at 0V when switch S1 is open, and prevents switching noise appearing on the signal when S1 is operated. Resistors R2 and R3 set the input impedance of the circuit at 50 kilohms, which should suit most electric guitars.

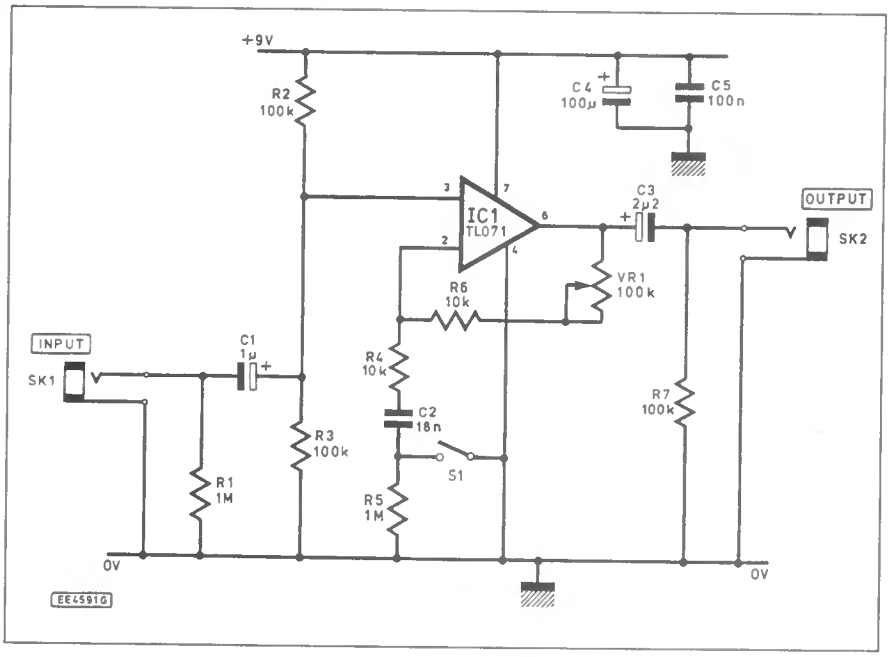
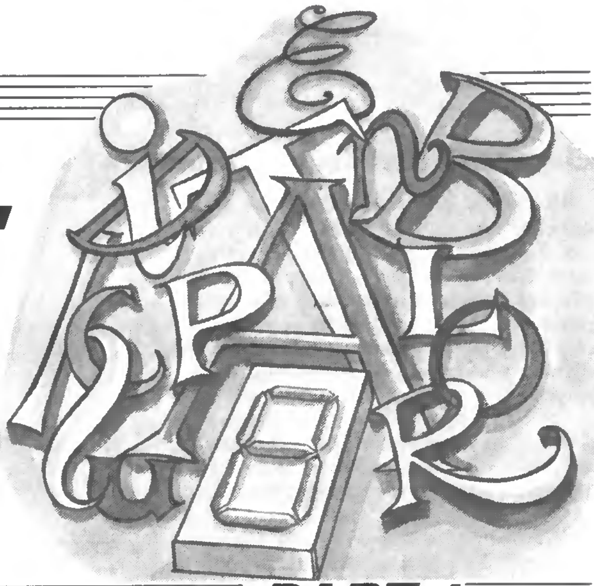


Fig. 3. Electric Guitar Treble Booster circuit diagram.

If the circuit is housed in a diecast case, S1 can be a foot-operated switch and SK1 could be a stereo jack socket with the sleeve and ring connections connected to the battery negative and 0V rail respectively. Thus the unit will switch on automatically whenever the guitar is plugged in. Connect the case to the "earth" side of the circuit. Expect reasonable life from a PP3 battery.

Alan Jones,
London SE16

Constructional Project



THE NAME OF THE GAME COUNTERSPELL

ROY BEBBINGTON PART 1

THE Name of the Game is a series of electronics projects based on party games or TV quiz games. Featuring something old, something new, there are electronic versions of popular, well-established TV games such as Countdown and Catchword with alphanumeric displays, new games employing electronic word-making, and games of skill.

Accessories, used in various games, such as an interval timer, an electronic dice, a precedence switch, a heads/tails unit, are the subjects of later constructional articles.

WHAT'S IT ALL ABOUT?

Counterspell is an electronic selector of letters for such popular TV quiz games as *Countdown* and *Catchword.* It features a decade counter driving a 7-segment l.e.d. capable of randomly displaying one of ten letters at the touch of a button. The series of letters can be switch-selected so that the *freeze* push-button switch provides one letter from:

the five vowels,
a selection of ten consonants, or
a mixture of five vowels and five consonants.

In addition, the project suggests a number of other simple word games.

ANCILLARY PROJECTS

A complementary unit, *Counterspin* is described next month and takes care of a Numbers game for *Countdown.* Equipped with *Counterspin,* you can pit your wits against a contestant, not only selecting the vowels and consonants for your word-making, but in addition (or perhaps it's *multiplication?*), selecting small digits, a large digit and the target for the numbers game.

Two other units, described in a later article, come into play after letters or numbers have been selected and written down: a pushbutton switch on a *Time's Up!* unit sets a thirty-seconds timer; at the end of this interval, a buzzer sounds to announce decision time. Then, at the end of the game, you could need the *On Your Marks!* unit with which two precedence switches eliminate any argument as to who reacted first if both contestants manage to unravel a selected conundrum. Merely add a good dictionary to sharpen your wordcraft, and for good measure, rope in a host who you can rely on to see fair play.

Other forthcoming *Name of the Game* projects include *Star Struck, 6-Shot Light Zapper, Electronic A-Z, and Wander Wands.*

COUNTERSPELL PRINCIPLE

The game of *Counterspell* presented here has been designed as a junior version broadly based on *Countdown.* Normally, in the TV game, a mixture of eight letters using vowels and consonants are chosen by a contestant, points being awarded to the one who can form the longest word. However, this version is limited to the five vowels (a, e, i, o, u) and nine of the 21 consonants (c, p, l, n, d, t, h, b, r). All the letters are presented in lower-case (as near as a 7-segment display can allow!). In addition, a "wild-card" letter represented by two vertical lines can stand for any chosen consonant, which extends the word-making possibility, for instance as a "g" to obtain a useful "ing" ending.

If desired, the word-making length can be limited to six or seven letters. Nevertheless, for children, a restricted word length would still provide plenty of skill with the available letters. The project offers a number of useful variations, which are considered later when the method of play is discussed.

FRONT PANEL DISPLAY

The front panel, as seen in the photo, contains a 7-segment one-inch display (X1), which serves as a dual-purpose indicator for the five vowels and the ten consonants. The top left-hand slider switch (S3) has three positions. The upper *Off* position disconnects the +9V supply from the unit. In the *On* position the supply is connected and the display X1 runs through its l.e.d. segments in fast sequence. Operating the left-hand *Freeze* pushbutton switch (S1) stops the counter and one of the letters is displayed.

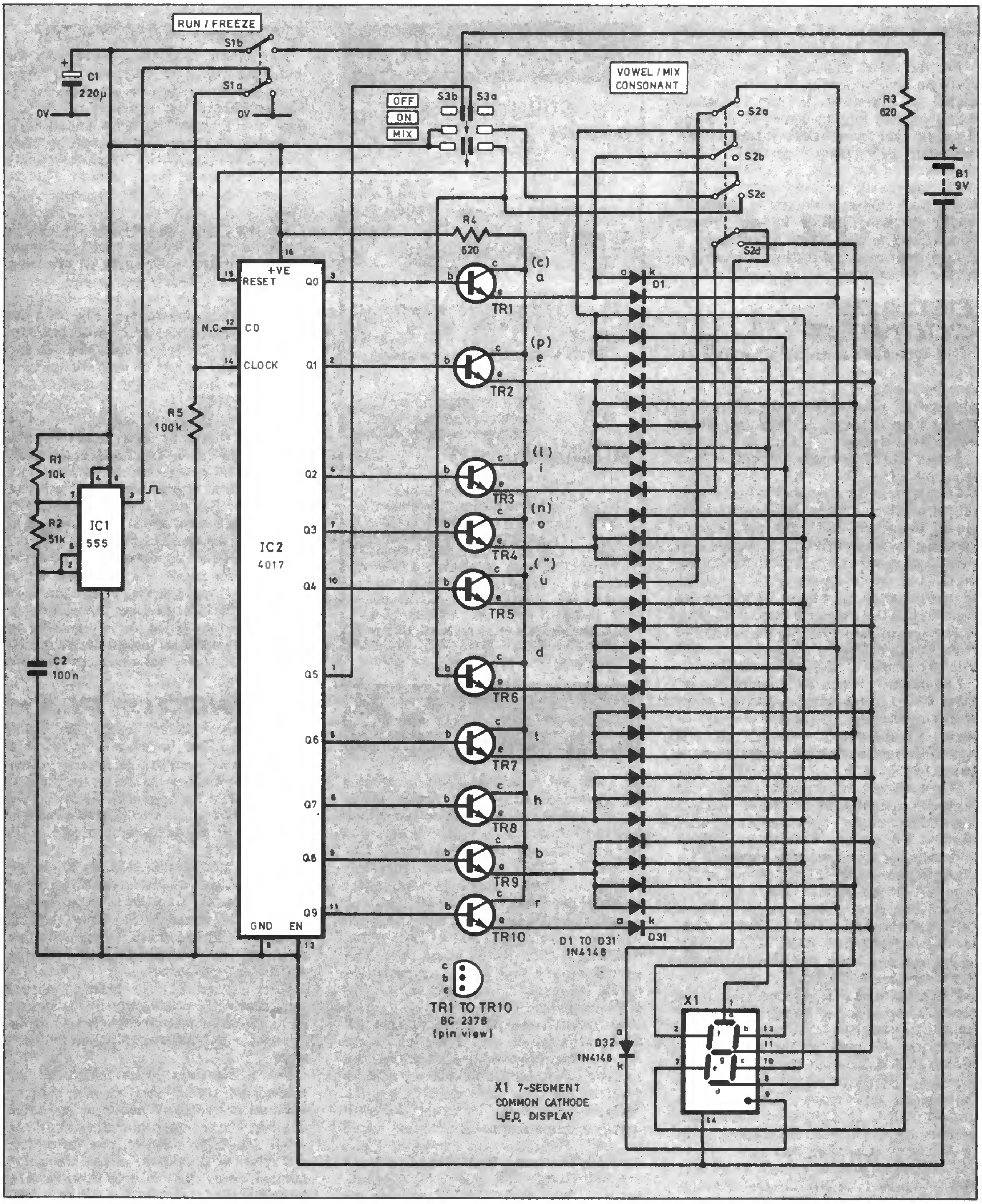


Fig. 1. Circuit diagram for the Counterspell unit.

The mode of the right-hand pushbutton switch (S2) determines whether one of the five vowels (button released) is displayed, or one of the ten consonants (button pressed). In the vowel mode, a mixture of five vowels and five consonants is available if the *On* slider switch S3 is moved to the *Mix* position.

OPERATION

The Countspell unit operates as follows:

S3 (OFF)
Battery is disconnected – circuit is not powered

S3 (ON), S2 (VOWEL)
Five vowels run sequentially
S1 (FREEZE) operated – one vowel is displayed

S3 (ON), S2 (CONSONANT)
Ten consonants run sequentially
S1 (FREEZE) operated – one consonant is displayed

S3 (MIX), S2 (VOWEL)
Vowels and consonants run sequentially
S1 (FREEZE) operated – one consonant or vowel is displayed.

COUNTERSPELL CIRCUIT

The circuit diagram for the *Counterspell* is shown in Fig. 1. Basically, it can conveniently be split into three stages: a clock generator stage supplying the timing pulses for a decade counter stage and the letters decoder stage for the display.

The clock pulses are generated by a type 555 timer, IC1, connected as an astable multivibrator. When the supply is turned on by switch S3b, pulses are output from IC1 pin 3 at a frequency dependent on the values of resistors R1, R2 and capacitor C2.

For the values shown, the rate is about forty per second (40Hz), but this could be varied, if necessary, to suit individual requirements. For instance, if a game suggests that some skill would be an advantage in selecting a particular letter, then resistor R1 could be replaced by a panel mounting potentiometer of 500 kilohms. A slower count rate is especially useful in some games to give young competitors a head start. Conversely, a faster count rate can provide a handicap for the "clever clogs".

DECADE COUNTER

The output pulses available from IC1 pin 3 are fed to input pin 14 of the type 4017 decade counter IC2. This gives a fast-running display through the letters selected by the position of switch S2 until the *Freeze* switch S1 is pressed.

Switch S1a disconnects the pulses from input pin 14 of counter IC2, which freezes the display number according to the counter output at which it stops. Resistor R5 is included to prevent IC2 input pin 14 from "floating" when switch S1a is operated, so preventing spurious signals from developing on this pin. At the same time, S1b switches the +9V supply via resistor R3 to energise segment *e* of the 7-segment display X1. This is an economy ruse, reducing the number of multiplexing diodes by ten since the *e* segment is common to all the chosen letters.

The point at which the counter is reset plays a vital role in which letters are available for selection. In the *On* position of switch S3, the output from IC2 pin 1 is routed through switch S3a to the wiper of switch S2c.

When *Vowel* is selected (switch S2 released), this provides a link from IC2 pin 1 to IC2's reset pin 15. Consequently, after the first five counter outputs go high in sequence, the high logic level appearing on the sixth output (pin 1) is fed to reset pin 15 to restart the sequence.

As shown, these outputs supply the base current to transistors TR1 to TR5. In turn, via the multiplexing diodes (D1 to D31, as appropriate), these transistors drive the vowel segments of display X1.

When *Consonant* is selected (switch S2 pressed), the wiper of switch S2c is connected to the base of transistor TR6. Therefore, the path to the reset pin is broken and IC2 output pin 1 is linked to the base of transistor TR6. This means that the counter now resets after ten pulses instead of five. In *Consonant* mode, each output causes one of the ten consonants to be displayed, as listed earlier.

When *Mix* is selected (switch S3 on *Mix* and switch S2 released), the first five outputs offer the vowels and the last five outputs offer the consonants "d", "t", "h", "b" and "r" as a useful variation. When switch S2 is in the *Vowel/Mix* position, in order to prevent a reset immediately after the vowels, the *Mix* contacts of switch S3a break the reset path to IC2 pin 15.

LETTERS DECODER

Although only one output of IC2 can be active at any time, the display segments required for each letter can demand more current than the 10mA maximum allowed from any output of a type 4017 counter chip. Consequently, driver transistors TR1 to TR10 have been included to provide the required l.e.d. segment current. Resistor R4 provides a common collector load to limit the current via the diode networks (D1 to D31) to the segments of display X1.

This load limiting method inevitably results in some letters glowing more brightly than others. Alternatively, each segment could be driven via its own current limiting resistor of about 560 ohms, replacing resistor R4 by a link wire. This should ensure that these segments are evenly illuminated irrespective of the displayed letter.

However, it should be noted that the total maximum current drawn could rise heavily. It is recommended, therefore, that six type-AA rechargeable cells are used instead of the disposable variety. Alternatively, a rechargeable 9V battery, or a 9V battery eliminator (mains adaptor), could be used. The circuit, as shown in Fig.1, normally consumes about 30mA.

In the *Vowel* mode (switch S2 released), the first five outputs of IC2 provide the vowels. As discussed, the count is limited to these five vowels by the reset switched routing.

For the "a" vowel, diodes D1 to D5 are necessary to activate display segments *a, b, c, d* and *g*. When consonant is selected, vowel "a" is converted to "c" by switch contacts S2b which disconnect diodes D3, D4 and D5 (segments *a, b, c*).

Similarly, to convert "e" to "p", "o" to "n", and "u" to two short vertical lines, switch contacts S2a disconnect segment *d*. Conversely, to convert "i" to "l", switch S2d contacts connect segment *f* and disconnect the decimal point (which flashes to indicate when *Vowel* is selected).

COMPONENTS

COUNTERSPELL

Resistors

R1	10k (see text)	
R2	51k	
R3, R4	620 (2 off)	
R5	100k	

All 0.25W 5% carbon film

See SHOP TALK Page

Capacitors

C1	220µ radial elect 25V
C2	100n polyester

Semiconductors

D1 to D32	1N4148 signal diode (32 off)
TR1 to TR10	BC237B *npn* transistor (10 off)
IC1	555 timer
IC2	4017 decade counter
X1	1-inch 7-segment l.e.d. common cathode display

Miscellaneous

S1	2-pole changeover p.c.b. mounting pushbutton switch (non-latching)
S2	4-pole changeover p.c.b. mounting switch (latching)
S3	2-pole 3-way slider switch

Plastic ABS case, 109·5mm x 179·5mm x 60mm (internal measurements); stripboard 0·1 inch matrix, 20 strips x 73 holes; 8-pin d.i.l. socket; 16-pin d.i.l. socket; AA-type cells (6 off) and communal holder with clip; stranded connecting wire; solder; etc.

Approx cost guidance only **£14** *ex. batteries*

CONSTRUCTION

The topside component layout and the underside stripboard track cuts and solder joints for *Counterspell* are shown in Fig. 2. The stripboard has a matrix of 20 vertical × 73 horizontal holes and is used to mount all components except the front panel switch S3 and the 7-segment display X1. The length of the stripboard is cut to slot into the walls of the suggested ABS case.

The two pushbutton switches, S1 and S2, are mounted on the stripboard and holes must be drilled accordingly in the front panel to accommodate their knobs.

Wire links from the outputs of counter IC2 have been omitted from Fig. 2 for the sake of clarity, but their transistor base destinations have been stated. Multi-strand insulated wire should be used for the connections to switch S3, the battery and to the display X1.

It is advisable to use sockets for the two i.c.s. Care should be taken to prevent any static damage to the i.c.s and it is advisable to keep them in their transit packing until ready for use, fitting them last. Note that all cathode (k) ends of diodes (normally denoted by a black band) are connected to the display segment bus-lines.

The stripboard copper-side layout shows all the solder points and the breaks to be cut in the copper strips. Make sure you leave no whiskers of copper that can short-circuit adjacent strips. It is advisable to check against this at various stages during construction, using an ohmmeter or continuity tester.

METHOD OF PLAY

One game idea for which the *Counterspell* unit can be used is to select a predetermined number of letters, vowels and/or consonants, to form the longest words against an opponent, as in the TV game *Countdown*. For a children's version, the length of word can be restricted to six or seven letters.

In turn, a contestant switches to *on* and selects a mixture of letters, consonants and vowels, by pressing the *Freeze* switch, having first selected the *Vowel* or the *Consonant* setting. Each letter is written down by both contestants onto a playing pad divided into sections.

After 30 seconds, or another pre-arranged time, the contestant with the longest word scores points for each letter, or in the event of a tie, both score points for each letter.

For a Numbers game (aided by the *Counterspin* article – next month), contestant's select five small numbers, one large number, and a target number. Any of the small and large numbers can be added, multiplied or divided to obtain the target number, or as close to it as possible. The score awarded could be five for *on target*, reducing by the difference number of the player nearest to the target.

OTHER GAMES

A simple version of the TV game *Catchword* can be played using the consonant mode of the *Counterspell* unit. Three consonants are selected and displayed in succession. A contestant must then try to find a word starting with the first consonant and including the other two consonants in the order selected. A limited time of a few seconds is set for each selection. Several selections are made for each contestant in turn. A bonus is given for the contestant offering the longest

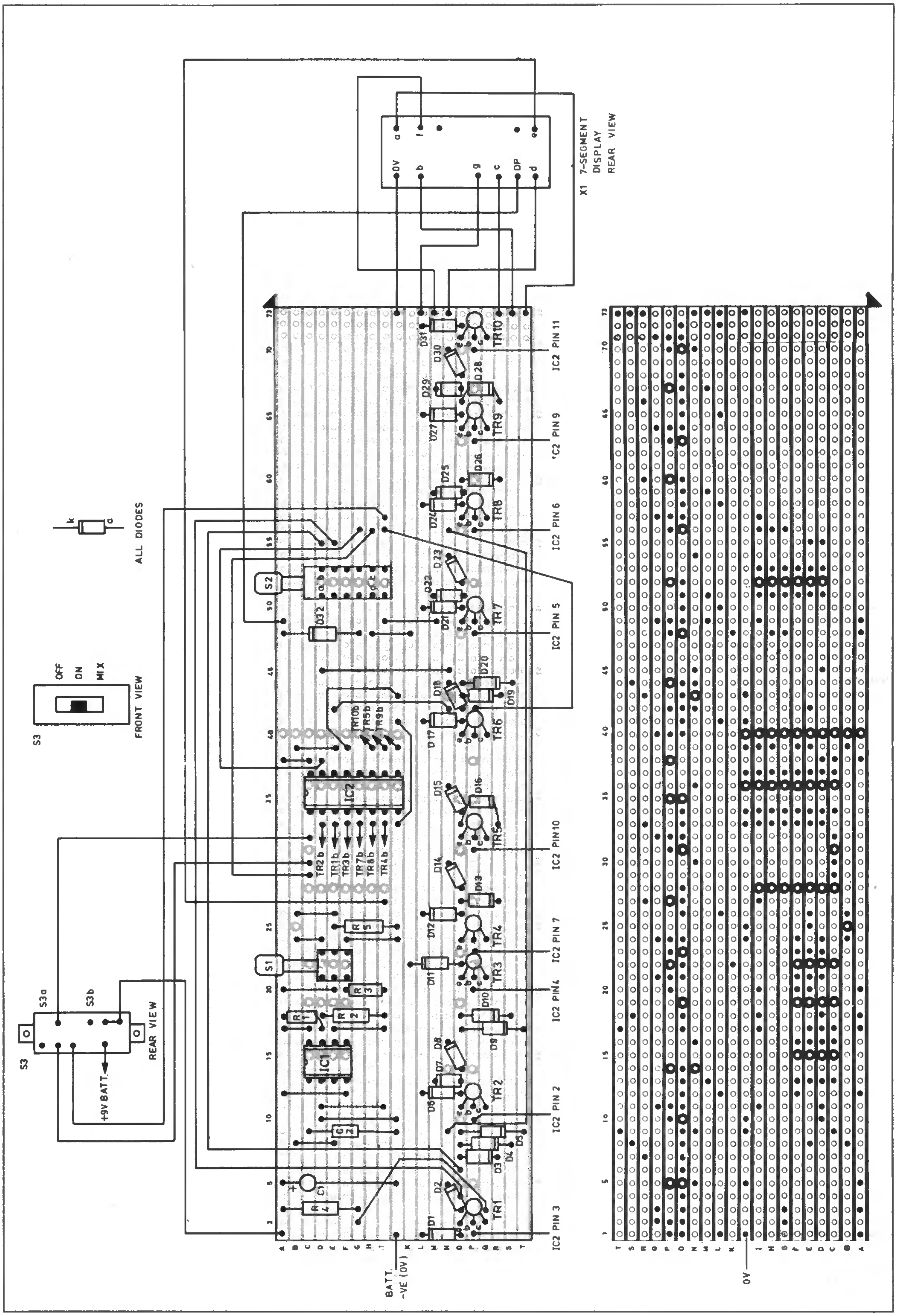


Fig. 2. Topside component layout and underside stripboard track cuts and solder joints for the Counterspell.

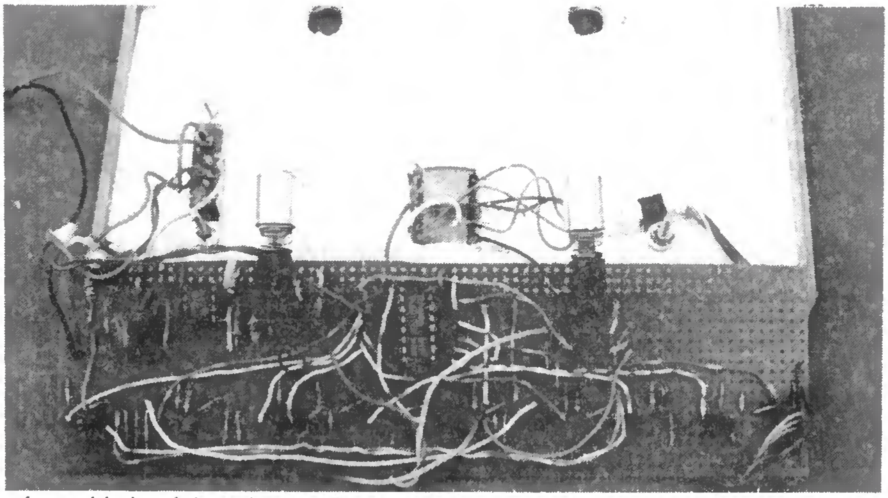
word. For example, the letters "NTL" may prompt the word "NaTuraL" from one player, another with the same combination of letters may suggest the longer word "NaTionaLisation".

Also, two consonants may be selected and a further consonant, as chosen by the contestant, slotted in between. The contestant then has 30 seconds to think up as many words as possible that start with the first consonant and include the other two in the right order. Again, the contestant with the longest word adds a bonus to his or her score.

Another simple game, *Famous Initials*, can use the *Mix* facility. Two letters are selected and contestants have to write down the names of famous people or characters in history, in sport or on TV, etc., that fit the initials, e.g. Abraham Lincoln, Ryan Giggs, Eric Cantona, Ian Botham, Donald Duck.

In the game *Word Power*, a *Mix* of letters is displayed, say six or seven, and written down in turn. Each contestant has to make as many words as possible from three or more letters in a pre-arranged time.

In another game, *Word String*, while again in the *Mix* mode, letters are displayed, and written down in sequence until a contestant spots a word in the string. The contestant shouts out the word (or pushes a precedence switch on an appropriate additional unit) and is awarded points according to the word length. A false claim incurs a penalty. A new string is started whenever a word is claimed. The first player to reach a target number, 20 points for example, is the winner.



Assembled stripboard showing wired interconnections to the front panel components.

VARIATIONS

After much deliberation, the illustrated circuit was designed to generate a useful selection of lower-case letters. Nevertheless, it must be admitted that the vowels would look better if displayed as upper-case letters. The slight problem is with the vowels "a" and "e", which are larger. However, the multiplexing principle should be clear to experienced constructors and, if desired, circuit changes can be made accordingly along the following lines:

A number of variations are possible by using a separate counter for consonants. For instance, one of the author's prototype models used upper-case letters: the five vowels (A, E, I, O, U) on one counter and five consonants (L, P, F, C, H) on another. Resets occurred after each set of five characters by strapping output pin 1 to reset pin 15 on each counter.

For games with small children this combination gave a reasonable vocabulary, but adding more consonants considerably extends the word power. For example, upper-case consonants B, J, F, L, P, H, C, G, and S could be used in the second counter.

SHOP TALK
with David Barrington

Multi-Purpose Thermostat

Several parts for the Multi-Purpose Thermostat require a special mention. The relay specified by the designer features automotive type crimp "spade" terminals, accessible from the top, for the heavy duty contacts. This avoids any problems associated with connecting heavy mains loads directly to a p.c.b.

The specified relay is a Siemens type, is fairly inexpensive, and was supplied by ***Farnell*** of Leeds (☎ ***0532 636311***), order code 224-607. Other relays can, of course, be used but we do not recommend it. Although different types may have a similar electrical rating they may not have the same safety features.

The unique 3-way screw terminal block used by the author incorporates a fuseholder which simplifies construction. This was also purchased from the above mentioned company and the 1¼ inch version is needed for the 13A rating, code 151-999. **Electromail** (☎ ***0536 204555***) will only supply these in "standard multiples of 10", stock code 452-619. Separate parts could be used instead, if desired.

The adjustable, reference voltage, precision shunt regulator type TL431 is currently listed and stocked by Farnell, code TL431CLP and Electromail, code 283-845. If difficulties are experienced in sourcing a supplier of the *CR* snubber network, the one used in the model was purchased from Electromail and is the radial p.c.b. mounting version, code 238-463.

The box used on the prototype came from **ElectroValue** (☎ ***0704 442253***) stock no. 3503. Most of our component advertisers should be able to supply a suitable mains transformer. The model used the Farnell one, code 141-471.

The Thermostat printed circuit board is available from the *EPE PCB Service*, code 931. Finally, due to the presence of mains voltage on the p.c.b., ***extreme care MUST*** be taken when constructing and testing this project.

Name Of The Game – Counterspell

A couple of minor problems could arise when ordering components for *Counterspell*, the first project in the *Name Of The Game* series.

Looking through our library of component catalogues, it appears that a piece of stripboard with the exact number of "holes" is not going to be available over the counter and a certain amount of wastage will have to be tolerated. The answer here is to go for the extra outlay and purchase a piece with enough "extra" holes/strips to cater for a possible future project.

The 2-hole *3-way* slider switch is an item that seems a rarity and may take some finding locally. Some suppliers stock a right-angled p.c.b. mounting version and, as the switch is fixed to the case lid and then interwired to the circuit board, this could be used here. However, a standard vertical type, with screw fixing, is currently listed by **Electromail** (☎ ***0536 204555***), code 334-101.

A similar situation could arise with the one inch 7-segment display. You will have to check very carefully the pinout arrangement of this device as various versions are marketed. The display is also attached (glued) to the case lid, so each lead should be double-checked against each segment when soldering wires to the pins or holder.

Sound Activated Switch

The first of our free p.c.b. projects is a *Sound Activated Switch* and only one component needs carefull selection. The item in question is the relay and if it is to be used to switch mains voltages the contact rating MUST be chosen so it can handle the appliance to be controlled.

The relay can be any 12V type which has a coil resistance of about 300 ohms or more, plus suitable contacts for your particular application. The specified relay can control currents up to 10A, and can be used with a.c. voltages of up to 240V (or a maximum of 30V d.c.). This was purachsed from **Maplin**, code YX97F (10A Mains Relay).

Light Beam Communications

Practically any "ultra-bright" l.e.d. having a light output of about 1·5cd or more at a current of 20mA can be used for the Transmitter output source in the *Light Beam Communication*, free p.c.b. project.

Various 5mm, 8mm, and 10mm l.e.d.s were tried by the author, and the **ElectroValue** (☎ ***0704 442253***) 10mm type (code L8135RC) gave the best results. The highest output **Maplin** 5mm and 8mm l.e.d.s also worked well. All these l.e.d.s have the usual shorter lead to denote the cathode ("k") terminal.

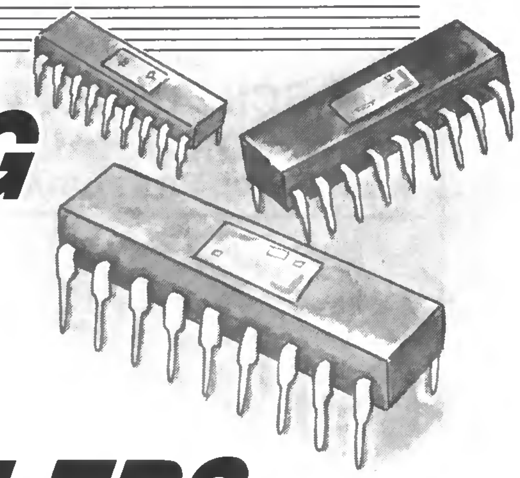
Turning now to the Receiver, all components seem straigthforward and should not present any sourcing difficulties. Most of our component advertisers should stock the BPX25 phototransistor or its equivalent. This includes the TIL81 and the BPY62 types.

The lenses used in this system do not have to be high quality types, and the cheapest of plastic lenses are perfectly satisfactory. The ones used in the models are the red plastic type sold by Maplin, code FA95D, and have a focal length of 80mm, an overall diameter of 37mm, and a lens diameter of 30mm.

Extra printed circuit boards for all the "Multi-board" projects are available from the *EPE PCB Service*, code 932.

All components for the *Audio Amplifier* are standard "off-the-shelf" devices and should be readily available.

Special Feature



UNDERSTANDING PIC MICROCONTROLLERS

BRETT GOSSAGE

A short and simple guide to the new and exciting world of the microcontroller chip, and what it can do for the electronic designer/constructor.

THE NEW buzzword that's been flying around for quite a while now is "microcontroller". It all sounds very "techy" and interesting, but what actually is it all about?

Electronics was revolutionized in the late seventies when the microprocessor chip became readily available to the average electronics buff at a price that he could afford. Thousands of would-be designers got these chips to do what they wanted in their mainly "digital" projects. They learnt about the memory chip and how it could store large amounts of data.

The EPROM allowed you to permanently store "bytes" or "words" in the form of a program which actually did something useful, and keen programmers spent endless nights in front of a VDU screen writing various forms of assembly code that looked quite awe inspiring and frighteningly complex (as well as boring) to the non-technical bod. The I/O chip allowed you to connect your lonely microprocessor to the outside world so you could see things happening when programs were "run". Even timer chips allowed accurate synchronization with other devices.

When all these chips were put together, you essentially had a simple "computer" and an exciting world of possibilities opened up, as you dreamt up new applications for such fast machines.

Table. 1: Comparision of PIC devices.

Features \ PIC type	16C54	16C55	16C56	16C57	16C64	16C71	16C84	17C42
EPROM (bytes)	512	512	1024	2048	2048	1024	1024*	2048
RAM (bytes)	32	32	32	80	128	36	36+64*	232
I/O pins (ports)	12 (4+8)	20 (4+8+8)	12 (4+8)	20 (4+8+8)	33 (6+8+8+8+3)	13 (5+8)	13 (5+8)	33 (6+8+8+8+3)
No. instructions	33	33	33	33	35	35	35	55
Instruction size (bits)	12	12	12	12	14	14	14	16
Stack size (bytes)	2	2	2	2	8	8	8	16
Number of pins	18	28	18	28	40	18	18	40
Interrupt sources	-	-	-	-	-	4	4	11
A/D converter	no	no	no	no	no	yes	no	no
Power up timer	no	no	no	no	yes	yes	yes	yes
Direct Microprocessor Interfacing	no	no	no	no	yes	no	no	yes

MICROCONTROLLER

Enter the *microcontroller* – all those i.c.s that you painstakingly learnt about and connected together now appear in the guise of a single chip. Gone are the days of designing complicated address decoding circuits, involving lots of extra logic i.c.s. No more need to design stable oscillators, power-up or memory refresh circuits. Everything that you could ever think of has now been designed and sorted out for you.

A disadvantage I hear you cry! well, this is one of the few disadvantages of microcontrollers – the design of the basic computer part of your circuit has been done for you, and this may take away some of the satisfaction of building your project. But the advantages are endless.

This new technology uses very high clock speeds up to 20MHz, and together with efficient single word processor instructions, makes programming a lot simpler. Of course traditional microprocessors will still be used for the more ambitious projects, or applications where lots of data needs to be handled or processed. So it's not quite the end for the good old 8-bit micro ... well not yet anyway!

Microcontroller projects have already begun to appear in *EPE*, especially in recent issues. However, I did find one project in *EPE* dating back over two years to June 1992 (*Digital Servo Interface*) which used a PIC 16C54 type microcontroller.

Those of you with microprocessor experience who have not succumbed to this new idea should be warned that it looks like microcontrollers are becoming very popular already, so familiarising yourself with these beasts is definitely a good thing. I'm sure that a lot of simple projects will start to use them, and because they are so easy to use, they might attract new designers into the field who could never really get the hang of microprocessor circuits!

TAKE YOUR PIC

Here are a few of the advantages of using a microcontroller in your next project as opposed to the usual microprocessor and its associated hardware:

a) Because the microcontroller takes the place of several discreet i.c.s, there is a lower component count, so your circuit will:

i) Cost less to build
ii) Have a simpler p.c.b. and overlay design and will therefore be easier to make.
iii) Due to ii), will have a reduced overall physical size, allowing a neater design and construction with fewer possibilities of error in both.

b) Higher clock speeds coupled together with single word instructions allow faster processing of data, opening up more applications for microcontrollers.

c) Power saving. As microcontrollers are CMOS devices, a miniscule amount of power is required to supply them, and even the voltage levels have reduced to around 1·5V in some cases. Yes, battery power seems to be the thing!

DESCRIPTION

There are several families of microcontrollers currently available from different manufacturers, and each family has a varied range of i.c.s which have different functions, so the idea is to pick out a particular microcontroller from a range to fit your project's needs. As it would be too difficult to outline all types of microcontroller, only one of the more popular series is described in this article. The one chosen is the "PIC" (Peripheral Interface Controller) series, manufactured by Arizona Microchip.

As with most i.c.s, these are manufactured in 0·3 and 0·6 inch d.i.l. style packages. The 0·3in. type are 18-pin devices, and are no bigger than most logic i.c.s.

The 0·6 inch EPROM variety look so much like ordinary EPROMS that a close look inside the "window" is needed to tell the difference. Whereas the EPROM has one or two distinct regions on the silicon wafer that constitute the memory areas, the microcontroller has several smaller regions.

GENERAL OVERVIEW

There are essentially two differing families of PIC microcontroller. These are denoted by the 16CXX or the 17CXX series. The "XX" denotes various members within the family, and some of the pinout differences are outlined in Fig. 1. The smaller i.c.s have two "ports" A and B whose pins are denoted by RAn and RBn. (where "n" refers to each bit of the respective ports which can be programmed as an input or an output).

The 16C71 has a four channel analogue-to-digital converter (AIN0-3). The 16C84 is an EEROM version of the 16C71 (without the A/D converter). The 17C42 has five ports of various sizes, serial comms. functions with various timers, as well as the ability to connect directly to existing microprocessor circuits.

The main distinct advantage of the microcontroller design is that the RAM and EPROM (and sometimes EEROM as in the new PIC 16C84) are located all within the one package, and as mentioned earlier, there is no more need to worry about address decoding.

In PIC microcontrollers, these memory areas tend to be small, in the order of 1K or 2K bytes, and therefore the types of programs that can be run using them is limited. It is only in the most demanding of applications requiring large blocks of memory for data storage in which microcontrollers become less useful.

Never mind, they can't be all good! As a matter of fact, the widespread use of microcontrollers in simple applications has worried a lot of the manufacturers of "peripheral" i.c.s (memory I/O TTL logic etc.), as they are no longer required. In a way, it seems a bit of a cheat putting most of these functions all on one chip, but that's technology for you!

It seems that two of the main differences between the controller chips is the amount of memory they have on board, and the number of I/O or Input/Output pins they have available. To compare the differences between the different PIC microcontrollers, see Table 1.

EPROM VERSUS OTP

For development and test purposes, you need to alter any on-board program within the microcontroller chip, so all devices are available in EPROM and OTP (One Time

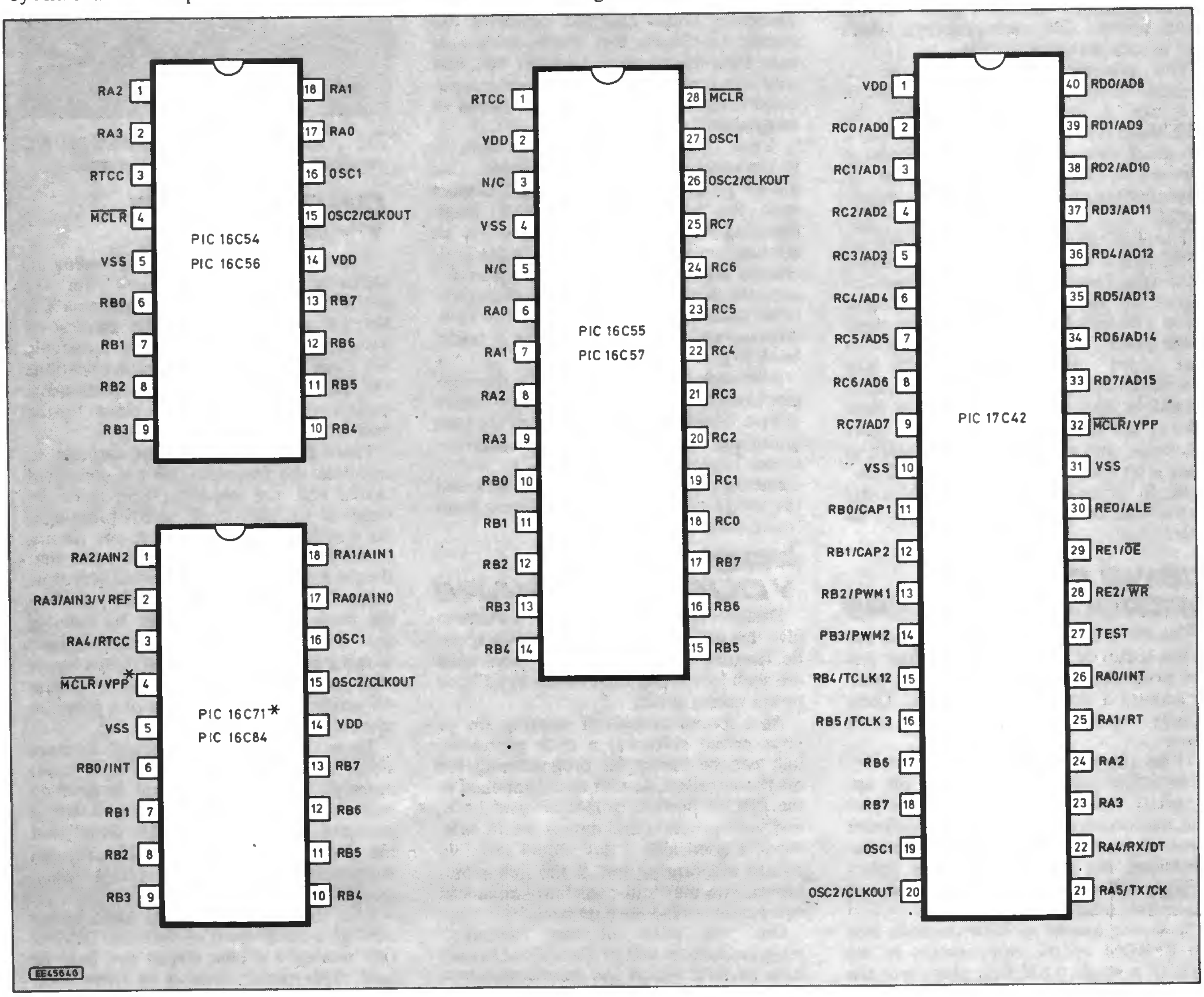


Fig. 1. Pinout details for part of the family of PIC Microcontrollers.

Programmable) types. The latter are relatively cheap but can only be "blown" with a program once – if you get your program wrong, the chip will be useless and it will have to be consigned to the bin! So, the idea is to thoroughly debug and test your software before programming it into an OTP device.

The EPROM types, as already mentioned, look like ordinary EPROMs and similarly, have a life of over 10,000 program/erase cycles, so under normal use should never wear out! Their cost runs at about three or four times that of their OTP counterparts, e.g. about £25 for the EPROM 16C71 PIC and about £7 for the OTP version. The design engineer will typically buy only one or two types of EPROM PIC to experiment with.

One point to mention is that the OTP devices come with specific oscillator configurations, so not all combinations of OTP chip are available. Check by looking at the last two letters on the chip markings, which denote the oscillator type.

RISCy BUSINESS

For quite some time now, there have been dedicated microprocessor i.c.s on the market designed for use in everyday items such as washing machines or drink dispensers. Because of the simple and often repetitive functions that they have to control within these machines, they operate using a program which may be large, but consists only of a handful of different instructions (much unlike the good old, and much revered Z80 microprocessor which had to cope with nearly 700!).

This inherent design makes the i.c. cheaper to manufacture and also easier to program. A name was coined for this specialised type of "controller" chip, and it has stuck ever since. "RISC" or Reduced Instruction Set Computer, is now an important anacronym in todays computer world.

The PIC microcontroller i.c.s are all RISC based, having around thirty instructions (the functions of some of the i.c.s higher up the range warrant a couple more additional instructions than those lower down), and all of these consist of one "word" containing 14 or 16 bits. The advantages of single word instructions should be obvious: Programs using them take up less space in ROM, they run more efficiently, and consequently run faster, as there is no need to execute a second "fetch" cycle to bring in data for a particular instruction, unlike many of the usual 8-bit micro i.c.s.

USING PIC MICROCONTROLLERS

The PIC chip on its own is not much use unless it can be programmed! Before you can program any such chip, you'll need to acquire a development system. These usually consist of the following three items:

1) An assembler program, run on a PC, to assemble your programs into the appropriate "machine" code for the respective microcontroller (Yes! – the different types of controller may have similar instructions, but the object code is unfortunately different! – as some are 14-bit and others are 16-bit devices).

2) A programmer to blow the code into the EPROM on the chip, usually in the form of a single p.c.b. that plugs into the serial or parallel port of a PC.

3) A simulator, again a program for your PC that simulates running a PIC program at a greatly reduced speed, so you can see how the contents of various registers are changing as each instruction is executed.

Armed with a set-up consisting of these three basic elements, you're ready to go!

The manufacturers of PIC microcontrollers, Arizona Microchip (who have their European headquarters based at Bourne End near Henley-On-Thames), offer several kits, and these usually comprise of hardware connected to a PC via a comms. port, and PC software in the form of floppy disks.

The "Picstart" system (available from Radio Spares (Electromail), Maplin Electronic Supplies etc.) is regarded by Arizona Microchip as a basic "Low-cost" system. The price of approx £170 certainly made me think twice about spending a fair sum of hard-earned cash on a system which I knew nothing about. Once I'd spent a while playing with the software and consulting the concise manuals, I found this package quite acceptable, and a good introduction to the PIC microcontroller devices, although it did not cater for the 17CXX series.

The items supplied in the kit are: a data book, laid out in the standard form of data books! and can therefore be quite difficult to follow in certain areas, especially for beginners. A floppy disk containing an assembler to assemble the code for any of the 16CXX chips, and a simulator to "run" the assembled code to check for programming errors etc. The simulator did appear to operate too slowly, (this may have been due to my rickety old PC), and was not very useful for the more complicated programs, however, it was found to be a necessary tool.

A small piece of hardware, that connects to the serial port of a PC is included. This allows programming of the said devices with the usual verification and blank checking features. Also thrown in, is an applications manual which includes both circuits and software for typical "starter" projects, ranging from serial communications (simplex and duplex), driving l.e.d. displays and multiplexing. Quite a useful book to give you some ideas.

Although the whole idea of a development system sounds inconceivably complex at first, having to learn how to use the programs and hardware all at once, it soon becomes interesting as you begin to understand the concepts of microcontrollers, and the things that make them different from traditional microprocessors.

PROTECTING YOUR SOFTWARE

Designers have been working overtime to give this new range of i.c.s their own specific features. Those yet to be mentioned are such interesting ones as the SLEEP, or power saving mode.

As a special method of securing any of your prized software, a code protection link can be blown on programming the microcontrollers, so that data contained in the PROM portion cannot be read back, and your program and data is totally safe. What a good idea – this should certainly reduce software piracy! If the link is not blown, you may still need fairly advanced equipment to read the data back.

One side effect of this "designer" programming, is that projects in magazines such as *EPE* which use microcontrollers, require the constructor to "buy" the software in the form of a pre-programmed PIC i.c. to make that project do anything. As it is obviously useless without it, and because most microcontroller projects use few i.c.s (sometimes only the PIC i.c. itself), the excitement of constructing and testing bits of your circuit might be reduced.

The current price of the cheapest PIC device, the 16C54 OTP, is about £5.

FEATURES

Here is a brief outline of some of the more common features that most PIC i.c.s have in common (see Table. 1 for some specific differences). A large amount of flexibility has been designed into these i.c.s, one area being the type of oscillator that can be used to drive the devices.

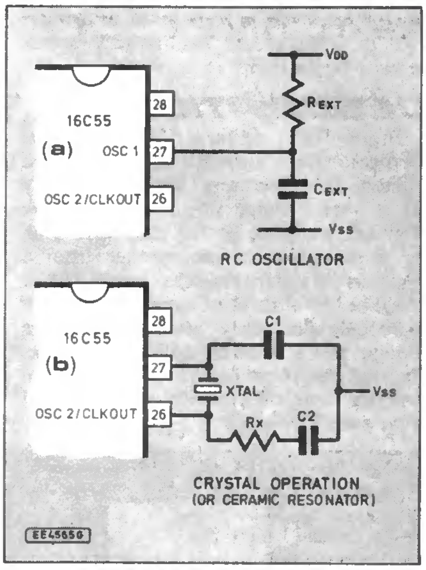


Fig. 2. Oscillator configuration (a) RC oscillator and (b) crystal operation.

OSCILLATOR TYPE

There are four methods of providing an oscillator to act as a "clock" for the 16CXX series i.c.s, these are known as XT, HS, LP and RC modes. The simplest of these and the most convenient is the simple *RC* clock (See Fig. 2a). Most applications will use this, as only two extra components make a neat and simple clock circuit for the microcontroller.

There is no hard and fast formula to calculate the frequency of the generated clock, and the capacitor can even be removed for high clock speeds (although, for stability purposes, this is not recommended). Another unusual feature is that the clock speed can be reduced to very slow values by using a large capacitor, enabling the more ambitious designer to monitor any PIC signals on an oscilloscope. Slowing down the clock speed in this way is also good for tuition purposes, by seeing the action of each instruction of a program more clearly.

Those applications requiring a more stable clock signal, e.g. for serial communications, a crystal circuit is strongly recommended. "XT" mode is used with a standard crystal. (A few tests found that the clock speed varied dramatically with temperature and supply voltage when using the simple *RC* circuit!).

Also, for any high speed applications needing a clock speed of 8MHz to 20MHz (HS mode), a crystal circuit can only be used. This circuit consists of three components (See Fig 2b), the crystal itself (or ceramic resonator), and two low value stabilizing capacitors. For certain crystals, an additional resistor (Rx) may be required to prevent overdriving of the crystal. The fourth oscillator configuration is the "LP" or Low Power mode. For use with low frequency crystals.

OSCILLATOR START-UP TIMER

Quite important for the dedicated designer – when power is supplied to a crystal or ceramic resonator type oscillator circuit, it takes a while for it to stabilize. Here, a start-up timer acts as a power-on-reset circuit for the i.c. and waits for 18mS after the level on the MCLR pin has gone "high", before the chip starts running its program.

REAL TIME CLOCK

The use of a real time clock for controlling any I/O is invaluable. I once tried to write a 24-hour digital clock program using software timing loops, and having spent ages adjusting and re-adjusting these loops on a day-to-day basis, its inaccuracies soon became very apparent! A crystal oscillator is an absolute must to give good timing accuracy.

The Real Time Clock has its own eight-bit register or file, address 01H, and it is incremented at a quarter of the oscillator's clock speed. There is a built-in (surprise !) "prescaler" which is basically a divider which slows down the count in file 01H by one of a set of fixed amounts which is set up by a special register called the OPTION file.

On power up, the default division is set to 1, and the Real Time Clock file, 01H, increments as each instruction is executed. If an external signal is present on the RTCC pin, the file will be incremented by that. It is up to the programmer to make use of the number in this file, testing it for particular values such as zero, and then acting on that condition.

Another use for the Real Time Clock is in the transmission or reception of serial data. Accurate communication with an external device without any form of synchronization can be achieved. If the PIC clock speed is known, an accurate calculation can be made to determine what value the Real Time Clock file needs to count up to, during the output of each bit of data.

ARE YOU ASLEEP YET?

An interesting feature of all PIC microcontroller i.c.s is the ability to shut down if not required, and then "wake up" dependent on some specific input. This has the tremendous advantage of power saving when the circuit is not in use, and, dependent on what your application is, can even eliminate the need to incorporate an On/Off switch into the circuit.

Power consumption is so small during this "sleep" mode that the device can be left on continuously, making it ideal for battery operated projects. How many times have you left your project running, and returned to find yet another set of flat batteries? The PIC also knows whether it was woken from the sleep mode, or merely just reset, such a clever little chip!

WATCHDOG TIMER

Also included on board the i.c. is a Watchdog Timer. This is a totally independent piece of circuitry with its own clock, that detects if the program has "crashed", i.e. has stopped running, and resets the chip automatically to restart the program again. This can be disabled.

The delay before the Watchdog Timer "times out" can be programmed. A feature of this sort is important in security applications, or projects where continuous monitoring is required. A sudden short power failure may cause a circuit to "glitch" or lock up, so here, a Watchdog Timer is necessary.

If you've got this far, you should now know a little about the hardware and the features of PIC microcontrollers. Now is the time to take the "lid" off them and see how to drive them.

INTERNAL ARCHITECTURE

Those of you with some microprocessor experience will notice some similarity in the hardware design of the register "map". Fig. 3 shows the basic layout of registers or "files" used with most of this particular series of PIC microcontrollers. Most are 8-bit, and have a unique file address allotted to them. i.e. when outputting data to PORT A, the data is written to file 05H (See "Use the Instructions").

The working register or "accumulator" is W, and general purpose registers are allotted file numbers from 08H through to 7FH, so there are many more of these user registers, (up to 72 depending on which PIC i.c.) compared to the six that are available in a Z80 micro for instance. These general purpose registers constitute the RAM in the chip, and at first, seem to be a measly amount. Surprisingly, they usually end up being quite adequate, depending on the complexity of the program.

All the 16CXX series PIC i.c.s have PORTS, (some 4 or 5-bit – usually PORT A, and some 8-bit – PORTS B and C) and these always have the same file addresses of 5, 6 and 7 respectively (some i.c.s do not have port C, address 07H, see Fig. 1).

The STATUS or "Flags" register's job is to keep a running commentary on the result of various mathematical operations, among other functions, and is labelled as file 03H.

The PROGRAM COUNTER is always file 02H, and can be written to, like any of the other registers. Writing to the PC would cause the program to "jump" and continue running from a different location in memory, rather like executing a GOTO instruction.

File 01H contains the count for a REAL TIME CLOCK chip that is built into the hardware and can be used or disabled as appropriate.

Finally, file 00H is not a register at all, but is used to indirectly address other registers via the FILE SELECT REGISTER, file 04H.

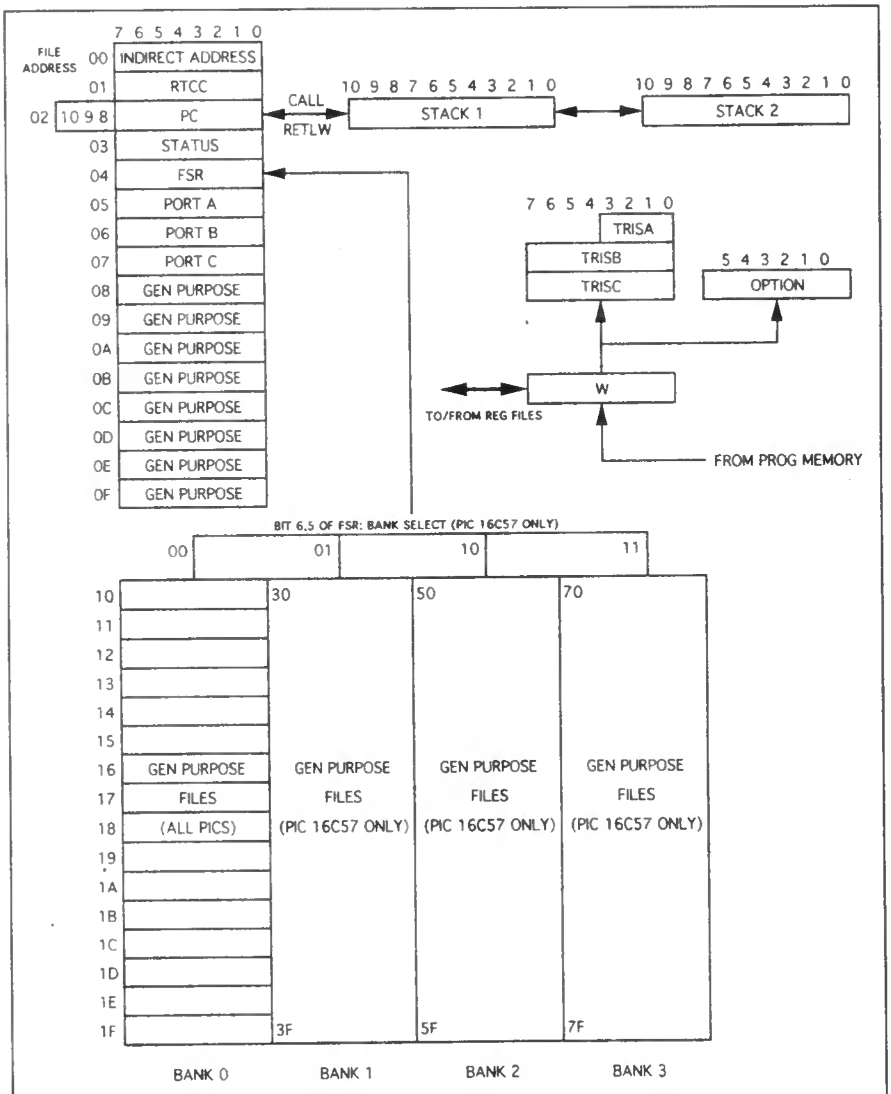


Fig. 3. File allocation and Data memory map.

A two level stack of 10 bits is incorporated on some PIC i.c.s, so your program can only have up to two nested subroutines, or "calls".

The TRIS files are set-up, usually at the beginning of a program to configure the ports. Each bit of any port can be defined as an input or an output. i.e. loading TRIS B with 0FH would set up the higher four bits of PORT B as outputs, with the rest of the bits as inputs. The default on boot-up is to set all ports as inputs, to protect the chip should these pins be shorted to ground etc.

USE THE INSTRUCTIONS

As already mentioned, due to the PIC's RISC based operation, it's easy to get to know all the thirty or so instructions, and then use them in quite complex programs. Fig. 4 shows the complete list of the instructions. Again this section is mainly useful to those who have experience of microprocessors and machine code assembly, to compare the types and functions of, these instructions with those of their favourite micro.

```
Label   Instruction      Comments

        CLRW             Clear the Working register
        MOVWF   10,f     and clear file 10H
NEXT    MOVF    10,W     Put value in file 10H into W
        CALL    TABLE    Go and get data from 'TABLE'
        MOVWF   5,f      'Output' data in W to port A
        INCF    10,f     Increment the data count in 10H
        BCF     10,2     Reset bit 2 (count must not exceed 3)
        GOTO    NEXT     Continue

TABLE   ADDWF   2,f      Add value in W to Program Counter
        RETLW   5AH      Return to main prog. with 5AH in W
        RETLW   01H      Return to main prog. with 01H in W
        RETLW   88H      Return to main prog. with 88H in W
        RETLW   59H      Return to main prog. with 59H in W
```

Fig. 5. Using subroutines.

Instruction (Hex)	Name	Mnemonic	Operands
1Cf	Add W and f	ADDWF	f, d
14f	AND W with f	ANDWF	f, d
06f	Clear f	CLRF	f
040	Clear W	CLRW	-
24f	Complement f	COMF	f, d
0Cf	Decrement f	DECF	f, d
2Cf	Dec f & skip if 0	DECFSZ	f, d
28f	Increment f	INCF	f, d
3Cf	Inc f & skip if 0	INCFSZ	f, d
10f	Inclusive OR W & f	IORWF	f, d
20f	Move f	MOVF	f, d
02f	Move W to f	MOVWF	f
000	No operation	NOP	f, d
34f	Rotate left f	RLF	f, d
30f	Rotate right f	RRF	f, d
08f	Subtract W from f	SUBWF	f, d
38f	Swap halves f	SWAPF	f, d
18f	Exclusive OR W and f	XORWF	f, d
4bf	Bit clear f	BCF	f, b
5bf	Bit set f	BSF	f, b
6bf	Bit test f,skip if clear	BTFSC	f, b
7bf	Bit test f,skip if set	BTFSS	f, b
Ekk	AND literal and W	ANDLW	k
9kk	Call subroutine	CALL	k
004	Clear watchdog timer	CLRWDT	-
Akk	Goto address	GOTO	k
Dkk	Incl. OR literal and W	IORLW	k
Ckk	Move literal to W	MOVLW	k
002	Load option register	OPTION	-
8kk	Return,literal in W	RETLW	k
003	Go into standby mode	SLEEP	-
00f	Tristate port f	TRIS	f
Fkk	Excl. OR literal and W	XORLW	k

Fig. 4. The Instruction Set.

The following section briefly shows the use of most of the instructions for the PIC i.c. family:

To load a user register, say file 10H, with some data, say 55H, the following two steps are required:-

MOVLW 55
MOVWF 10

Here, the data is first moved into the W, or "Working" register (the accumulator). The instruction means "Move Literal W", and then the contents of this register are then moved into the "f" or file register specified, in this case file 10H.

Similarly, to move data from one file to another requires the use of the W register as shown, and this is also achieved in two steps:

MOVF 10,W
MOVWF 11

Here, the data in file 10H is first moved into the W register using the "Move File" instruction, and then the data is as in the previous example, moved into file 11H. This may appear long-winded when compared to some micros, but remember that each line is executed as a single 14 or 16-bit instruction.

THE SECOND OPERAND

To increment or decrement the contents of a file, the corresponding INCF or DECF instruction is used. The result however, can be put into the W register leaving the file register unchanged.

This can be useful if you need to test the result of a function before putting the value back into its file register. A lot of instructions have this feature, and it is determined by the second operand in the instruction.

e.g. XORWF 10,f

means exclusive OR the contents of the W register with the contents of file 10H, and then put the result back in file 10H, overwriting the original data in file 10H, whereas

XORWF 10,W

places the contents of the result in W, leaving file 10H unchanged. This second operand does not always need to be specified in the assembler code, if it does not, the default value is "f" so the following instruction format is valid:

XORWF 10

Other "logical" instructions include:
'inclusive OR' (IORLW, IORWF);
'AND' (ANDLW, ANDWF);
'ADD' and 'SUB'tract (ADDWF, SUBWF)
(Note that on some of the smaller PIC i.c.s, the ADDLW and SUBLW instructions are unusually omitted).

BIT FILE INSTRUCTIONS

The simplest form of the bit manipulation instructions is BSF, which need two operands to be specified, i.e. which bit in which file is to be "SET":

e.g. BSF 10,6

this sets bit 6 in file 10H. Conversely, the BCF instruction works in the same way, but resets the bit. A useful extension of the bit manipulation instructions are the bit test pair of instructions.

BTFSS means bit test the file and skip if the bit is set:

e.g. BTFSS 10,6

means test bit 6 of file 10H, and then skip the next instruction of the code if it is SET. This is where a GOTO or branch instruction is placed, and splits the program execution into two sections. Depending on the result of the bit test, the GOTO is either executed, or skipped.

There are only two "rotate" instructions, but these both work differently dependent on the status of the "carry" bit, which is bit 0 in the STATUS file (03H):

e.g. RLF 10

rotates the contents of file 10H to the left, which is effectively the same as multiplying the contents by two, whereas:

RRF 10

rotates the contents to the right, effectively dividing by two.

AND THE REST

Several instructions are self explanatory, NOP is the famous "no operation" and its opcode is not surprisingly 00H. Complementing (2's complement) file 10H can be achieved using:

COMF 10.

A specific file can be cleared, or loaded with 0 using CLRF, and similarly, the working register W can be cleared using CLRW.

The TRIS instruction sets up the function of the ports:

e.g. TRISA 1F = (00011111)

sets the three high bits of port A to act as outputs, and the lower five bits to become inputs. All the bits of all ports are set up as inputs on boot-up of the i.c.

The SWAPF instruction swaps the higher and lower "nibbles" (four bits) of any register, this could be quite useful for 7-segment display driving purposes.

SUBROUTINES

Most of the PIC microcontrollers only have two levels of "stack" i.e. only two "nested" subroutines can be called. These are 10-bit registers (see Fig. 3).

The CALL instruction calls a subroutine directly, and that subroutine must end with the instruction RETLW. The RETLW instruction (return with a "literal" value in W) is the same as the more familiar RETURN instruction used with most micros, but has the additional feature of going back to the main program with this value in W.

This may not appear very useful when used as in a normal subroutine call,

```
Label       Instruction          Comments

            CLRW      0          Put 0 in the Working register
            TRIS      6          Set up PORT B as all outputs

NEXT        BSF       6,0        Set bit 0 of port B

DELAY       DECFSZ    10,f       Decrement delay count and skip if 0
            GOTO      DELAY      Repeat until 0

            BCF       6,0        Clear bit 0 of port B

DELAY2      DECFSZ    10,f       Decrement delay count and skip if 0
            GOTO      DELAY2     Repeat until 0

            GOTO      NEXT
```

Fig. 6. Software routine to flash an l.e.d. on bit 0 of PORT B.

but suddenly becomes invaluable when accessing a table of data. Remember that the RAM in a microcontroller is effectively the general purpose files or registers. Data in the EPROM can be accessed indirectly by adding a value to the program counter file (02H). The example in Fig. 5 repeatedly outputs a set of four bytes of data to port A.

SLEEP INSTRUCTION

The clock on the OSC pins of any PIC device is stopped when a SLEEP instruction is executed. This is known as the power-down mode.

The i.c. can be "woken up" by an externally applied low pulse on the $\overline{MCLR}$ pin, or the watchdog timer with its own oscillator can cause a "wake up" condition if it times out (if enabled). The useful aspect is that the i.c. knows whether it was woken from sleep, or just powered up normally via a bit in the STATUS register (03H).

GETTING STARTED

The first attempt at working with a 16C54 PIC controller was to flash an l.e.d on one bit of one of the ports. This may seem a little unambitious, but it was thought that it was essential to get to know the basic programming concepts of the PIC.

It was simply done by outputting an alternating high and low logic level on bit 0 of PORT B (RB0), with a suitable software delay in between. This simple exercise was useful to appreciate the setting up of the port configurations, and the use of software delays. An example of the software is shown in Fig. 6.

The description of what each instruction does should be fairly straightforward, especially for those familiar with microprocessors. If not, try reading the "Use the Instructions" section of this article. The two delays, to slow down the flashing, use file 10H in each case and are shown separately for simplicity. Notice how the circuit, shown in Fig. 7, has a minimum of components.

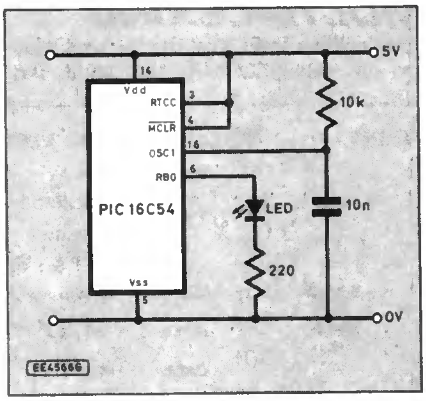


Fig. 7. Circuit diagram for the flashing l.e.d. example.

After that, the above was expanded to increment a binary count on eight l.e.d.s, again on PORT B (RB0-7), and then only after pressing a button which grounded a bit set up as an input on the other port, PORT A (RA0). Again, the software for this is shown in Fig. 8, and the circuit in Fig. 9.

Notice how the software execution is confined to the small section called "LOOP" until the button is pressed. Port A does not need to be set up because it is already configured as inputs on power-up of the i.c.

Next, a table of data in ROM was made up, in which each value was called sequentially, to drive a 7-segment display connected to PORT B, (RB0-6), so that it counted from 0 to 9 repeatedly. This introduced the use of subroutines and the ability to access data stored in a table in memory (See Fig. 10).

The 7-segment display used was the common cathode type, so the common was tied "low" (See Fig. 11). The display therefore works with "positive" logic, i.e. segments light up when the outputs from PORT B go "high".

File 10H is used for the delay as in the previous example, and file 11H, "digit count", is the offset which is added to the program counter when the subroutine is called, to return with segment data. i.e. first time through the program, its value is

```
Label      Instruction        Comments
           CLRW     0         Put 0 in the Working register
           TRIS     6         Set up PORT B as all outputs

LOOP       BTFSC    5,0       Has button been pressed?
           GOTO     LOOP      Back to 'LOOP' if not
NEXT       INCF     6,f       'Increment' data in PORT B

DELAY      DECFSZ   10,f      Decrement delay count and skip if 0
           GOTO     DELAY     Repeat until 0

           GOTO     NEXT
```

Fig. 8. A binary count on PORT B (8 l.e.d.s).

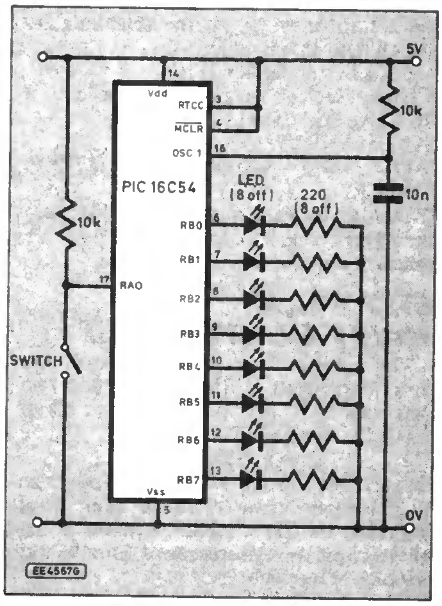


Fig. 9. Circuit diagram for the binary count example.

zero, so it picks up the first value from the table "3F" which is the data for the segments of digit "0".

DISPLAY MULTIPLEXING

Moving on from this, driving one digit was not enough! Finally that night, the ambition was to drive four 7-segment displays by multiplexing them. Once again, the 16C54 i.c. is designed beautifully to accommodate the drive for the segments of the displays *a* to *f* on PORT B, (RB7 is not used), and the four bits of PORT A were used to drive each digit sequentially.

The idea being that data would be written to only one display at a time, but due to the speed of operation of the i.c. (800kHz in this case), all four digits would appear to be lit. See the circuit diagram shown in Fig. 12.

```
Label      Instruction        Comments
           CLRW     0         Put 0 in the Working register
           TRIS     6         Set up PORT B as all outputs

RESET      CLRF     11,f      Start/reset the digit count at 0
NEXT       MOVF     11,W      Put next digit count in W
           CALL     CONVRT    Call subroutine to get segment data
           MOVWF    6         Output the segment data to PORT B
DELAY      DECFSZ   10,f      Decrement delay count and skip if 0
           GOTO     DELAY     Repeat until 0
           INCF     11,f      Increment the digit count
           MOVF     11,W      Put this value in W
           XORLW    0A        Check if count is beyond '9'
           BTFSC    3,2       Check zero flag in the Status File
           GOTO     RESET     If flag set then reset digit count
           GOTO     NEXT      Get data for next digit (0-9)

CONVRT     ADDWF    2,f       Add offset to PC to get segment data
           RETLW    3F        '0' in 7-segment code
           RETLW    06        '1' in 7-segment code
           RETLW    5B        '2' in 7-segment code
           RETLW    4F        '3' in 7-segment code
           RETLW    66        '4' in 7-segment code
           RETLW    6D        '5' in 7-segment code
           RETLW    7D        '6' in 7-segment code
           RETLW    07        '7' in 7-segment code
           RETLW    7F        '8' in 7-segment code
           RETLW    6F        '9' in 7-segment code
```

Fig. 10. Software routine to drive a 7-segment display count on PORT B.

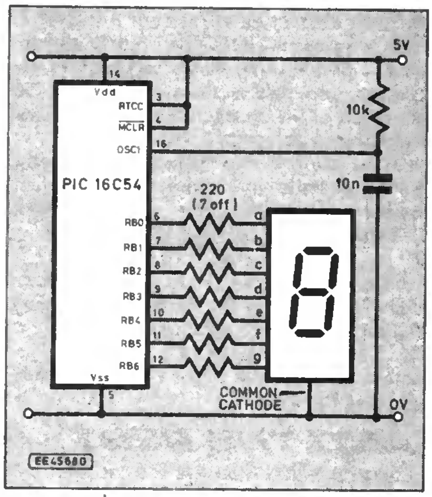


Fig. 11. Circuit diagram for driving a 7-segment display.

Multiplexing in this way is useful to simplify the circuitry, but it does tend to increase the complexity of the software. Fig. 13 shows a simplified example of multiplexing, with all four displays driven with a count of 0-9.

The complete listing consists of a large repeating loop of instructions, and every time around that loop, a different display is driven. So with four 7-segment displays, each digit is driven only once in every four "loops" of the program. A bit cycles around the lower "nibble" of PORT A, corresponding to the digit to be driven.

Good programming should ensure that only one display is driven at a time, and also that the data for it is not changed whilst it is being driven, otherwise uneven illumination or flickering may occur. A flowchart shows this procedure more clearly in Fig. 14.

SIDE EFFECTS

There are some side effects of multiplexing displays in this way. One is that because each display is only on for a quarter of the time, it appears relatively dim. A simple

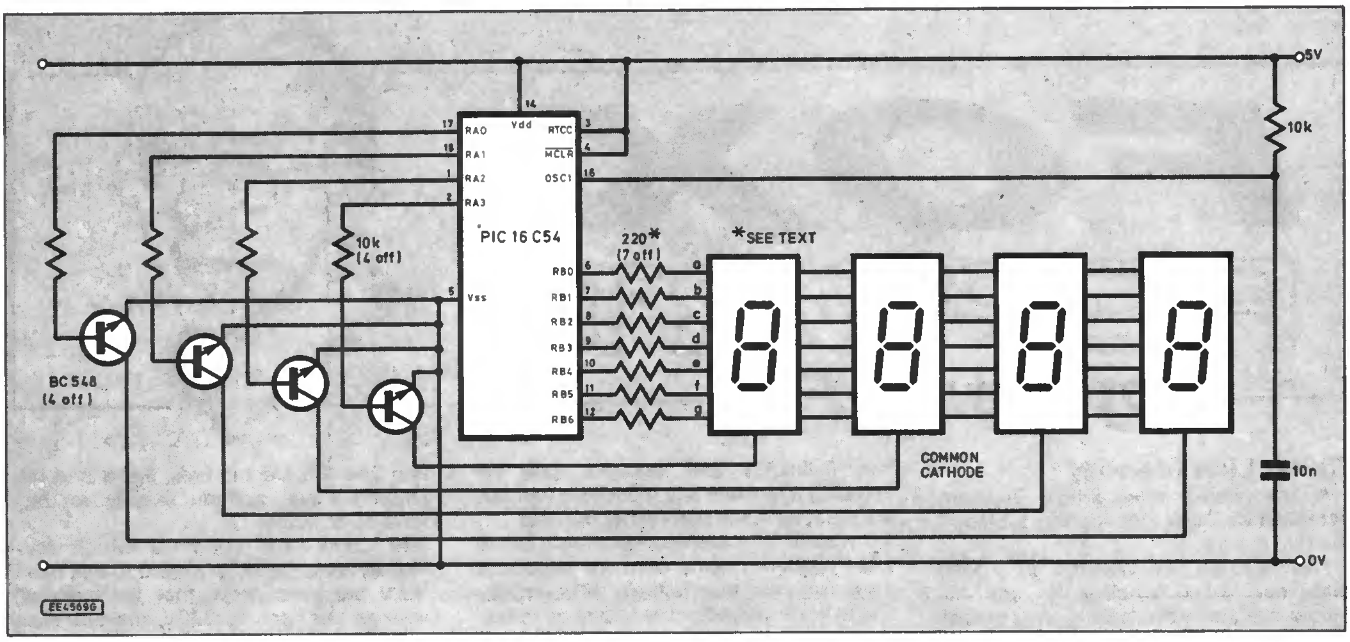


Fig. 12. Circuit diagram for driving four 7-segment displays using multiplexing.

```
Label       Instruction          Comments

            CLRW     0           Put 0 in the Working register
            TRIS     5           Set up PORT A as all outputs
            TRIS     6           Set up PORT B as all outputs
            MOVLW    1           Put 1 in the Working register
            MOVWF    12          Start drive on first digit

NEXT        BTFSC    12,3        File 12 is digit drive data
            GOTO     NEXT1       Goto NEXT1 if 4th digit just driven
            RLF      12,f        Rotate file to select next digit
            GOTO     NEXT2       Miss the next two instructions
NEXT1       BCF      12,3        Reset drive to 4th digit
            BSF      12,0        Set drive to 1st digit
NEXT2       CLRF     5           Switch off drive to any digit
            MOVF     13,W        File 13 holds any new segment data
            MOVWF    6           Output this to PORT B
            MOVF     12,W        Put digit drive data in W
            MOVWF    5           Switch on drive by output to PORT A
DELAY       DECFSZ   10,f        Decrement delay count and skip if 0
            GOTO     NEXT        Repeat whole loop until count is 0
DIGIT       INCF     11,f        File 11 contains offset for digit
            MOVF     11,W        Move this into W
            XORLW    0A          Check if count beyond '9'
            BTFSC    3,2         Result would set zero flag if true
            CLRF     11          Reset offset count if zero flag set
            MOVF     11,W        Put this into W
            CALL     CONVRT      Call subroutine to get segment data
            MOVWF    13          Put this new data into File 13
            GOTO     NEXT        Go back to main loop

CONVRT      (As per Fig. 10)
```

Fig. 13. Software routine to drive four 7-segment displays by multiplexing.

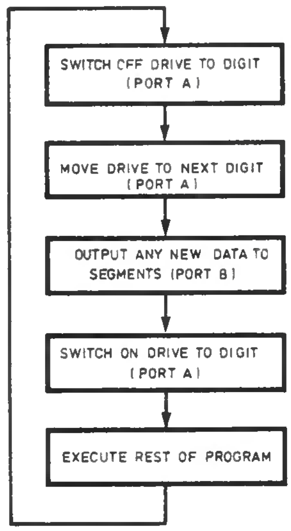


Fig. 14. A software procedure for multiplexing.

solution is to reduce the value of the current limiting resistors shown to 56 ohms and "overdrive" the segments with four times their rated current. The displays should survive this, but care should be taken as the i.c. is now also providing four times its rated "port" current to drive them! (The maximum rated port current as a whole, is around 40mA, so current limiting resistors are needed when driving this number of l.e.d.s).

Transistors are also needed to sink current from each of the common cathodes of the displays, as this could be around 150mA if all segments are on. This process of expanding on a simple idea is great to get to know the features of PIC microcontrollers. Notice how simple the circuits can be!

I'm now totally engrossed, and have no end of projects and ideas I want to try out using these chips, and I'm sure other keen experimenters will be the same once they've caught the Microcontroller bug! □

NOTE: *We intend to publish a PIC Development and Training System for the PIC16C5X range of microcontrollers in two or three months – Ed.*

FOX REPORT

by Barry Fox

Caller Line Identity

A few weeks after British Telecom launched its Caller Line Identity system, I did two things.

I wrote to Sir Iain Vallance, BT's head man, and asked whether he and his fellow directors were leaving their private business and home lines unblocked – so that those numbers could be displayed or recorded on any phones that Vallance *et al* called. This seems a reasonable question when you bear in mind that British Telecom have imposed CLI on the British public on an opt-out basis, i.e. people's numbers are by default displayed or recorded unless callers know how to take the positive steps needed to block display.

I have to hand it to Sir Iain Vallance for his fancy-footwork and first attempt at dodging the question. He just passed my letter to a BT minion who then said he could not divulge confidential information about his boss's telephone numbers.

I have now written back to Sir Iain Vallance pointing out that the whole point of my writing to him personally was to give him the opportunity to answer personally, without breaching any confidences. If necessary I will write to all other directors personally, although I should have thought it was easier all round simply to copy them my letter.

Surely if Sir Iain Vallance and the other directors of BT have confidence in CLI, they will be only too pleased to publicize the fact that they are not defeating their own service by withholding their own numbers?

Number Unavailable

The other thing I did was buy one of BT's CLI display units. Made in the Philippines "for BT" it costs £50 and stores 50 numbers. But to use it I had to sign a year's service contract, costing a total of £16.

Using it was a revelation. Out of the first fifty calls, only 11 displayed numbers, and in some cases I have my doubts on whether the numbers displayed were correct. Twenty-six showed up as "number unavailable", often because the callers were large businesses using Mercury lines.

All calls from the BBC and publisher IPC, for instance, show up as "number unavailable". The other thirteen showed up as "number withheld", either because callers had dialled 141 ahead of their calls or had put a permanent display block on their line.

This makes CLI completely, utterly useless for the purpose for which BT promotes it, namely filtering and sifting out malicious and obscene calls by refusing to answer any that come without a displayed number ahead of the ring.

I would have rejected two-thirds of the calls received, many of them important business calls from people who employ me to write articles or broadcast on radio.

When Less Means the Same

On 1 January, the UK reduced its mains supply voltage from 240V to 230V, while other countries in Europe increased from 220V to 230V. Northern Ireland was already on 230V so needed no change.

The boring bit is that voltage harmonisation conforms to document HD 472-S1 drafted by CENELEC, the European Committee for Electrotechnical Standardization. The surprise is that this is one piece of European legislation that makes sense. Consumer electronics factories around the world can now make just one European model, instead of several with different voltage ratings.

If you do the paper sums, using Ohm's Law, you end up with a 4 per cent drop in voltage which means an 8 per cent drop in power through resistive loads. A one kilowatt fire bar will dissipate 918 watts, so will give out less heat and cost less to run. Likewise electric light bulbs will give out less light, and give a slightly redder light, but last much longer. On the Continent exactly the opposite should happen, with hotter, brighter glows and shorter life.

Computers, and other equipment which uses switch mode power supplies, will self-adjust. But hifi amplifiers use transformer power supplies and should also deliver less output. A 100 watt amplifier will only pump around 90 watts into the speakers.

In fact, the situation is quite different. No-one should notice any change. The reason is some very clever drafting of the new voltage regulations, and the tolerances under load e.g. when everyone is cooking their Sunday lunch and the mains voltage drops.

When the UK was running on a nominal 240V, the permissable swing was ±6 per cent, giving a legal range of 225·6V to 254·4V. The new voltage, nominally 230V, can vary by +10 per cent or −6 per cent. This creates a legal range of between 216·2 volts and 253V. So the electricity supply authorities can go on delivering power just as before, without replacing any distribution transformers. All they have to do is keep a slightly closer check on voltage peaks to make sure they do not stray into the now forbidden territory between 253V and 254·4V. Electric fires, lights and hifi amplifiers will perform exactly as they have done before.

In continental countries which previously used 220V, the latitude has been ±10 per cent. Now that the nominal voltage has risen to 230V, the tolerance has been changed to +6 per cent or −10 per cent. This preserves the status quo there, too. But manufacturers can take advantage of single production runs for Europe.

Over the next few years, manufacturers must re-design their equipment for the next stage of the change, which is scheduled for 1 January 2003. On that date the latitude on the 230V across Europe changes to ±10 per cent in all countries. In the meantime we can expect to see more equipment like electric fires and light bulbs labelled with a power rating 230V.

Frequency

The situation on frequency has not changed at all. Under continuing regulations the mains frequency can vary by ±1 per cent. But over a 24 hour period the gains and losses must even out. So although a mains powered clock may seem to gain or lose a little at different points of the day, at the same time every day or night it is back to spot-on accuracy.

In practice, this does not matter very much. Most wall clocks are now battery powered and thus independent of main frequency. Record and tape decks now seldom rely on mains frequency for their running speed. TV systems are never now locked to the mains, even though the European and North American standards were originally tailored to the 50Hz and 60Hz mains. Everything is now locked to an internal oscillator.

The Japanese had especially good reasons to push down the price of oscillator control. Their factories supply both Europe, with 50Hz mains and the USA with 60Hz mains. And Japanese cities Osaka and Tokyo use different frequencies. One is on 50Hz and the other on 60Hz.

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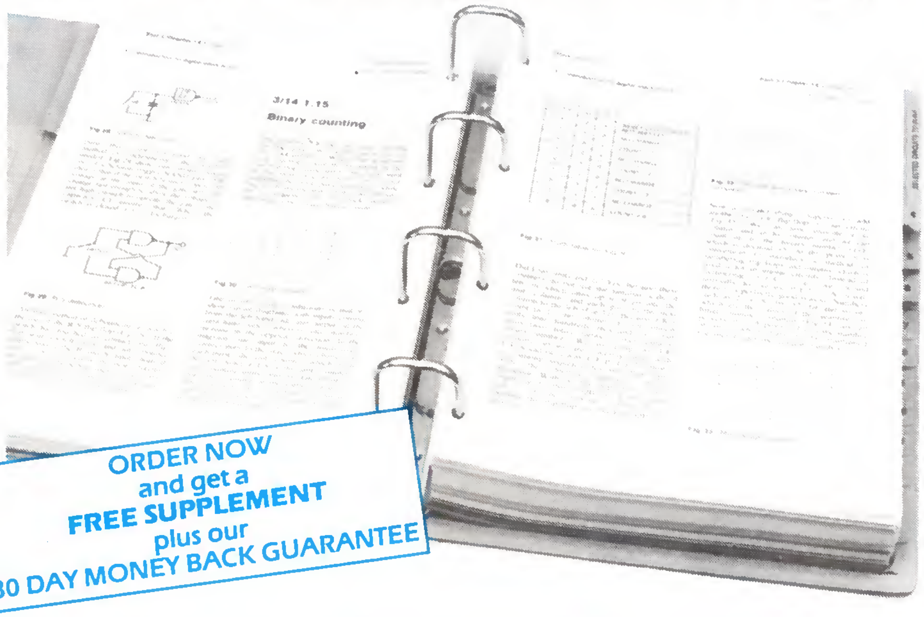

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ABOUT YOUR FREE PCB

MULTI-PCB PROJECTS

A SELECTION of "Pick and Mix" projects that can *all* be built on the FREE, cover mounted, printed circuit board attached to this issue.

This month we present three projects: a **Sound Activated Switch ★ Audio Amplifier ★ Light Beam Communicator.** Next month's three projects will be a **Switch On/Off Timer ★ Light Activated Switch ★ Continuity Tester.**

If you wish to build all these "mini board" projects, then extra p.c.b.s. will be needed and can be purchased from the *EPE PCB Service*, code 932, for the sum of £3 each (including VAT and postage). Alternatively, you can purchase extra copies of the March '95 issue from your Newsagent, whilst it is still on sale, and make a small saving on each additional p.c.b.

A further selection of projects, all "tailored" for this p.c.b. will be published in the Autumn when another FREE p.c.b. will be attached to an issue.

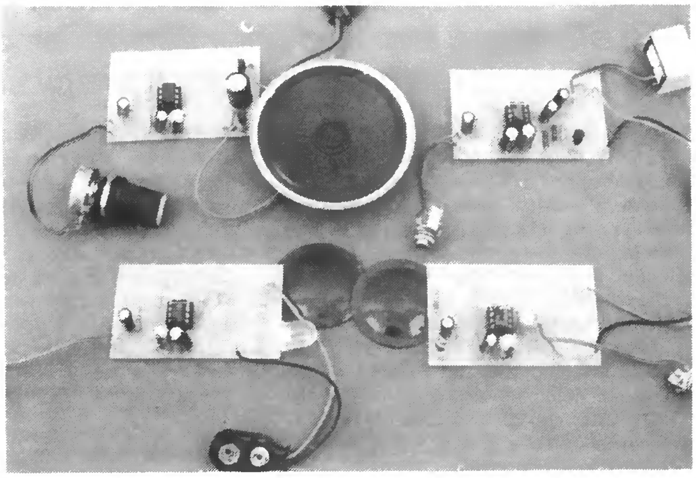
Circuit Board

These simple projects cover a wide range of applications, but they are all based on the same printed circuit board design. The board is designed to take a single operational amplifier having an 8 pin d.i.l. encapsulation and the standard 741 style pinout arrangement. The operational amplifier can be used in the inverting and non-inverting amplifier modes, as a voltage comparator, or as a trigger. At least two types of oscillator can also be accommodated. The board has provision for discrete relay driver and complementary class B output stages.

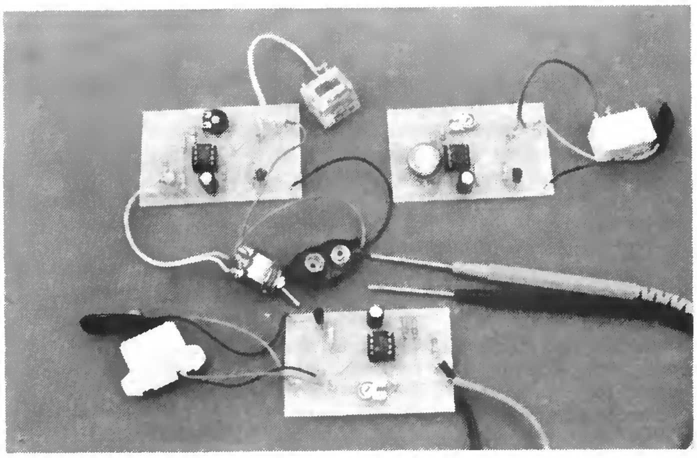
While the restriction of a single operational amplifier clearly limits the complexity of projects based on this board, using various modern operational amplifiers it is still possible to accommodate a wide range of projects within its confines. Further projects will be featured in the Autumn, and many readers will no doubt be able to fit their own designs onto the board.

Pad Carefully

Using the board is reasonably straightforward, but it does require slightly more care than when using a custom printed circuit board. None of the projects utilize all the pads, and in most cases more than 50 per cent of the holes in the board are left vacant. This makes it essential to take a little more care when fitting the components, and to double-check the positioning of each one. Apart from this, using the multi-pcb should be as easy as project building on a custom board.



THIS MONTH'S PROJECTS (left to right, top to bottom): ★ AUDIO AMPLIFIER ★ SOUND ACTIVATED SWITCH ★ LIGHT BEAM COMMUNICATOR (two p.c.b.s) ★



NEXT MONTH'S PROJECTS (left to right): ★ SWITCH ON/OFF TIMER ★ LIGHT ACTIVATED SWITCH ★ CONTINUITY TESTER ★

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SOUND ACTIVATED SWITCH

ROBERT PENFOLD

Use your FREE p.c.b. to build this useful sound-operated switch. Ideal for alarms, sound monitors and as a sound trigger for photographic work.

THIS automatic switch activates a relay when the user talks into the microphone. The relay contacts can be used to control virtually any piece of electronic or electrical equipment, but probably the most common use for a sound activated switch is for automatic control of a tape recorder.

Most inexpensive cassette recorders have a remote control switch on the microphone, and it is not difficult to use this sound activated switch instead of the microphone switch. Another possible application of a sound switch is as a sensor for a burglar alarm system.

Sound switches can also be used to automatically operate a suitable camera, and no doubt they have many other applications.

HOW IT WORKS

The block diagram of Fig. 1 helps to explain the way in which the Sound Activated Switch functions. The signal from the microphone will normally be at a very low level. In fact it will usually be no more than about one millivolt peak-to-peak. A high gain amplifier is therefore used to boost this signal to a more useful level of a few volts peak-to-peak.

The boosted signal is fed to a simple rectifier and smoothing circuit. This provides a positive d.c. output signal that is roughly proportional to the amplitude of the input signal. The output of the smoothing circuit drives a relay via a driver stage that provides the relatively high current required to activate the relay coil.

Under standby conditions the output voltage from the smoothing circuit is too low to operate the relay driver, and the relay remains switched off. In the presence of a strong input signal the output from the smoothing circuit is strong enough to activate the relay.

A relay is a mechanical switch that is operated by an electromagnet. Although this is a rather old fashioned component, a relay has its advantages. One of these is that the switch contacts can be used to control practically any *a.c.* or *d.c.* powered equipment, with no significant voltage drop. There is also complete electrical isolation between the driver circuit and the controlled equipment. This avoids restrictions on the way in which the switch contacts can be used, and enables the unit to be used safely with mains powered equipment.

CIRCUIT DESCRIPTION

The circuit diagram for the Sound Activated Switch appears in Fig. 2. A low-noise op.amp IC1 is used as the basis of the high gain amplifier, and this is an inverting mode circuit. Resistors R1 and R4 set the voltage gain and input impedance of the circuit at approximately 4700 times and one kilohm (1k) respectively.

This gives good results with low impedance dynamic and electret microphones. The audio quality of the microphone is clearly of no importance in this case, and the cheapest low impedance microphone you can obtain is the best choice.

Due to the high closed loop voltage gain of IC1 it is essential that this is a high quality operational amplifier having a large gain-bandwidth product. Even the 10MHz gain-bandwidth product of the NE5534A only provides a bandwidth of just over 2kHz in this circuit. This is substantially less than the full audio bandwidth, but is

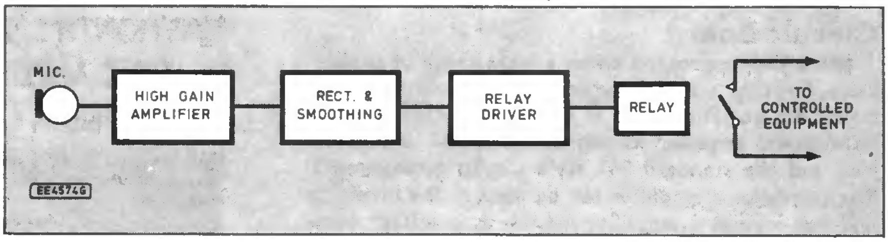


Fig. 1. Block diagram for the Sound Activated Switch.

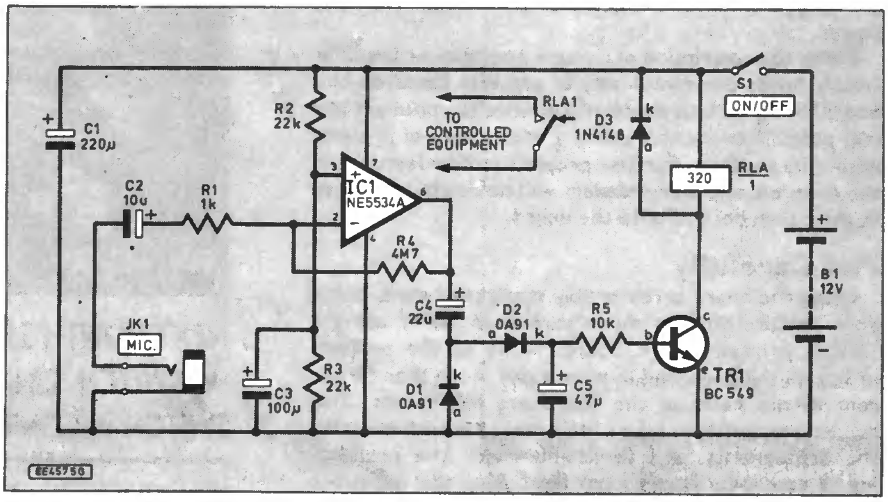


Fig. 2. Circuit diagram for the Sound Activated Switch.

wide enough to give good results with a speech signal. The slight lack of high frequency response will not significantly reduce the sensitivity of the circuit.

The output from IC1 is coupled by capacitor C4 to a simple half wave rectifier circuit which utilizes diodes D1 and D2 in a standard configuration. Germanium diodes are used in the D1 and D2 positions because they have lower voltage drops than silicon diodes. This gives the circuit slightly improved sensitivity.

Capacitor C5 is the smoothing capacitor, and the value used here determines the decay time of the circuit. The specified value gives a decay time of approximately one second.

This is long enough to ensure that the relay does not cut out during the brief pauses that occur in normal speech. On the other hand, it is short enough to avoid having the relay remain switched on for a long time after the user has finished speaking. If a shorter decay time is preferred, reduce C5 to 22µ.

A longer decay time can be obtained by increasing the value of C5, but this might increase the attack time to an unacceptable degree. The relatively low output impedance of IC1 helps to give a short attack time, so that the unit responds rapidly when the user starts to speak, but it inevitably takes a short time for C5 to charge up.

RELAY DRIVER

Transistor TR1 is the relay driver, and it operates as a simple common emitter switch. D3 is a protection diode which suppresses the high reverse voltage that is generated in the relay coil as the relay switches off.

Although at a high impedance, this voltage spike might otherwise cause damage to semiconductors in the circuit. The relay can be any 12V type which has a coil resistance of about 300 ohms or more, plus suitable contacts for your particular application.

The quiescent current consumption of the circuit is about six milliamps, but about an extra 30mA is drawn when the relay is switched on. The unit must therefore be powered from a fairly high capacity battery, such as eight HP7 cells in a holder.

The circuit might work properly using a 9V supply (such as six HP7 size cells in a holder), which would give substantially reduced running costs. This is only possible if the particular relay used will operate reliably at a coil voltage as low as 7·5V, which most 12V relays seem to do.

CONSTRUCTION

This simple circuit can be built on the *FREE* printed circuit board (p.c.b.) attached to the front cover of this magazine. (If you intend to build all the designs using this p.c.b., you can obtain extra boards from the *EPE PCB Service*, code 932, for the sum of £3 each. Alternatively, you can, of course, purchase extra copies of this issue from your Newsagent and make a small saving on the cost of the p.c.b. – the extra copies could be passed to a friend.) The topside component layout and underside full size copper foil master pattern for the Sound Activated Switch is shown in Fig. 3.

Although the NE5534A is not a static sensitive device, it is worthwhile fitting it in a holder. Diodes D1 and D2 are germanium types, and are therefore fairly susceptible to heat damage when they are being soldered into place.

COMPONENTS

See SHOP TALK Page

Resistors
R1 1k
R2, R3 22k (2 off)
R4 4M7
R5 10k
All 0·25W 5% carbon film

Capacitors
C1 220µ radial elect. 16V
C2 10µ radial elect. 25V
C3 100µ radial elect. 10V
C4 22µ radial elect. 25V
C5 47µ radial elect. 16V

Semiconductors
D1, D2 OA91 germanium signal diode (2 off)
D3 1N4148 signal diode
TR1 BC549 *npn* silicon transistor
IC1 NE5534A low-noise op.amp

Miscellaneous
JK1 3·5mm jack socket
RLA 12V 320 ohm coil relay, with s.p.d.t. 10A changeover contacts (see text)
S1 s.p.s.t. min. toggle switch
B1 12V battery pack (8 x HP7 size cells in holder)

Printed circuit board, one FREE cover-mounted (or additional boards from *EPE PCB Service*, code 932); case, size to suit; low impedance dynamic microphone; 8-pin d.i.l. socket; PP3 type battery clip; multistrand connecting wire; solder, etc.

Approx cost guidance only **£9** excl. Mic. & Batts

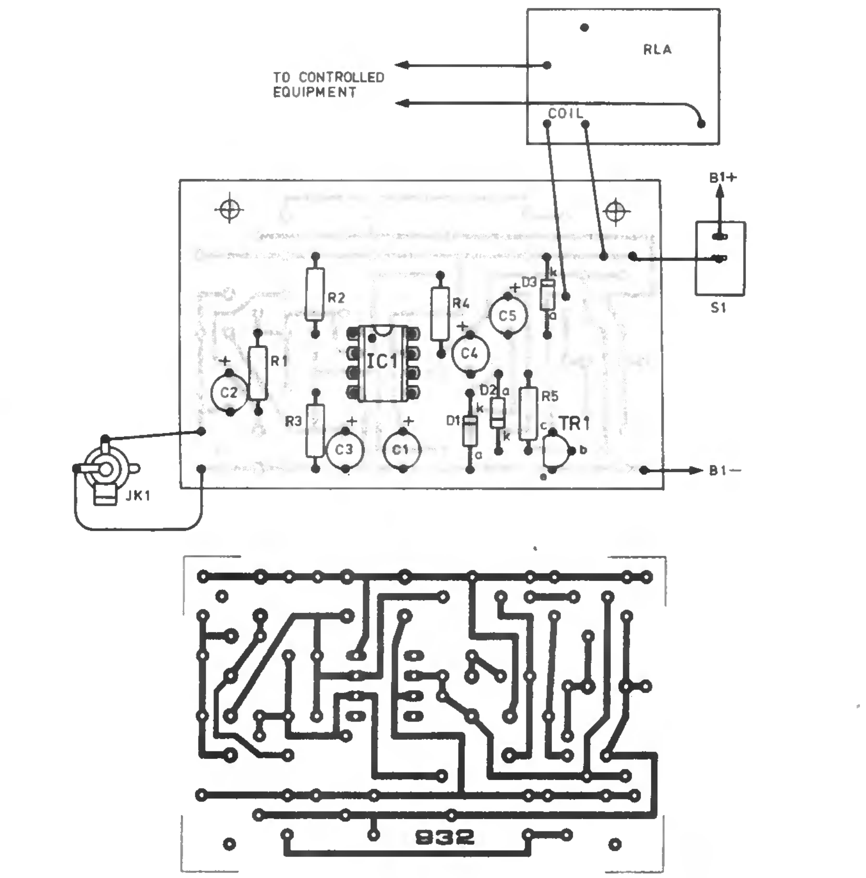
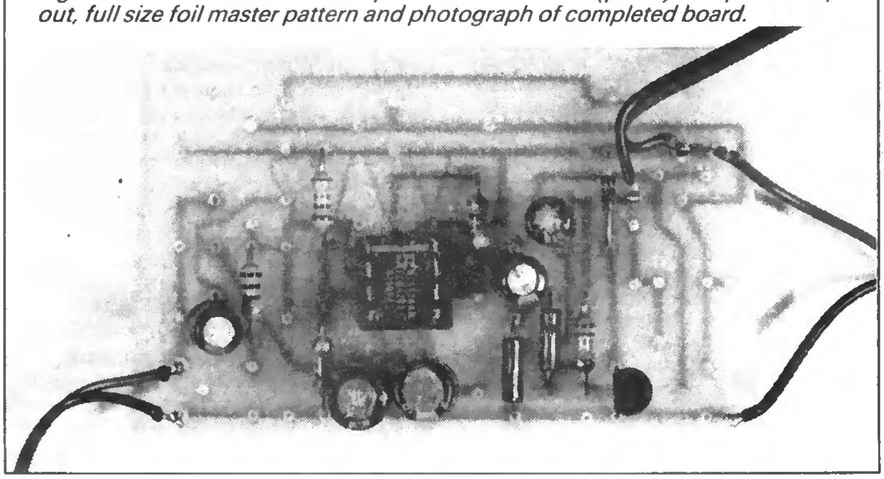
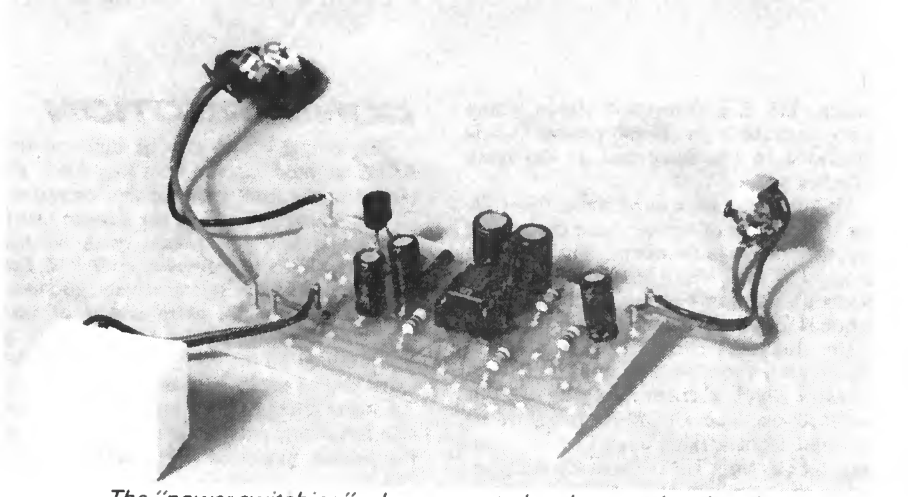


Fig. 3. Sound Activated Switch printed circuit board (p.c.b.) component layout, full size foil master pattern and photograph of completed board.





The "power switching" relay connected to the completed p.c.b.

Normally, it has not been found necessary to use a heatshunt when fitting germanium diodes, but the soldering iron should not be applied to each joint for more than a second or two. Be very careful when fitting diode D3. Fitting it with the wrong polarity could easily result in the destruction of both transistor TR1 and D3 itself.

The connections to the battery pack are made via a standard PP3 style battery connector. JK1 is a 3·5mm jack socket, which matches the plugs normally fitted to low impedance dynamic microphones.

Many of these microphones are actually fitted with two plugs, which are 3·5mm and 2·5mm jacks. The 3·5mm plug connects to JK1, and the 2·5mm plug (which connects to the microphone's remote control switch) is left unused.

The connections to the "off-board" relay shown in Fig. 3 are correct for the specified "10A mains relay". This has s.p.d.t. contacts, but in most sound switch applications only basic on/off switching is needed. Consequently, one tag of the relay is left unused.

If you use an alternative relay it will almost certainly have a different pinout configuration. The retailer's literature should provide connection details for other relays.

There is no room for the relay on the circuit board, and it must therefore be mounted off-board. The specified relay, in common with most modern types, is intended for printed circuit mounting, and has no provision for screw-fixing. However, it can be fixed to the inside of a suitable case using a high quality adhesive, such as an epoxy type.

If the unit is to be used to control a cassette recorder the two switch contacts of the relay are connected to a two-way lead terminated with a 2·5mm jack plug. The latter connects to the remote control socket of the recorder. The leads can be connected to the plug with either polarity.

The specified relay can control currents at up to 10A, and can be used with a.c. voltages of up to 240V (or a maximum of 30V d.c.). The relay can therefore be used to control mains powered equipment, but it should only be used in this way by those who have the necessary experience. ***Those of limited experience should not use this unit with mains powered equipment.***

IN USE

At switch-on there will probably be a delay of a few seconds before the unit starts to function correctly. This is simply the time it takes for capacitor C2 to charge via resistors R4 and R1 to its normal working level.

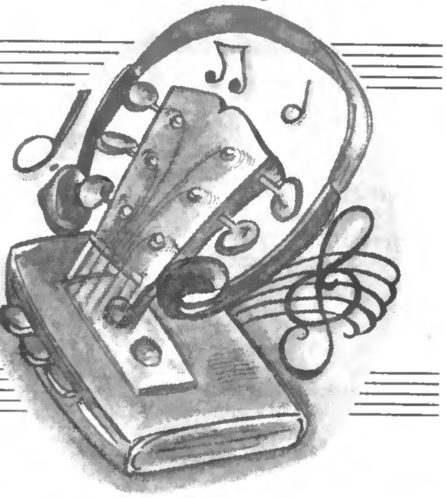
The unit should be reasonably sensitive, but it is unlikely to work well with the microphone more than about half a metre or so from the user's mouth. High sensitivity is not really a good idea with equipment of this type as it tends to produce frequent spurious triggering.

When using the unit it must be borne in mind that the relay does not respond instantly when someone starts talking into the microphone. The electronics and the relay itself produce a delay of a few milliseconds before the relay contacts close.

If the unit is used with a cassette recorder there will almost certainly be a somewhat longer delay before it gets up to speed and operates normally. This will not necessarily cause major problems, but it might result in the first word of each block of speech being lost. The normal solution is to simply add a "dummy" word such as "start" at the beginning of each block of speech, so that the system is up and running properly before you start dictating in earnest. □

Constructional Project

AUDIO AMPLIFIER



A low-cost, low-voltage 350mW amplifier that can be built on the FREE p.c.b. attached to this issue.

THIS small Audio Amplifier module is suitable for use as a general purpose test bench amplifier, or it could be incorporated into a larger project such as a radio receiver. Before too long practically every electronics hobbyist finds the need for a simple audio amplifier such as this.

The amplifier is powered from a 9V battery and it provides an output power of about 350mW r.m.s. into an 8 ohm impedance loudspeaker. With the volume control at maximum the input impedance is about 23 kilohms, and approximately 250 millivolts r.m.s. is needed in order to produce maximum output.

CIRCUIT OPERATION

The full circuit diagram for the Audio Amplifier is shown in Fig. 1. IC1 is an operational amplifier which is used in the inverting mode.

The NE5534A specified for IC1 can provide quite a high output current by the standards of operational amplifiers, but it is not able to drive an 8 ohm load with a few hundred milliwatts r.m.s. A complementary emitter follower output stage is therefore used to increase the maximum output current to a satisfactory level.

Adding a discrete output stage of this type presents a problem with "cross-over" distortion. This occurs with all semiconductor complementary output stages due to the forward transfer characteristics of transistors. In this case the output transistors are ordinary bipolar transistors, and as such they do not begin to conduct until the base to emitter voltage reaches about 0·5V to 0·6V.

When used in a complementary output stage this produces some odd results. Output signals of less than about one volt peak-to-peak fail to materialise at all, because they are too small to bring the output transistors into conduction.

At higher volume levels the output signal is present, but it is severely distorted, with the bottom 0·5V to 0·6V of each half cycle totally absent. Fig. 2a shows a sinewave input signal, and the waveform of Fig. 2b shows the same signal if it is subjected to this severe form of crossover distortion.

DISTORTION

The normal way of avoiding severe crossover distortion is to provide a quiescent bias to the output transistors so that they are just about brought into conduction. This tends to be problematic, since the output transistors are operating on the verge of destruction.

In order to prevent an excessive bias current from flowing it is normally necessary to have this current carefully controlled. In fact it is usually essential to have a circuit that accurately compensates for changes in the temperature of the output devices.

Even with a quiescent bias current through the output transistors the crossover distortion is not eliminated. This is due to the fact that bipolar transistors tend to have relatively low gains at low operating currents.

The result is a relatively mild form of crossover distortion, but even in this mild form it tends to be quite noticeable. Unfortunately, crossover distortion is at its worst at low volume levels, and it is at these low volume levels that distortion tends to be most noticeable.

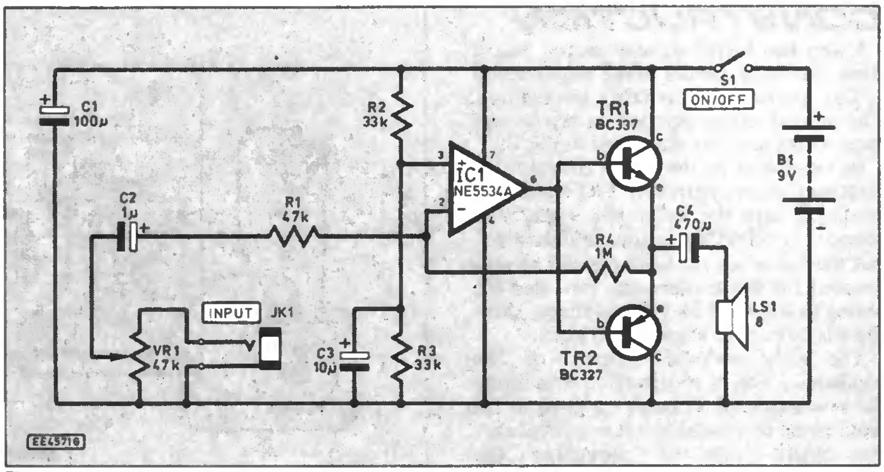


Fig. 1. Full circuit diagram for the Audio Amplifier.

FEEDBACK

Most class B audio power amplifiers use negative feedback to reduce crossover distortion to an insignificant level. This circuit is slightly unusual (but not unique) in that it relies solely on negative feedback to counteract crossover distortion.

The effect of the feedback is to distort the output signal from IC1 in a way which counteracts the distortion through the output stage (Fig. 2c). This is not a particularly hi-fi way of doing things, but it works well enough when applied to a small power amplifier such as this one. It also has the advantage of avoiding the complication of having to stabilise the quiescent current through the output stage.

In order to give acceptable results it is necessary to use a fair amount of negative feedback. The amplifier has its closed loop voltage gain set at about 20 times (26dB) by resistors R1 and R4.

The NE5534A has a gain-bandwidth product of 10MHz, which gives an open loop voltage gain of 500 (54dB) at 20kHz. The circuit therefore has nearly 30dB of feedback at the highest audio frequencies, but this increases to around 60dB at middle audio frequencies where the open loop gain of IC1 is much higher.

There is over 80dB of feedback at the lowest audio frequencies. This is sufficient to give good results.

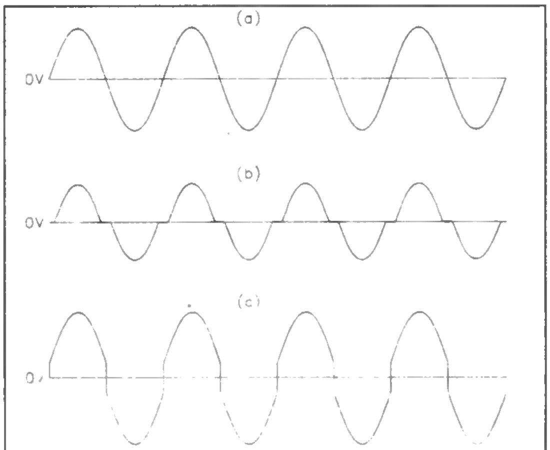


Fig. 2a. Sinewave input waveform (b) effect of crossover distortion and (c) output waveform from IC1.

The crossover distortion can actually be heard quite clearly if the amplifier is run at extremely low volume and you place an ear close to the loudspeaker. However, in normal use there is no obvious distortion, and the audio quality of this amplifier compares quite well with most other small power amplifiers.

On the input side of the amplifier VR1 acts as a conventional Volume control. At the output capacitor C4 provides d.c. blocking. It is possible to use the amplifier with a high impedance loudspeaker, but the maximum output power will be greatly reduced.

A loudspeaker having an impedance of *less* than 8 ohms should *not* be used, and neither should a supply potential of *more* than 9V. The result in either case could be the *destruction* of the output transistors.

The quiescent current consumption of the amplifier is approximately 4mA, but the consumption can rise to nearly 100mA at high volume levels. The battery *must* therefore be something more substantial than a PP3, such as six HP7 size cells in a holder.

COMPONENTS

Resistors
R1 47k
R2, R3 33k (2 off)
R4 1M
All 0·25W 5% carbon film

See SHOP TALK Page

Potentiometer
VR1 47k rotary carbon, log

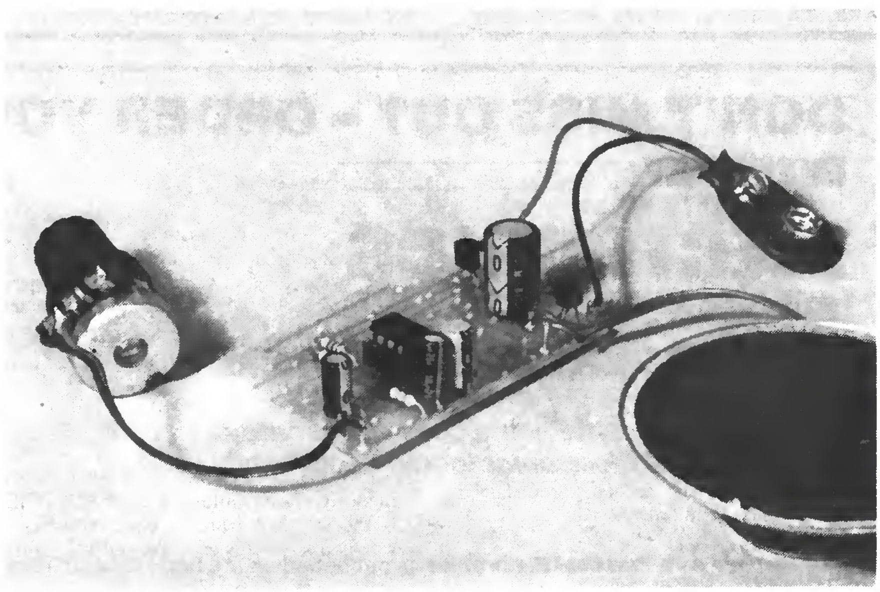
Capacitors
C1 100µ radial elect. 10V
C2 1µ radial elect. 50V
C3 10µ radial elect. 25V
C4 470µ radial elect. 10V

Semiconductors
TR1 BC337 *npn* silicon transistor
TR2 BC327 *pnp* silicon transistor
IC1 NE5534A low-noise op.amp

Miscellaneous
JK1 3·5mm jack socket
S1 s.p.s.t. min. toggle switch
LS1 miniature 8 ohm loudspeaker
B1 9V battery pack (6 x HP7 size cells in holder)

Printed circuit board, FREE (cover mounted with this issue or additional boards from *EPE PCB Service*, code 932); case, size to suit; PP3 type battery clip; control knob; 8-pin d.i.l. i.c. holder; connecting wire; solder, etc.

Approx cost guidance only **£9** *excl. Batts*



The completed Audio Amplifier p.c.b. with the Volume control and loudspeaker connected to it.

CONSTRUCTION

Using the FREE printed circuit board from this issue should make construction of this Audio Amplifier fairly trouble free. The printed circuit component layout and hard wiring are fully illustrated in Fig. 3.

Be careful to fit the two transistors the right way round, especially TR1 which will readily fit into the layout the wrong way round. The NE5534A is not static sensitive, but the use of an i.c. holder is still recommended for this component. Provided the wiring to VR1 and SK1 is reasonably short there is no need to use screened leads.

The only awkward aspect of the mechanical side of construction is in fitting the loudspeaker LS1 behind a grille in the front panel of a suitable housing. Probably the easiest way of producing the loudspeaker grille is to drill a neat matrix of holes about 5mm in diameter.

This is slightly more difficult than you might imagine, since even very small errors in the positioning of any holes tends to be quite obvious. Be very careful with the positioning of the holes, and drill small pilot holes first.

Alternatively, a round cutout having a slightly smaller diameter than the loudspeaker can be made in the panel. This can be cut roughly to size using a needle file, "Abrafile", coping saw, etc., and then carefully filed to the correct size and a neat finish using a large half round file. Some loudspeaker material or fret is then glued in place behind the cutout using a good quality adhesive such as an epoxy type.

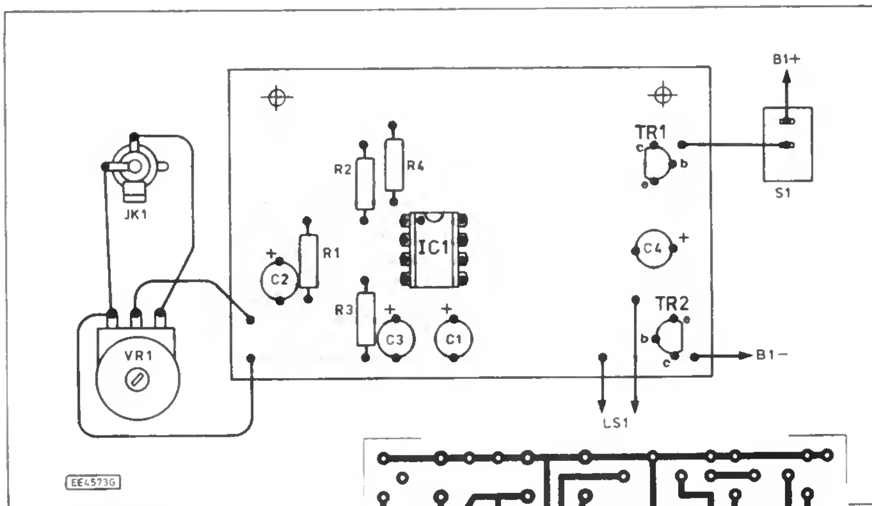
Most miniature loudspeakers do not have provision for fixing screws, and must be glued in place. Again, use a good quality general purpose adhesive. Only apply the adhesive to the outer rim of the loudspeaker, using no more than is really necessary. Be careful not to smear any onto the loudspeaker's diaphragm.

IN USE

If possible it is a good idea to use a multimeter to check that the quiescent current is only about 4mA. Switch off at once and recheck the wiring if it is significantly more than this.

A simple way of checking that the amplifier is functioning properly is to feed the output from the earphone socket of a radio set to the input jack of the amplifier. With the radio's Volume control well advanced it should be possible to get plenty of volume from the amplifier, with an audio quality that will be limited mainly by the small size of the loudspeaker.

The amplifier will work well with high level sources, such as personal stereos and f.m. tuners, but it is not sensitive enough for direct use with low level sources such as microphones and some guitar pick-ups. For operation with low level input signals a suitable preamplifier must be added ahead of the Audio Amplifier.



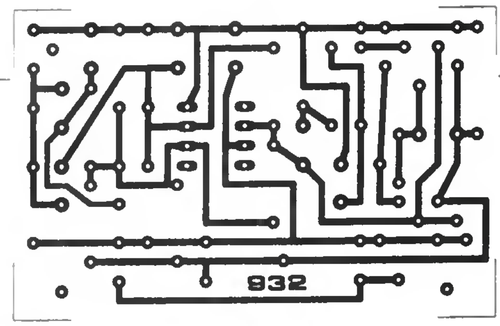
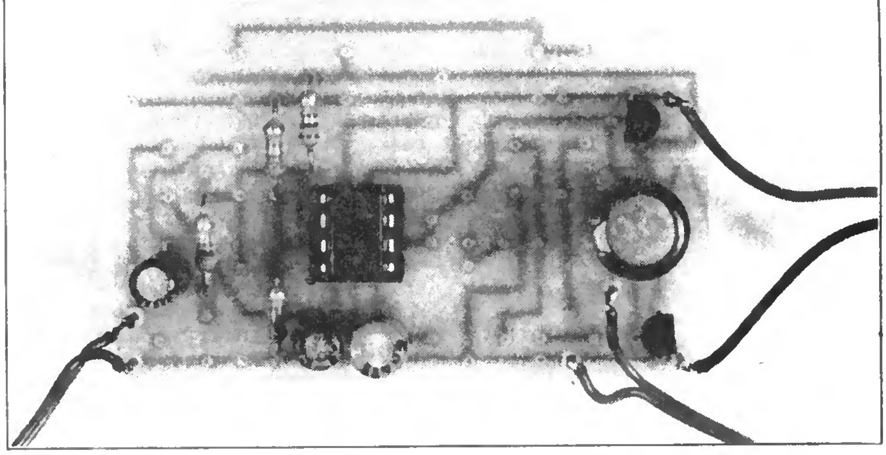


Fig. 3. Audio Amplifier p.c.b. component layout, full size copper foil master and (below) components mounted on the completed board.



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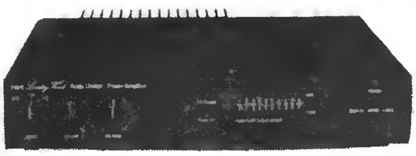
AUDIO DESIGN 80 WATT POWER AMPLIFIER.



This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hifi system. This kit is your way to get £K performance for a few tenths of the cost!. Featured on the front cover of 'Electronics Today International' this complete stereo power amplifier offers World Class performance allied to the famous HART quality and ease of construction. John Linsley Hood's comments on seeing a complete unit were enthusiastic:- "The external view is that of a thoroughly professional piece of audio gear, neat elegant and functional. This impression is greatly reinforced by the internal appearance, which is redolent of quality, both in components and in layout." Options include a stereo LED power meter and a versatile passive front end giving switched inputs using ALPS precision, low-noise volume and balance controls. A new relay switched front end option also gives a tape input and output facility so that for use with tuners, tape and CD players, or indeed any other 'flat' inputs the power amplifier may be used on its own, without the need for any external signal handling stages. 'Slave' and 'monobloc' versions without the passive input stage and power meter are also available. All versions fit within our standard 420 x 260 x 75mm case to match our 400 Series Tuner range. ALL six power supply rails are fully stabilised, and the complete power supply, using a toroidal transformer, is contained within a heavy gauge aluminium chassis/heatsink fitted with IEC mains input and output sockets. All the circuitry is on professional grade printed circuit boards with roller tinned finish and green solder resist on the component ident side, the power amplifiers feature an advanced double sided layout for maximum performance. All wiring in this kit is pre-terminated, ready for instant use!
K1100 Standard Amplifier Kit complete with IEC mains lead and Hart Super Audiograde Silver Solder. Total cost of all parts is over £500.
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K1100M Monobloc Amplifier Kit **£261.20**
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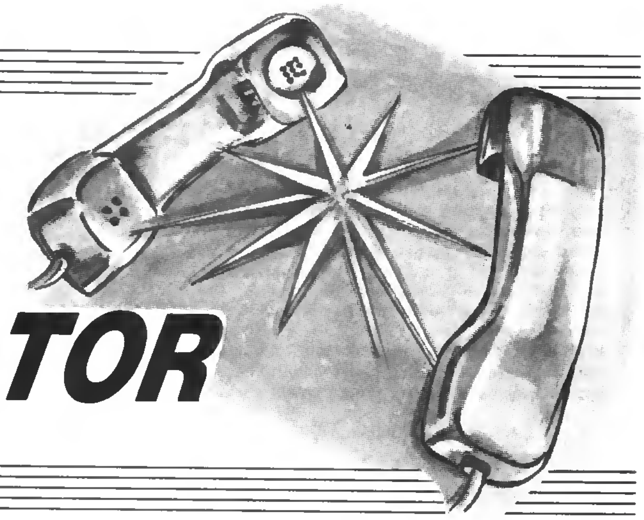


LIGHT BEAM COMMUNICATOR

ROBERT PENFOLD

Use your FREE p.c.b., and one extra board, to build a modern-day version of the old "torch bulb" telephone!

COMMUNICATION using a modulated light system is very topical, with fibre-optic cables now starting to play an important role in modern telecommunications. However, light beam voice links predate fibre-optic cables by many years, and at one time simple "light-beam telephones" were popular amongst electronic project builders.

Systems of this type were mainly based on a torch at the transmitter end of the system. The audio input signal was used to amplitude modulate the torch beam.

In other words, the brightness of the light beam was made to vary in sympathy with the input voltage from the microphone. Positive input voltages gave a proportionate increase in the bulb's brightness, and negative input voltages gave a proportionate decrease.

At the receiver end it required nothing more than a photocell and a load resistor to convert the variations in light level into corresponding voltage changes. This gave an output signal that is, more or less, the same as the signal from the microphone at the transmitter.

BRIGHT LIGHT

This Light Beam Communicator system is really just a modern version of the old torch bulb type. It differs from a torch bulb design in one important respect. It has a large ultra-bright l.e.d. instead of a torch bulb. One advantage of an l.e.d. is that it requires far less power than even a small torch bulb.

The light output from this unit is admittedly rather less than that from most filament bulb designs, but it is adequate in this respect. The average power fed to the l.e.d. is only about 20 milliwatts, but its high efficiency ensures that the light output level is sufficient to give an adequate operating range.

Another advantage of using an l.e.d. is that it gives a very wide frequency response. Systems based on filament bulbs have rather restricted frequency responses due to the so-called thermal inertia of the bulb. Even with the aid of some treble boost the bandwidth is barely sufficient for intelligible speech.

An l.e.d. is a low temperature light source which does not have to heat up and cool down on each cycle. It can handle frequencies well beyond the 20kHz upper limit of the audio range. Using an l.e.d. it is possible to accommodate the full audio bandwidth without the need for any equalisation.

One possible drawback of using an l.e.d. is a lack of linearity through the system. Any lack of linearity results in distortion on the audio output signal. A torch bulb is not perfect in this respect, but is adequate for speech signals.

An l.e.d. performs rather better than one might expect, and this system provides a distortion level that is at least as good as a torch bulb equivalent. With the wider audio bandwidth provided by the l.e.d., the overall audio quality is far better than that of a torch bulb communications system.

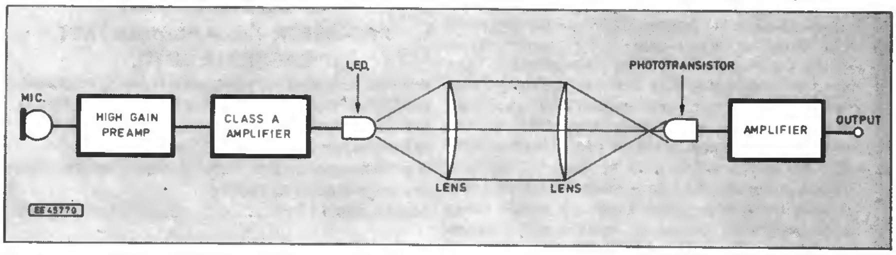


Fig. 1. Light Beam Communicator system block diagram.

SYSTEM OPERATION

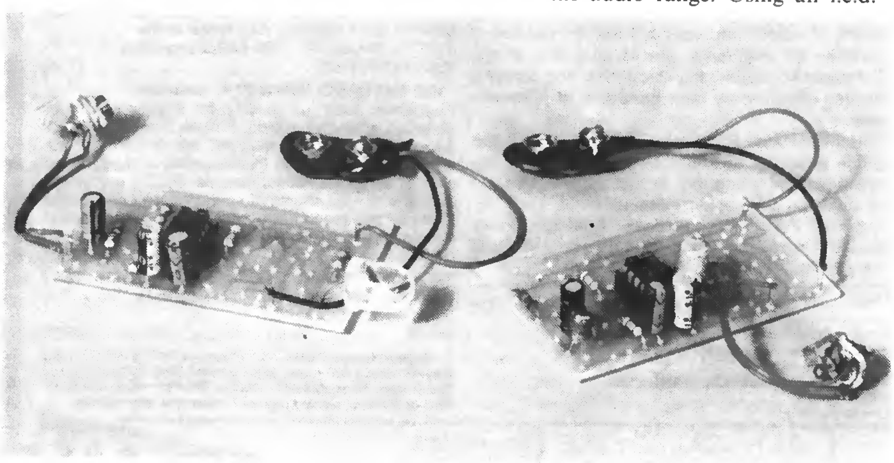
The block diagram for the Light Beam Communicator is shown in Fig. 1. The output signal from the microphone is at a very low level, and it is therefore boosted to a more useful level using a high gain preamplifier.

The boosted signal is then fed to the input of a simple class A output stage. This must be biased so that the l.e.d. operates at normal brightness under quiescent conditions. The brightness of the l.e.d. is varied around this bias current by the input signal.

The fluctuations in the bulb's brightness are not obvious to a human observer, since the input frequencies are too high. Some perceivable flashing usually occurs, but this is due to the non-symmetry of most speech signals.

The l.e.d. does vary in brightness though, and a phototransistor is able to follow even the highest input frequencies. The output signal from the phototransistor will usually be quite weak, and some amplification is needed in order to produce sufficient volume from headphones or an earphone.

It would be desirable to use a high level of gain here in order to give the unit a large operating range. In practice the maximum usable voltage gain is limited to a moderate level by the relatively high noise level from the phototransistor.



The completed Transmitter and Receiver printed circuit board. You will need an extra p.c.b. to build both sections of this project.

FAR SIGHTED

Both the l.e.d. and the phototransistor have built-in lenses which help to give good efficiency. The lens on the l.e.d. concentrates the light into a relatively narrow and intense beam. The lens of the phototransistor gathers light over a relatively large area and concentrates it onto the small silicon chip.

Unfortunately, the built-in lenses provide a rather restricted operating range. In fact they give a maximum range of just a few metres. In order to obtain a useful range from the system it is essential to use additional lenses.

The additional optics have the same basic function as the built-in lenses, but they take things a stage further. The lens at the Transmitter concentrates the light into a very tight beam that diverges very little, even over a range of many metres. The intensity of the light within the beam therefore decreases very gradually as the range of the system is increased.

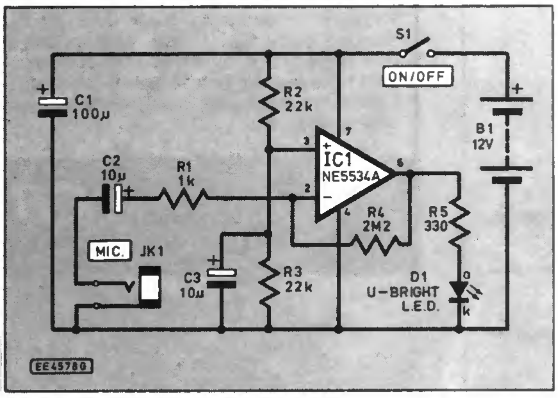


Fig. 2. Circuit diagram for the Modulated Light Transmitter.

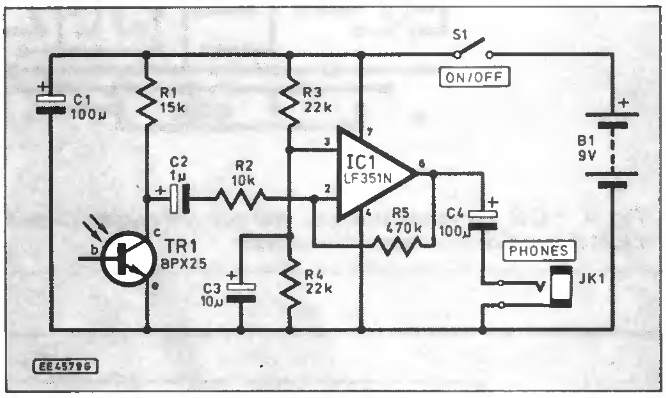


Fig. 3. Circuit diagram for the Modulated Light Receiver using a phototransistor.

The beam does become progressively weaker at longer ranges, since the beam will not be perfectly focused and there will be some attenuation through the atmosphere (which is not totally transparent). However, an additional lens at the transmitter can boost the range of the system by a factor of about ten times.

Like the phototransistor's built-in lens, the additional lens at the Receiver gathers up light over a relatively large area, and then concentrates that light onto the silicon chip. The larger the lens, the greater its light gathering capability, and the greater the range that can be obtained. In practice it is probably not worthwhile using a large and expensive lens, but a small and very cheap lens will provide a very worthwhile increase in the system's operating range.

It is impossible to accurately specify a maximum range for a system such as this, since the range is dependent on a number of variable factors. The most important of these is the accuracy of the optical system.

This is not just a matter of getting the photocells accurately centred behind their lenses, and separated from them by the correct distance. Both the Transmitter and the Receiver are highly directional, and must be aimed very accurately if the system is to operate at all.

It is not too difficult to obtain a range of about 50 metres, but the aim of the Transmitter and Receiver need to be carefully adjusted. Greater operating ranges were not tried, but a range of well over 100 metres should be possible. However, at such long ranges the optics would have to be spot-on in order to provide good results, and it might be difficult to get everything set up with adequate precision.

TRANSMITTER CIRCUIT

The circuit diagram for the Modulated Light Transmitter is shown in Fig. 2. This is basically just an operational amplifier used in the inverting amplifier mode.

The circuit is designed for use with a low impedance dynamic microphone, which is the type sold as low cost replacements for use with cassette recorders. Most low impedance dynamic microphones do not provide a particularly high quality output signal, but they are more than adequate for a simple speech link.

The output from the microphone is likely to be no more than about one or two millivolts peak-to-peak, and IC1 must therefore operate with a high closed loop gain in order to fully modulate the l.e.d. D1. The negative feedback network is formed by resistors R1 and R4, which set the input impedance and closed loop voltage gain at one kilohm (1k) and 2200 times respectively. This should give good results with any low impedance dynamic microphone, or a type which has similar output characteristics (an electret type for example).

The NE5534A specified for IC1 is a high quality type designed for use in low noise, low distortion preamplifiers. This may seem to be an over-specified component for this application, but the high closed loop gain of the circuit makes it essential to use a high quality device.

A standard 741C has a gain-bandwidth product of 1MHz, which would give a bandwidth of only about 450Hz in this circuit. Even the NE5534A with its 10MHz gain-bandwidth product gives a bandwidth of only 4·5kHz, but this is comfortably more than the 2·5kHz or so needed for intelligible speech.

The ultra-bright l.e.d. D1 is driven from the output of IC1 via current limiter resistor R5. This sets the quiescent l.e.d. current at about 12mA, which is sufficient to give a good light output level. The output stage of IC1 is probably a class B type rather than a class A design, but due to the way in which the l.e.d. is driven, it effectively operates as a class A output stage, with the l.e.d. current varying in sympathy with changes in IC1's output voltage.

The current consumption of the circuit is approximately 16 milliamps. This gives a very long life from the 12V battery pack, which is comprised of eight HP7 size cells in a holder.

RECEIVER CIRCUIT

The circuit diagram for the Modulated Light Receiver appears in Fig. 3. TR1 is the phototransistor, and although a BPX25 is specified for this component, almost any silicon *npn* phototransistor seems to work in this circuit. This includes the TIL81, the BPY62, and the RS type 585-220.

The collector (c) to emitter (e) leakage of TR1 is used as a sort of light dependent resistance, and no connection is made to its base (b) terminal. This makes it possible to use phototransistors which do not have a base leadout wire, which includes the RS device, which is physically the same size as a 5mm l.e.d.

The leakage through TR1 varies in sympathy with the changes in the light level received from the transmitter. This generates a low level audio signal at the collector of TR1.

An inverting mode amplifier, IC1, boosts the output from TR1 to a high enough level to drive headphones or an earphone at good volume. It operates at a closed loop voltage gain of about 47 times.

The output of the circuit will drive a crystal earphone, or medium impedance headphones of the type sold as replacements for use with personal stereo units. With the latter the two phones should be driven in series. The circuit will *not* work properly with a *low* impedance earphone.

A PP3 size 9V battery is adequate to power the receiver circuit, which has a current consumption of only about 2mA.

CONSTRUCTION

The Light Beam Communicator can be built on the FREE, cover mounted, printed circuit board (p.c.b.) You will however need an extra p.c.b. Extra p.c.b.s can be purchased from the *EPE PCB Service* for the sum of £3 each; code 923. Alternatively, you can, if you wish, buy an extra copy of this issue.

The component layouts, full size underside copper foil master and wiring for the Transmittter and Receiver are shown in Fig. 4 and Fig. 5. Commence construction of the Transmitter by fitting single-sided pins to the board at the points where the connections to off-board components will be made. Then fit the resistors, capacitors, and the semiconductors.

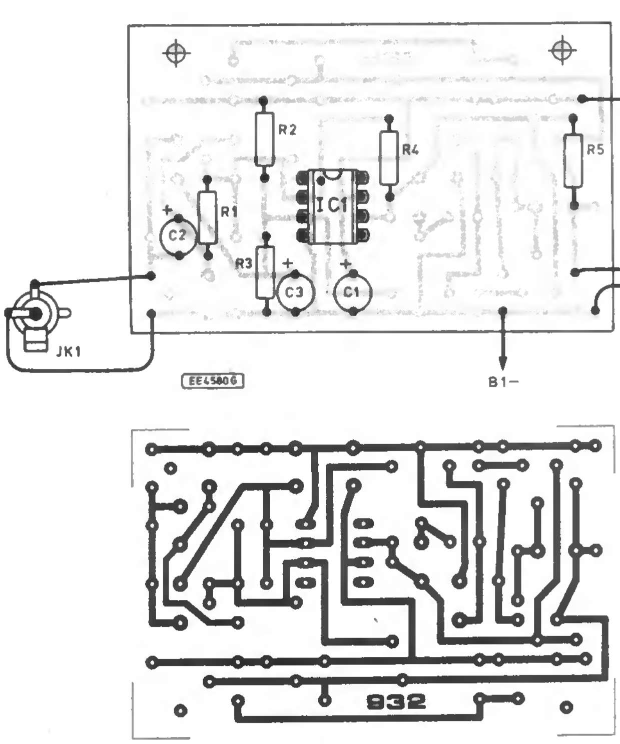


Fig. 4. P.C.B. component layout, full size foil master pattern and wiring for the Light Beam Communicator Transmitter.

COMPONENTS

TRANSMITTER

Resistors

R1	1k
R2, R3	22k (2 off)
R4	2M2
R5	330

All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors

C1	100µ radial elect. 16V
C2, C3	10µ radial elect. 25V (2 off)

Semiconductors

D1	ultra-bright l.e.d. (see text)
IC1	NE5534A low-noise op.amp

Miscellaneous

JK1	3·5mm jack socket
S1	s.p.s.t. min. toggle switch
B1	12V battery pack (8 x HP7 size cells in holder)

Printed circuit board, FREE with this issue (plus one extra board for Receiver – available from *EPE PCB Service*, code 932); case, size to suit; low impedance dynamic microphone; PP3 type battery connector; 8-pin d.i.l. i.c. holder; lens (see text); connecting wire; solder, etc.

Approx cost guidance only **£8**

excl. Case, Mic. & Batt.

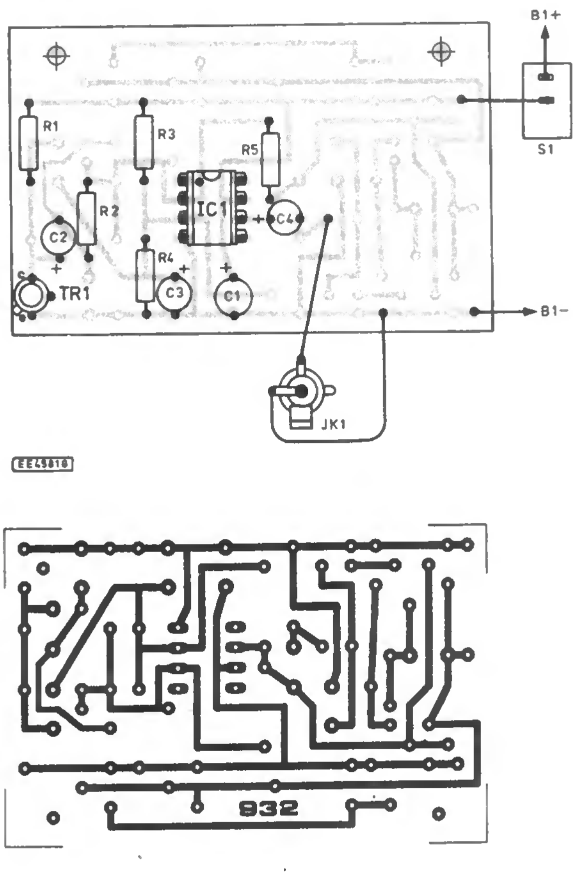


Fig. 5. Receiver p.c.b. component layout and full size foil master pattern. An extra printed circuit board will be required for this project and can be purchased from the EPE PCB Service, *code 932.*

COMPONENTS

RECEIVER

Resistors

R1	15k
R2,	10k
R3, R4	22k (2 off)
R5	470k

All 0·25W 5% carbon film

See SHOP TALK Page

Capacitors

C1, C4	100µ radial elect. 10V (2 off)
C2	1µ radial elect. 50V
C3	10µ radial elect. 25V

Semiconductors

TR1	BPX25 *npn* phototransistor (see text)
IC1	LF351N Bifet op.amp

Miscellaneous

JK1	3·5mm jack socket
S1	s.p.s.t. min. toggle switch
B1	9V battery (PP3 size)

Printed circuit board (extra) available from *EPE PCB Service*, code 932); case, size to suit; 8-pin d.i.l. i.c. holder; lens (see text); crystal earphone or medium impedance headphones; battery clip; connecting wire; solder, etc.

Approx cost guidance only **£9**

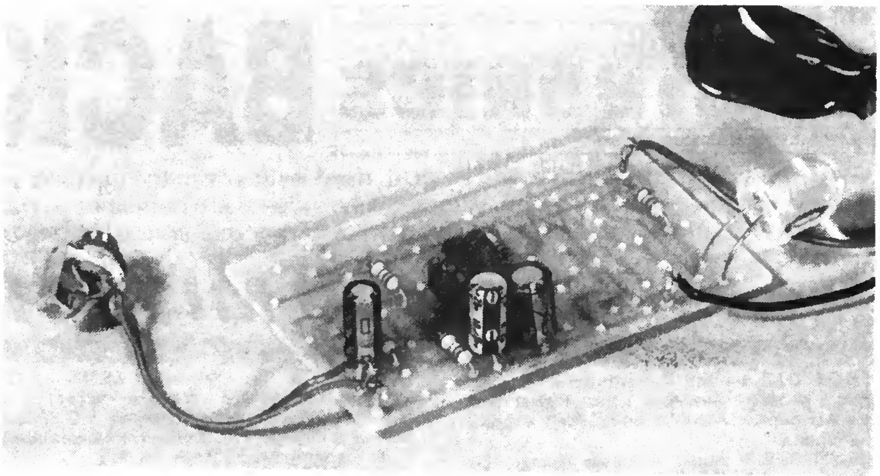
excl. Case, Phones & Batt.

The NE5534A is not a static sensitive component, but it is not the cheapest of operational amplifiers either. It is therefore worthwhile using a holder for this device.

Practically any ultra-bright l.e.d. having a light output of about 1·5cd or more at a current of 20mA can be used for D1. Various 5mm, 8mm, and 10mm types were tried, and the ElectroValue 10mm type gave the best results. The highest output Maplin 5mm and 8mm l.e.d.s also worked well. All these l.e.d.s have the usual shorter lead to denote the cathode ("k") terminal.

The lead from the Microphone input jack socket JK1 to the board must be kept quite short (about 50mm or less), or a *screened* lead must be used here. Otherwise there is a risk of excessive "hum" and general noise pick up in this lead.

Some low impedance dynamic microphones are fitted with 3·5mm and 2·5mm plugs. The 3·5mm plug carries the output signal from the microphone and connects to socket JK1. The 2·5mm plug connects to the microphone's remote control switch, and is not used in this application. The connections to the plastic battery holder are made via a standard PP3 size battery clip.



The completed Transmitter board showing the "ultra-bright" l.e.d.

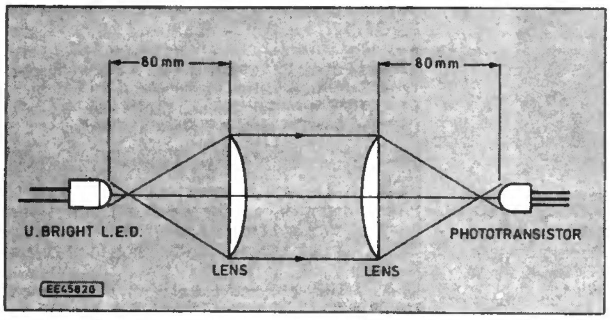


Fig. 6. Details of the optical system. The photocell-to-lens distance is equal to the focal length of the lenses.

RECEIVER

The component layout and wiring for the Modulated Light Receiver are provided in Fig. 5. This is very straightforward and should present no real construction difficulties. If a phototransistor having an l.e.d. type encapsulation is used for TR1, the shorter lead is the collector (c) terminal.

The wiring to JK1 is correct for a 3·5mm mono jack socket for use with a crystal earphone. If medium impedance stereo headphones are used, JK1 must be a 3·5mm stereo socket. The two leads from the printed circuit board then connect to the two non-earth tags of the socket, so that the phones are driven in series. No connection is made to the earth tag.

OPTICS

The mechanical side of construction is complicated by the additional optics. Any positive (convex) lens having a diameter of about 25mm to 50mm and a focal length of about 50mm to 100mm should give good results.

The lenses do not need to be high quality types, and the cheapest of plastic lenses are perfectly satisfactory. The lenses used in the models have an overall diameter of 37mm, and a lens diameter 30mm. The focal length is 80mm.

In order to obtain good results the distance from the front of each photocell to the rear of its lens (the flat surface) should be equal to the 80mm focal length of the lens, as shown in Fig. 6. If you use lenses having a different focal length, then the photocell to lens distance must be adjusted accordingly.

For optimum results the distance between the l.e.d. and its lens should be adjustable, so that it can be set to produce the narrowest beam of light. The l.e.d. produces light in the visible red part of the spectrum, and the width of the beam can be seen by holding a piece of paper a metre or so in front of the transmitter. The position of the l.e.d. is adjusted for the smallest and brightest patch of light on the piece of paper.

There is no easy way of optimising the position of the phototransistor relative to its lens, so it is just a matter of using careful measurement to get the phototransistor positioned as accurately as possible.

It is obviously necessary to use a certain amount of ingenuity when dealing with the mechanical side of construction, but it should not be too difficult to get everything set up correctly. Each lens has a rim about 3·5mm wide which enables it to be glued in front of or behind a 30mm diameter hole in the case. Any good general purpose adhesive will do, but try not to smear any onto the lens itself.

IN USE

It is probably best to give the unit an initial check before the lenses are finally glued in place. The unit will then be less directional, although the built-in lens of the l.e.d. and phototransistor still make the system fairly directional. A maximum operating range of about two or three metres should be obtained if the circuits are working properly.

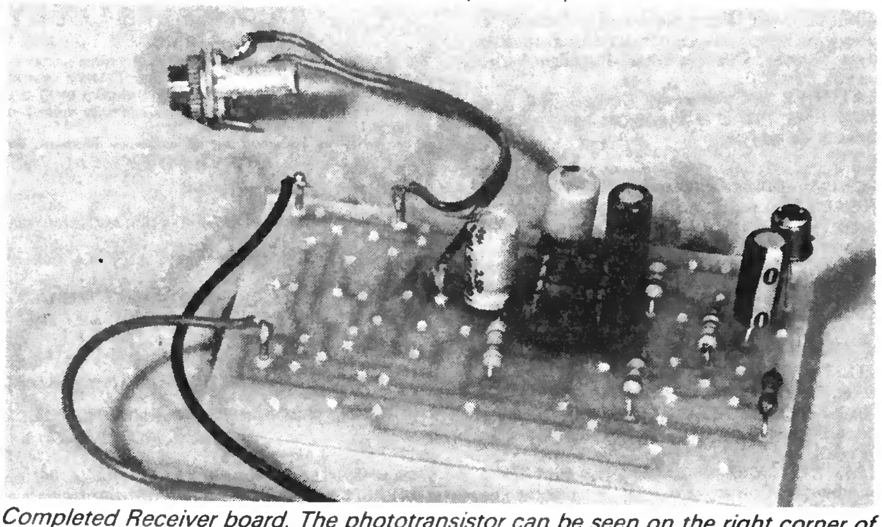
With both lenses in place the equipment becomes *highly directional*, and even at short distances a link will only be established if the aim of the transmitter and receiver are both very accurate. When setting things up it is best to get the aim of the transmitter correct first.

The l.e.d. looks very much brighter when you are within its beam than when you are even slightly off axis, making it easy to detect and correct any error in the aim of the transmitter. With the receiver within the beam, it is then carefully oriented for maximum audio output with someone speaking into the transmitter microphone.

Any system of this type tends to be vulnerable to interference from light sources near the transmitter. In particular, mains lighting near to the transmitter should be avoided, as it will produce 100Hz "hum" on the audio output from the receiver.

As described here the unit only provides one-way communications. For two-way operation it is merely necessary to build a second system to provide the link in the opposite direction. □

Next Month: Three more projects for your Free p.c.b.



Completed Receiver board. The phototransistor can be seen on the right corner of the p.c.b.

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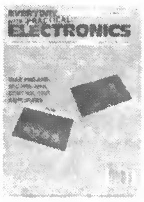

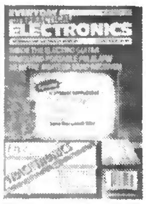

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JAN. '94

PROJECTS • Autolight (automatic nightlight) • Timer and NiCad Capacity Checker • 250W/600W Inverter and Uninterruptable Power Supply, Part 2 • Multi-Purpose Audio System, Part 4 • Pond Heater Thermostat.
FEATURES • Safety First, Part 2 • Calculation Corner, Part 1 • Electronics Testing and Fault Diagnosis, Course Review.

FEB. '94

PROJECTS • Whistle Controlled Light Switch • Reviving the Valve Sound (rebuilding the Quad II power amp) • Introduction to Microcontrollers – Timeout • Battery To Mains Inverter and Uninterruptable Power Supply, Part 3 • Multi-Purpose Audio System, Part 5.
FEATURES • Calculation Corner, Part 2 • Safety First, Part 3 • European International Audio & Video Fair.

MARCH '94

PROJECTS • Smart-Key Immobiliser • Audio/R.F. Monitor • CCD TV Camera, Part 1 • Visual Doorbell • Three-Phase Generator.
FEATURES • Safety First, Part 4 • Calculation Corner, Part 3 • Free Wall Chart – Electronics Formulae 1.

APRIL '94

PROJECTS • MOSFET Variable Bench Power Supply • *EPE* Soundac PC sound output board • CCD TV Camera, Part 2/Frame Grab • Impulse Clock Master Unit • Telephone Ring Detector.
FEATURES • Best of British, Part 1 • Calculation Corner, Part 4 • Electronics Workbench Review • Free Wall Chart – Electronics Formulae 2.

MAY '94

PROJECTS • Simple TENS Unit (transcutaneous pain relief) • Capacitance/Inductance Meter • L.E.D. Matrix Message Display, Part 1 • Stereo Noise Gate • Dual Stepping Motor Driver for PCs.
FEATURES • Calculation Corner, Part 5 • Best of British, Part 2.

JUNE '94

PROJECTS • Microcontroller P.I. Treasure Hunter • Digital Water Meter • Microprocessor Smart Switch • Advanced TENS Unit (transcutaneous pain relief) • L.E.D. Matrix Message Display, Part 2.
FEATURES • Best of British, Part 3 • Calculation Corner, Part 6.

JULY '94

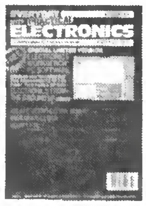
PROJECTS • Voxbox Voice Recording Board • Simple NiCad Charger • Watering Wizard (automatic garden watering) • Pocket Print Timer • Stereo HiFi Controller, Part 1.
FEATURES • Best of British, Part 4 • Calculation Corner, Part 7.

AUG. '94

PROJECTS • Experimental Noise Cancelling Unit • Dancing Fountains, Part 1 • Charged-Up (PC battery tip) • 6802 Development Board • TV Camera Update • Stereo HiFi Controller, Part 2.
FEATURES • Calculation Corner, Part 8 • Best of British, Part 5 • I'll Be Seeing You (multimedia communications)

SEPT. '94

PROJECTS • Protector Plus Car Alarm • Greenhouse Watering System • Experimental Seismograph, Part 1 • Three-Channel Lamp Controller • Dancing Fountains, Part 2.
FEATURES • Calculation Corner, Part 9 • The Invisible Force (magnetic force).



OCT. '94

PROJECTS • Digilogue Clock • Visual/Audio Guitar Tuner • Hobby Power Supply • Audio Auxiplexer • Experimental Seismograph, Part 2.
FEATURES • Electronics from the Ground Up, Part 1 with Free PC Software • Calculation Corner, Part 10.

NOV. '94

PROJECTS • 1000V/500V Insulation Tester • Video Modules, Part 1 (Simple Fader, Improved Fader, Video Enhancer) • Active Guitar Tone Control • Power Controller • TV Off-er.
FEATURES • Electronics from the Ground Up, Part 2 • Consumer Electronics Show.

DEC. '94

PROJECTS • Spacewriter Wand • *EPE* Fruit Machine • Universal Digital Code Lock • Video Modules, Part 2 (Horizontal Wiper, Vertical Wiper, Audio Mixer) • Rodent Repeller.
FEATURES • Electronics from the Ground Up, Part 3 • Embedded Controllers • Index for Volume 23.

JAN. '95

PROJECTS • Magnetic Field Detector • Moving Display Metronome • Model Railway Track Cleaner • Beating the Christmas Lights • EPE Fruit Machine, Part 2 • Video Modules, Part 3 (Dynamic Noise Limiter, System Mains Power Supply).
FEATURES • Electronics from the Ground Up, Part 4 • Electromagnetic Compatibility • Checking Transistors.

FEB. '95

PROJECTS • 12V 35W PA Amplifier • Foot-Operated Drill Controller • The Ultimate Screen Saver • MIDI Pedal Board • Model Railway Signals.
FEATURES • Electronics from the Ground Up, Part 5 • Transformerless Power Supplies • Quickroute 3.0 Review.

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Shapeware Visio 3.0 Business Graphics Software

ALAN WINSTANLEY

A highly refined Windows drawing package for your schematic diagrams.

IF YOU own a personal computer then you might have considered enlisting it to help draft your own circuit diagrams, thereby gaining the advantages of flexible on-screen graphic designing over good old pen and ink. The process of "schematic capture" using printed circuit board software will produce a workmanlike circuit diagram with an engineering emphasis – but the results whilst functional, generally aren't always so "readable" or appealing to look at.

If you just want a presentation-quality circuit diagram – for use in theses, projects, articles or educational material perhaps – then **Shapeware's *Visio 3.0*** could be for you. Intended for the production of two-dimensional graphics such as flowcharts or floorplans, Visio 3.0 has several inherent features which lend themselves to circuit schematic capture.

DRAG AND DROP

Unlike popular graphics design packages such as CorelDraw!, Visio 3.0 centres around "drag and drop" drawing, whereby circuit symbols can be dragged from a "library" of standard shapes and dropped into place, and then "connected" to other components to form a complete schematic. However, if a component needs repositioning to improve the overall diagram layout then it can be repositioned easily, and the connectors will automatically re-route themselves, "rubber-banding" the lines as necessary. A similar technique is widely used in electronics p.c.b. CAD systems.

Hence it's possible to re-arrange circuit diagrams quite easily to produce the most attractive effect, without the hassle of having to completely re-route any associated connector lines by hand. Visio 3.0 uses the Windows GUI to the full to produce a highly polished and appealing package which is friendly and easy to use, yet has a host of powerful features to take much of the pain out of circuit drawing, enabling you to produce presentation-quality circuit diagrams efficiently.

Visio 3.0 requires up to 16MB (5·5MB minimum) of hard disk, and this gives you a mighty two-dimensional drawing package with a raft of useful symbol libraries or "stencils" – from flowcharts to maps, computer network diagrams and graphics, project control, space planning, quality or project management and more.

Windows' graphical abilities really are exploited to the maximum by Visio 3.0, with each symbol (or "master shape") being represented by individual thumbnail icons, themselves gathered together into stencils. Open a stencil and you have a selection to hand of shapes all related to a specific task.

You can open as many or as few stencils as you need for a particular job, or group your own favourite shapes in new stencils of your own. I found I was soon dragging and dropping and switching between different stencils without any problem once I had navigated myself around the libraries.

The Electrical Engineering symbol set which arrives with Visio 3.0 is basic but technically accurate – about 30 symbols to BS3939 which limits the initial capacity to lay down elaborate circuit diagrams. Resistors are shown as rectangles, for example, and the smattering of rectangular (and unloved) logic gate symbols will not be familiar to most *EPE* readers accustomed to our ANSI logic symbols.

Visio's basic symbols may be adequate for your needs but in any case it proved simple enough to create and save new symbols using Visio's comprehensive drawing tools. Connector "glue" points can be included as required to facilitate snap-to gluing of shapes.

SHIP SHAPE

Shapeware have produced a variety of add-on "Shape Libraries" covering many technical and commercial disciplines, available at extra cost. The optional Advanced Electrical Engineering symbols library uses a further 3MB of disk space and contains another dozen collections totalling 300 electronics-related symbols, each with individual help files, and definitely worth investing in if you are a more advanced user. These symbols are currently produced to American ANSI standards, so that capacitor symbols for instance resemble those found in the raft of US Data Sheets whilst the comprehensive selection of semiconductors and logic gates are similar to the regular *EPE* style.

Shapeware say they are looking at converting symbols to the British Standard at the moment. I think that the vast majority of requirements will be met by the symbols included in the add-on library, but you may need to draft your own more advanced i.c., logic or analogue symbols – not a problem with a little practise, I found.

Producing circuit diagrams involves dragging a Shape's icon from an open

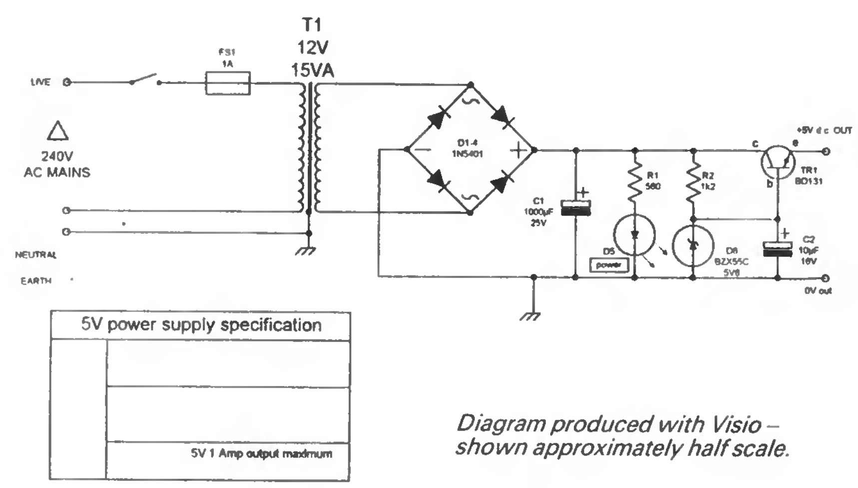
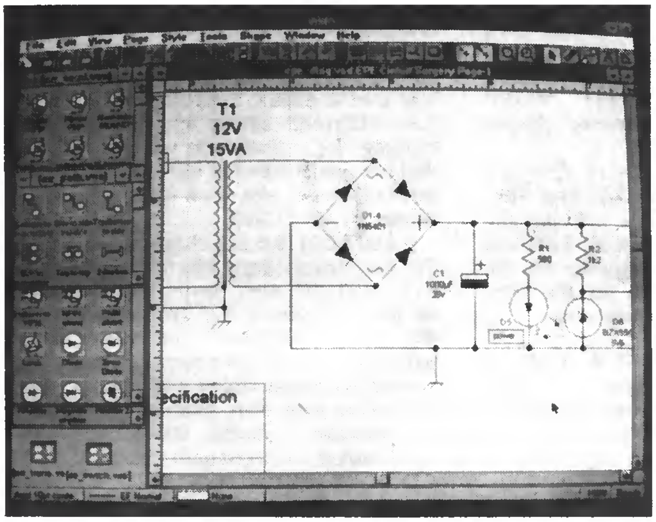
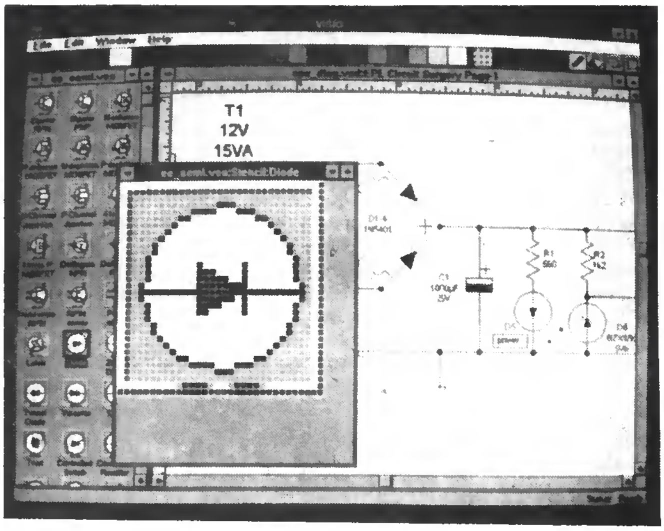


Diagram produced with Visio – shown approximately half scale.



Visio drawing with open stencils.



Visio icon editor.

stencil and then dropping it into place on the drawing. For text, Visio 3.0 recognises True Type fonts installed on the PC, and lines, boxes and circles can be incorporated too. The "micro" µ symbol for capacitor values can be accessed with a quick combination of keystrokes. Fonts, line weights and fill colours can all be modified as needed.

Templates can be created which are a collection of styles, stencils and scale drawing settings, so that you can ensure a consistent style, in a way similar to the style sheets found in some word processors. Indeed virtually everything is fully customisable, including the neat bitmap representations of the individual symbol icons.

The overall end result of your labours depends on your choice of printer. There were no problems outputting to my trusty HP IIIP LaserJet printer, and Visio 3.0 has an ability to split a large drawing over several sheets, so an A3 drawing can be tiled automatically and printed over several A4 pages, for example.

ICON TOOLBAR

An extremely welcome touch is Visio 3.0's ability to take on a Lotus Smartsuite or Microsoft Office appearance on the icon toolbar by adopting their respective icons wherever possible, alongside Visio's own dedicated icons. Being a seasoned Lotus Ami Pro user, I soon found myself very much at home with Visio's Lotus icons, which soon made me feel comfortable with the new software.

I liked the cute Lotus Organiser-like pop-up "help balloons" which appear automatically when the mouse pointer hovers over an icon for a short time. The package also automatically installed a Visio SmartIcon and macro in my Lotus Ami Pro as well.

Being primarily a graphics package, there is currently no order-checking or auto-numbering of electronic component designations, so care is needed not to duplicate part numbers and all i.c. pins need to be numbered and labelled by hand. Shapeware tell me that because of Visio's deliberately "open-ended" structure, it could be possible to incorporate an "add on" which could enumerate components automatically. This is not possible with the current version, though.

VISIO-THERAPY

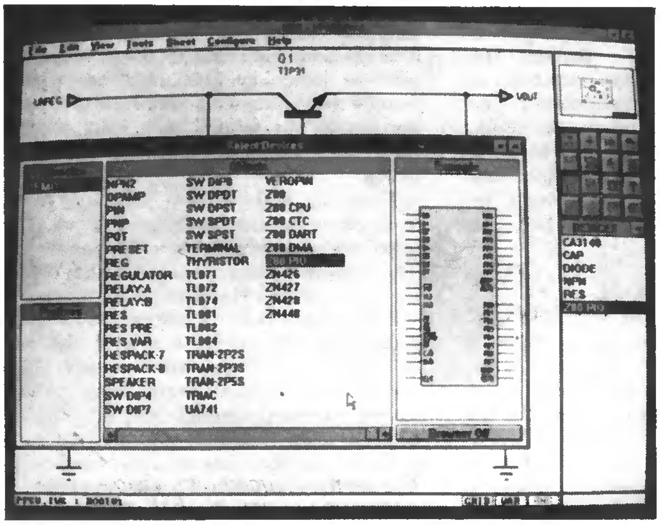
Comprehensive multiple help screens are included though the novice might still find the sophisticated capabilities of Visio a bit daunting or frustrating to start with, especially if they have no hands-on experience with any other drawing programs. Schematics drawn in Visio can be pasted into other Windows applications (such as a word processor) and Visio supports Lotus Notes and OLE – updating a Visio drawing results in all examples of that drawing being updated in other OLE linked applications. Also, drawings can be produced in layers, progressively adding or peeling away layers of graphics to strip the drawing down as required.

Each shape is supported by its own "ShapeSheet", a sort of mini-spreadsheet of data related to the symbol attributes themselves. These can be edited for more precise needs and symbols can be made to acquire clever characteristics – switches can be shown as open or closed, for example, at the double-click of a mouse, or diodes can be shown as with or without encapsulation. There's a whole raft of neat touches to keep users engrossed for hours.

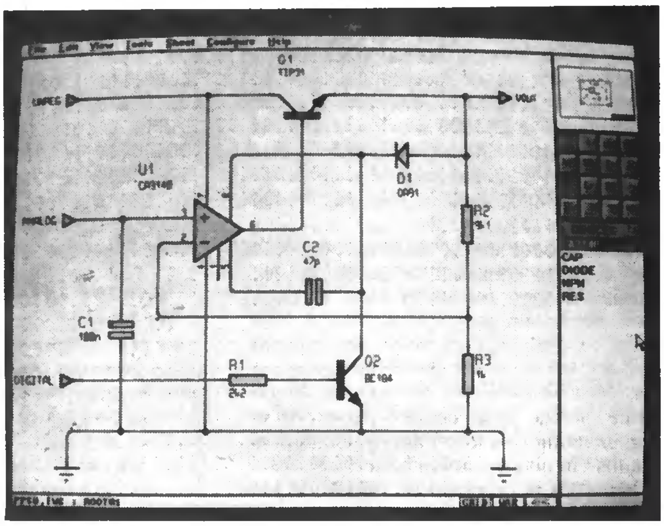
One drawback in this current version is that unlike traditional electronics-specific CAD packages, Visio does not automatically place a junction "blob" where connector lines join. These joints are either treated as separate symbols which have to be dragged and dropped in manually as a finishing touch using the rubber-stamping tool, or alternatively lay down a suitable connector SmartShape line with blobs (which can be sized with the mouse) at each end, which takes a little practise.

The requisite individual "junction blob" symbol was found in the add-on library set but isn't supplied in the basic stencil. Shapeware agreed that adding a connector junction automatically to a line joint could be done quite easily on a future update. It probably isn't a major setback though.

My other concern is the speed for



ISIS Illustrator symbol library.



ISIS Illustrator drawing.

drawing and refreshing. Unfortunately my 486SX didn't do full justice to the package, even copying a modest shape such as a junction took a second or two each on my PC. Other more demanding routines reduced my system to a crawl for up to nearly a minute.

This is very relevant to new PC owners such as students who may only just have invested in their first 486 machine, given that the SX is still touted as the entry level system. A co-processor is virtually essential, implying that this software is far better run on a 486DX or higher machine: otherwise expect some thumb-twiddling at times on an SX. Running Visio on a 486DX2-50 produced a much sprightlier performance.

Overall, I thought Visio 3.0 to be a first rate drag and drop graphics package for the more experienced Windows user, an intuitive and sophisticated drawing system using the graphics power of Windows to its fullest extent. Visio 3.0 enables you to produce a wide variety of 2D graphics, with Lotus and Microsoft toolbars making this package friendly and welcoming. Streets ahead of its nearest rival but really only feasible on faster co-processor machines. The Advanced Electrical Engineering Shapes library is worth having on tap if you can afford it, or you're faced with creating your own collection of symbols. ***Shapeware Visio 3.0 £89.00 + P&P + VAT from Watford Electronics Ltd. Tel. 01582 745555. Advanced Electrical Engineering Shapes £49 + P&P + VAT.***

Exclusive Offer to readers of *Everyday with Practical Electronics:* Watford Electronics and Shapeware are offering the Visio 3.0 plus the Advanced Electrical Engineering Shapes pack *together* for the sum of just £99 (ex. VAT). See the Visio advertisement elsewhere in this issue.

Also worth considering:

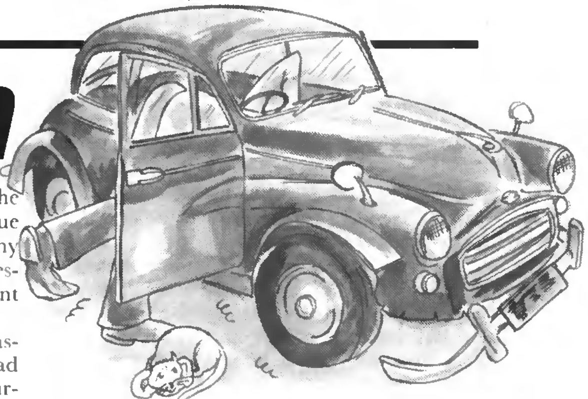
Labcenter ISIS Illustrator – a Windows package dedicated to electronics schematic capture. Features drag and drop placement with auto re-routing of connectors. On the same 486SX machine, I found Illustrator considerably quicker than Visio 3.0 when processing – Labcenter tells me that a co-processor is unnecessary. It will also automatically lay down junction blobs at connection points, plus automatic component annotation, so I found I was quickly producing circuit schematics. However, I thought it was much less intuitive to use than Visio, and had a less refined "feel".

It costs about the same as basic Visio 3.0, is less elaborate but on the other hand has a comprehensive electronics symbol library, with device pins named and numbered. If you own a 486SX machine and want to draw electronic circuit schematics – and nothing else – Illustrator will get you up and running quickest of all. ***£99.00 + P&P + VAT. Demo. disk from Labcenter Electronics, 01756 753440.***

CorelFLOW 2.0 is a cheap and cheerful 2D diagram package which might appeal to CorelDraw! users, having a similar sort of feel. Includes 2,000 symbols in over 40 "Smart Libraries", including basic American and a disappointing range of United Kingdom circuit symbols, or you can create your own. Features a tutorial, customisable connector styles, plus text Spellchecker. Supplied on floppies and also CD-ROM, bulked with 1,000 clip art images of varying degrees of relevance, 1,000 low resolution Corel Photos and 100 True Type fonts.

As a CorelDraw! user, I found the package reasonably straightforward to use, but uninspiring and much less satisfying or sophisticated than Visio. Co-processor recommended. New low price of ***£54.00 + P&P + VAT*** is good value from ***Watford Electronics.*** ☎ ***01582 745555.***

Ohm Sweet Ohm



Max Fidling

Stand by for action

MANY years ago, my technical twiddling brought forth a request from an acquaintance who had just bought his first car. Having become independently mobile albeit on a shoestring budget, his next problem was how to have music on the move.

Since car radio cassettes were still a bit expensive, I hit upon the idea of powering his ordinary portable cassette player from the electrical supply of the car. The theory was to place the cassette player on the passenger seat and plug it in to the car's electrics. Another example of Fidling's inventiveness!

The problem was that the 12V of the vehicle wasn't compatible with the 7·5V d.c. needed by the portable player. Some kind of an adapter was needed and this is where yours truly came in.

My friend brought the car round at the weekend for me to measure up and admire. I was greeted by the sight of a very old Morris Minor 1000 which was coloured mushroom and rust and had faded red vinyl seats, with the fungal smell of ancient rubber and mouldy interior you only find in clapped-out cars.

A quick rummage behind the dingy dashboard (in between coming up for fresh air) revealed a spare fuseholder dangling there, held back with gaffer tape around some faded wiring. A glint came into my eye like the sparkle from the chrome bezels of the Minor's art-deco instruments. Meantime, Piddles, my feline sidekick, arrived on the scene. Having given up on the mousing for the day, the cat ambled over to see what was going on, sensing that something was afoot.

I soon set about designing a simple voltage regulator circuit. The three-terminal regulator hadn't yet been invented and the more complex 723 chip was standard issue for these jobs. I prodded the buttons of my new Sinclair Cambridge calculator impressively, sketching out a rough circuit in front of my friend.

Fitting a suitable power socket to the cassette player posed no problem, once I had whizzed off the back using my multi-purpose screwdriver kit to reveal its innards. I traced through the battery wiring and soldered in a 3·5mm jack socket, such that when a "power" lead was plugged into it, the internal batteries were disconnected.

My friend looked on quite nervously – I think the sight of me madly drilling holes into the back of his cassette player with a whirring Black and Decker had unnerved him somewhat. No confidence, some people, I sniffed indignantly.

The regulator was built into an aluminium box during the following week, and my friend returned next weekend, driving the rusty relic. The alloy box was soon bolted into place behind the dashboard. There were a few extra holes in the box where I had miscalculated the drilling centres, but I glossed over those, hoping he wouldn't notice. "Ventilation holes, those" I told him. Anyway, the shiny box looked a bit incongruous amongst the scruffy car wiring, but there it was, bolted in and ready to go.

We have ignition

We grabbed the suitably modified cassette player and plonked it onto the Minor's vinyl passenger seat, then I plugged in the new power connecting lead. Piddles nosed his way through to the driver's seat, his tail tickling my right ear as I tried to complete the installation process. I'll bet NASA doesn't have this problem with its rockets, I mused, as I brushed the cat out of the way.

After hooking everything up, I instructed my friend to switch on the ignition of the elderly vehicle. Piddles' tail swished in anticipation – he had learned to recognise the tense atmosphere just before I switched on a project for the first time. A loud "crack" was heard from under the dashboard, quickly followed by a misty cloud of white smoke which filled the car with fumes, taking my credibility with it! Piddles disappeared underneath a tartan travel rug on the rear seat, fearing the worst. He had been here before.

Quickly switching off, the alloy box was opened to reveal the 723 had burst apart and was cooked to a crisp. I knew the design itself was sound enough because I'd checked it on my home-made bench power supply. I tried to look cool and unruffled, whilst secretly shrivelling with embarrassment and not having the faintest idea what should cause the premature death of my latest design.

There was nothing for it – I would have to check out the car's antiquated electrics. It took both of us to raise the rusty bonnet lid which yawned open with a groan that could have come from a Hammer horror movie.

Poking around in the engine bay, amidst decades of oily grime, I spotted the car battery, bolted down with a rusty strip of steel. Its terminals were crusty white, having corroded through several years of neglect. Then I slapped my forehead as I suddenly saw the cause of all my confusion! The wretched wreck had a positive earth!

Piddles' tail swished smugly as I retreated to the workshop and switched on the iron, muttering dark oaths. Cat One, Fidling Nil.

Electronics from the Ground Up

Mike Tooley, BA

Part 6

ELECTRONICS from the Ground Up is designed to provide you with a comprehensive and up-to-date introduction to the world of electronics. The series is based on *Electronics Workbench*, a remarkable software package that lets you use your PC to build and test a wide range of circuits. Back issues of earlier parts of this series are available – see *Back Issues* page.

In this sixth part we introduce oscillators. We begin by discussing the differences between negative and positive feedback and continue by describing a variety of astable circuits, beginning with a simple transistor "multivibrator". In addition, two forms of sinusoidal oscillator are described.

POSITIVE AND NEGATIVE FEEDBACK

In Part 5 of *Electronics from the Ground Up*, we showed how an operational amplifier (op.amp) could be used to form the basis of a simple amplifier stage which has a precisely controlled gain, the exceptionally high open-loop voltage gain being reduced to a manageable value by feeding a small proportion of the output voltage back to the inverting input.

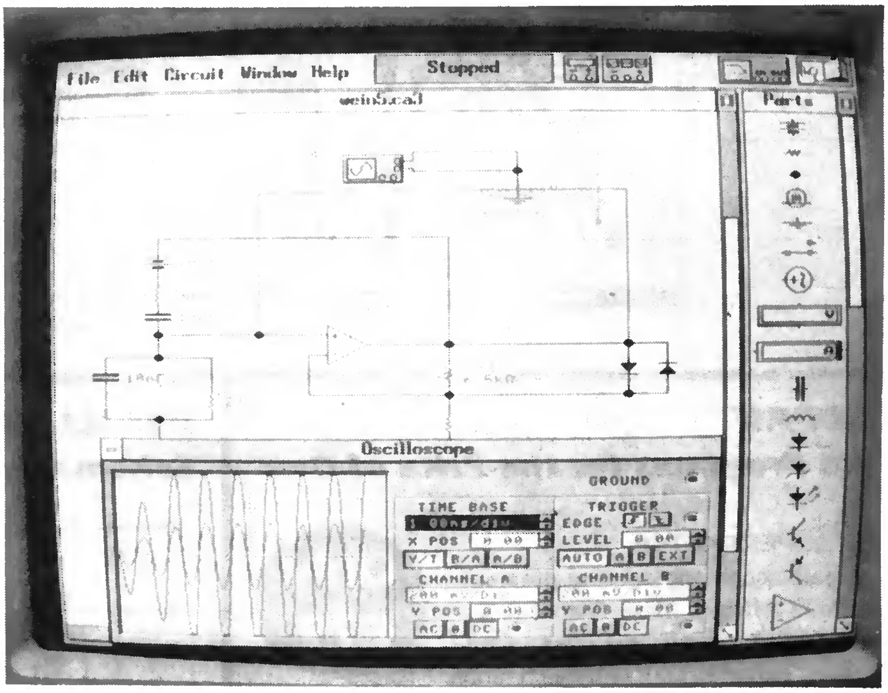
The amount of feedback (and hence the value of closed-loop gain) is determined by the ratio of feedback resistance to input resistance. Because this form of feedback has the effect of reducing the overall gain of the circuit, this form of gain is known as *negative feedback*.

An alternative form of feedback, where the output is fed back in such a way as to reinforce the input (rather than to subtract from it) is known as *positive feedback*. Such feedback can result in spontaneous oscillation.

The conditions for oscillation are:

(a) the feedback must be positive (i.e., the signal fed back must arrive back in-phase with the signal at the input)

(b) the overall loop voltage gain must be greater than one (i.e., the amplifier's gain must be sufficient to overcome the losses associated with any frequency selective feedback network).



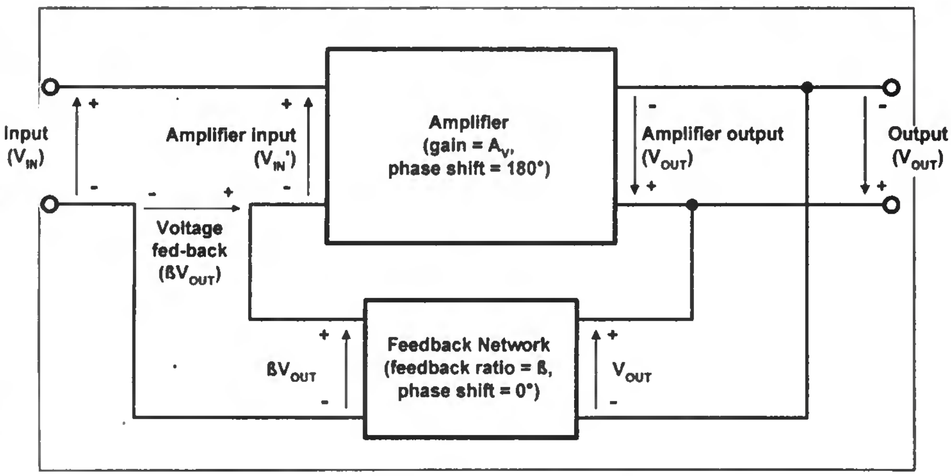


Fig. 6.1 Amplifier with negative feedback applied.

Fig. 6.1 shows the block diagram of an amplifier stage with negative feedback applied. In this circuit, the proportion of the output voltage fed-back to the input is given by the Greek letter β and the overall voltage gain will be given by:

$$\text{Overall gain} = \frac{V_{OUT}}{V_{IN}}$$

Now $V_{IN}' = V_{IN} - \beta V_{OUT}$ (by applying Kirchhoff's Voltage Law)

(note that the amplifier's input voltage has been *reduced* by applying negative feedback)

thus $V_{IN} = V_{IN}' + \beta V_{OUT}$

and $V_{OUT} = A_V \times V_{IN}'$ (A_V is the *internal gain* of the amplifier)

$$\text{Hence, overall gain} = \frac{A_V \times V_{IN}'}{V_{IN}' + \beta V_{OUT}}$$

$$= \frac{A_V \times V_{IN}'}{V_{IN}' + \beta(A_V \times V_{IN}')}$$

$$\text{Thus overall gain} = \frac{A_V}{1 + \beta A_V}$$

Since β is always less than 1, $\frac{A_V}{1 + \beta A_V}$ will always be less than A_V.

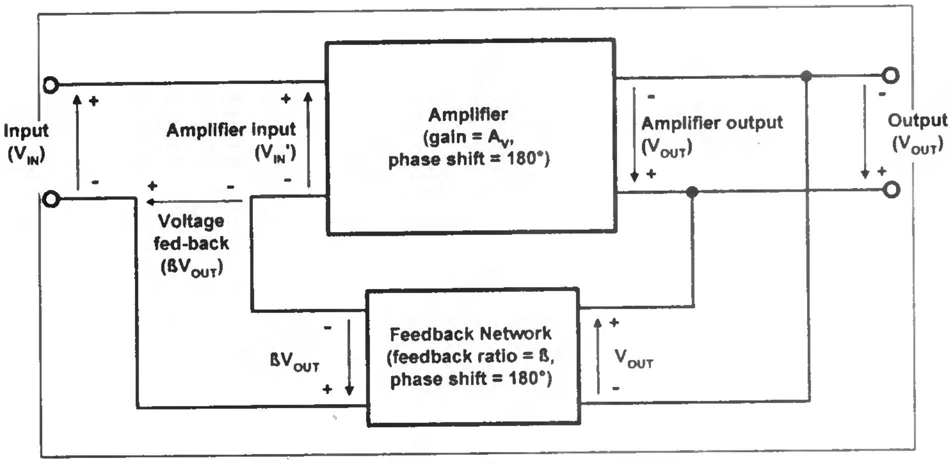


Fig. 6.2 Amplifier with positive feedback applied.

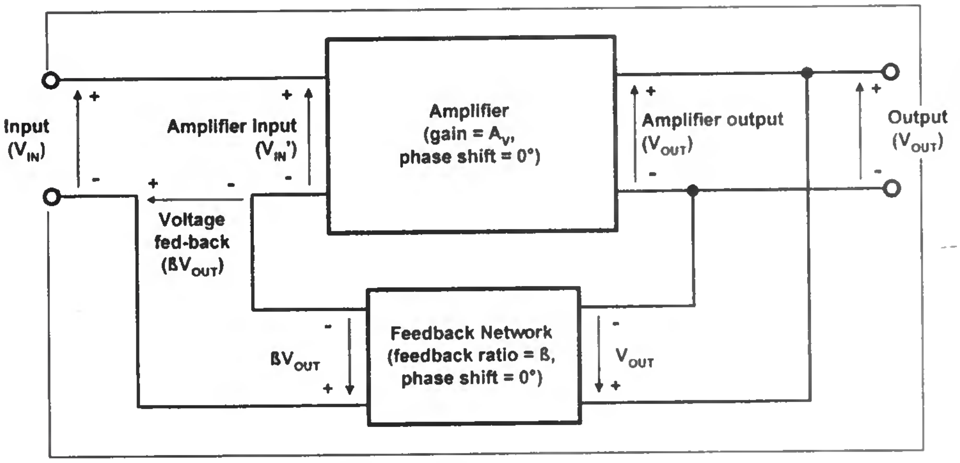


Fig. 6.3 Amplifier with positive feedback applied.

Hence, the overall gain with negative feedback applied, will be less than the gain without feedback. Furthermore, If A_V is very large (as is the case with an op.amp) the overall gain with negative feedback applied will be given by:

Overall gain (when A_V is very large) $= 1/\beta$

Fig. 6.2 and Fig. 6.3 show the block diagram of an amplifier stage with positive feedback applied (note that in both cases the overall phase shift is 0°). In either case, the overall voltage gain is given by:

$$\text{Overall gain} = \frac{V_{OUT}}{V_{IN}}$$

Now $V_{IN}' = V_{IN} + \beta V_{OUT}$ (by applying Kirchhoff's Voltage Law)

thus $V_{IN} = V_{IN}' - \beta V_{OUT}$

and $V_{OUT} = A_V \times V_{IN}'$ (A_V is the *internal gain* of the amplifier)

$$\text{Hence, overall gain} = \frac{A_V \times V_{IN}'}{V_{IN}' - \beta V_{OUT}}$$

$$= \frac{A_V \times V_{IN}'}{V_{IN}' - \beta(A_V \times V_{IN}')}$$

$$\text{Thus overall gain} = \frac{A_V}{1 - \beta A_V}$$

LOOP GAIN

Now consider what will happen when the *loop gain* (βA_V) approaches unity. The denominator $(1 - \beta A_V)$ will become close to zero. This will have the effect of increasing the overall gain, i.e., the overall gain with positive feedback applied will be greater than the gain without feedback.

It is worth illustrating this difficult concept using some practical figures. Assume that you have an amplifier with a gain of nine and one tenth of the output is fed back to the input (i.e., $\beta = 0{\cdot}1$). In this case the loop gain ($\beta \times A_V$) is 0·9.

With negative feedback applied the overall voltage gain will fall to:

$$\frac{A_V}{1 + \beta A_V} = \frac{9}{1 + (0{\cdot}1 \times 9)} = \frac{9}{1 + 0{\cdot}9}$$

$$= \frac{9}{1{\cdot}9} = 4{\cdot}7$$

With positive feedback applied the overall voltage gain will be:

$$\frac{A_V}{1 - \beta A_V} = \frac{9}{1 - (0{\cdot}1 \times 9)} = \frac{9}{1 - 0{\cdot}9}$$

$$= \frac{9}{0{\cdot}1} = 90$$

Now assume that you have an amplifier with a gain of 10 and, once again, one tenth of the output is fed back to the input (i.e., $\beta = 0{\cdot}1$). In this example the loop gain ($\beta \times A_V$) is exactly one.

With negative feedback applied the overall voltage gain will fall to:

$$\frac{A_V}{1 + \beta A_V} = \frac{10}{1 + (0{\cdot}1 \times 10)} = \frac{10}{1 + 1}$$

$$= \frac{10}{2} = 5$$

With positive feedback applied the overall voltage gain will be:

$$\frac{A_V}{1 - \beta A_V} = \frac{10}{1 - (0.1 \times 10)} = \frac{10}{1 - 1}$$

$$= \frac{10}{0} = \text{infinity}$$

This simple example shows that a loop gain of unity (or larger) will result in infinite gain and an amplifier which is unstable. In fact, the amplifier will *oscillate* since any input disturbance will be amplified and result in an output change.

Clearly, as far as an amplifier is concerned, positive feedback may have an undesirable effect – instead of reducing the overall gain the effect is that of reinforcing any signal present and the output can build up into continuous oscillation if the loop gain is one, or greater. Continuous oscillation is, however, *essential* in oscillator circuits. Such circuits can be thought of as amplifiers that generate an output signal without the need for any input.

MULTIVIBRATORS

Multivibrators are a family of oscillator circuits that produce output waveforms consisting of one or more rectangular pulses. The term "multivibrator" simply originates from the fact that this type of waveform is rich in harmonics (i.e., "multiple vibrations").

Multivibrators use regenerative (positive) feedback; the active devices present within the oscillator circuit being operated as switches, being alternately cut-off and driven into saturation.

The principal types of multivibrator are:

(a) *astable multivibrators* that provide a continuous train of pulses (these are sometimes also referred to as *free-running multivibrators*

(b) *monostable multivibrators* that produce a single output pulse (they have one stable state and are thus sometimes also referred to as *one-shot* circuits)

(c) *bistable multivibrators* that have two stable states and require a trigger pulse or control signal to change from one state to another.

In this part we shall confine our investigation to astable multivibrators. Bistable multivibrators will be described in a later part of the series.

ASTABLE MULTIVIBRATOR

A classic form of astable multivibrator based on two transistors is shown in Fig. 6.4. Fig. 6.5 shows how this circuit can be re-drawn in an arrangement that more closely resembles a two-stage common emitter amplifier with its output connected back to its input.

The operation of the circuit shown in Fig. 6.4 is as follows. The values of the base resistors, R3 and R4 are such that sufficient base current will be available to completely saturate the respective transistor. The values of the collector load resistors, R1 and R2, are very much smaller than R3 and R4. When power is first applied to the circuit, assume that transistor TR2 saturates before transistor TR1 when the power is first applied (in practice one transistor would always saturate before the other due to variations in component tolerances and transistor parameters).

As TR2 saturates, its collector voltage will fall rapidly from $+V_{CC}$ to 0V. This drop in voltage will be transferred to the base of TR1 via capacitor C2. This negative going voltage will ensure that TR1 is initially placed in the non-conducting state. As long as TR1 remains cut-off, TR2 will continue to be saturated. During this time, C2 will charge via R4 and TR1's base voltage will try to rise exponentially from $-V_{CC}$ towards $+V_{CC}$.

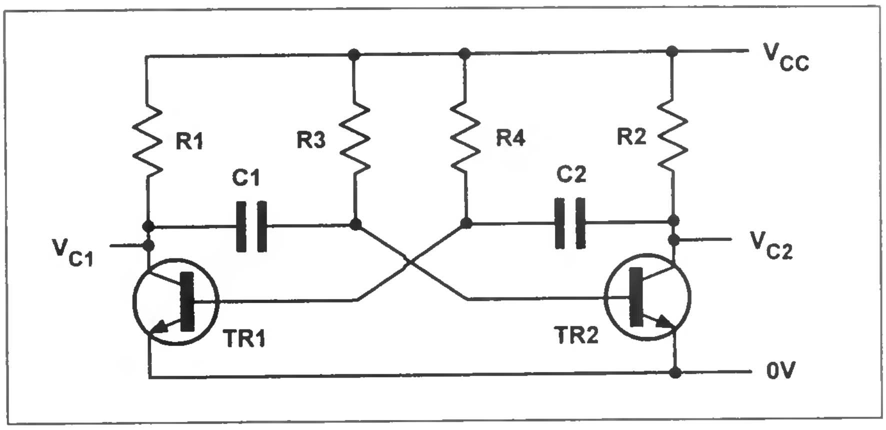


Fig. 6.4 Astable multivibrator using bipolar transistors.

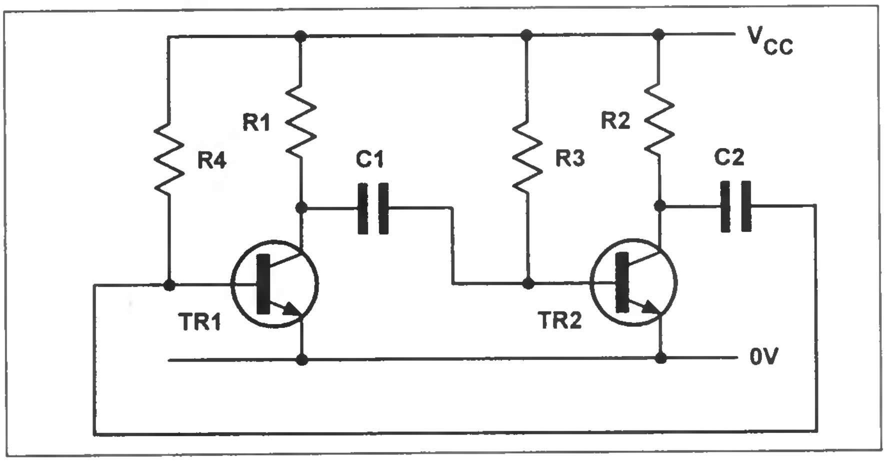


Fig. 6.5 Circuit of Fig. 6.4 redrawn to show the two common emitter stages.

However, TR1's base voltage will not rise much above 0V because, as soon as it reaches +0·7V (sufficient to cause base current to flow) TR1 will begin to conduct. As TR1 begins to turn on, its collector voltage will rapidly fall from $+V_{CC}$ to 0V. This fall in voltage is transferred to the base of TR2 via capacitor C1 and, as a consequence, TR2 will turn off. C1 will then charge via R3 and TR2's base voltage will try to rise exponentially from $-V_{CC}$ towards $+V_{CC}$. As before, TR2's base voltage will not rise much above 0V because, as soon as it reaches +0·7V (sufficient to cause base current to flow) TR2 will start to conduct. The cycle is then repeated indefinitely.

The time for which the collector voltage of TR2 is low and TR1 is high (T1) will be determined by the time constant, R4 × C2. Similarly, the time for which the collector voltage of TR1 is low and TR2 is high (T2) will be determined by the time constant, R3 × C1.

The following approximate relationships apply:

$$T1 = 0{\cdot}7\,C2\,R4 \text{ and } T2 = 0{\cdot}7\,C1\,R3$$

Since one complete cycle of the output occurs in a time, T = T1 + T2, the periodic time of the output is given by:

$$T = 0{\cdot}7\,(C2\,R4 + C1\,R3)$$

Finally, we often require a symmetrical "square wave" output where T1 = T2. To obtain such an output, we should make R3 = R4 and C1 = C2, in which case the periodic time of the output will be given by:

$$T = 1{\cdot}4\,C\,R$$

where C = C1 = C2 and R = R3 = R4.

Waveforms for the astable oscillator are shown in Fig. 6.6.

Astable oscillators can be built using a variety of amplifying devices, including op.amps (see Fig. 6.7), as our next practical assignment shows.

Practical assignment 6.1: Astable multivibrator

In this practical assignment using the *Electronic Workbench* software you will investigate the action of an astable multivibrator based on two op.amps.

Objectives:

6.1.1 To investigate the behaviour of a simple astable multivibrator.

6.1.2 To determine the relationship between component values and output frequency for a simple astable multivibrator.

Instructions:

1. Connect the circuit shown in Fig. 6.8. Note that the 1V battery is used to unbalance the circuit so that oscillation commences. This component would not be required in a real circuit as the components would not be perfectly balanced.
2. Switch on the power to your circuit and display the output waveform using the oscilloscope. Recommended initial settings for this instrument are shown in Fig. 6.9.
3. Use the oscilloscope to accurately measure the periodic time of the output waveform. Record this together with the value of feedback resistance (100kΩ) in Table 6.1.

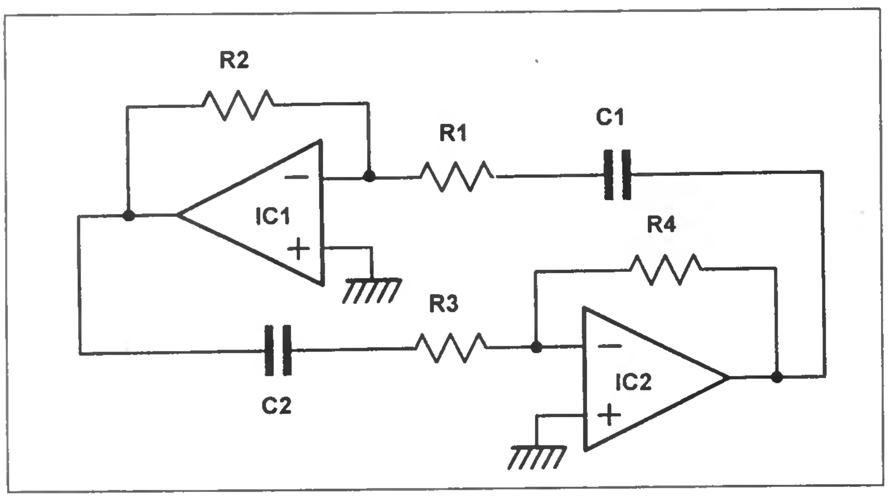


Fig. 6.7 Astable oscillator using operational amplifiers.

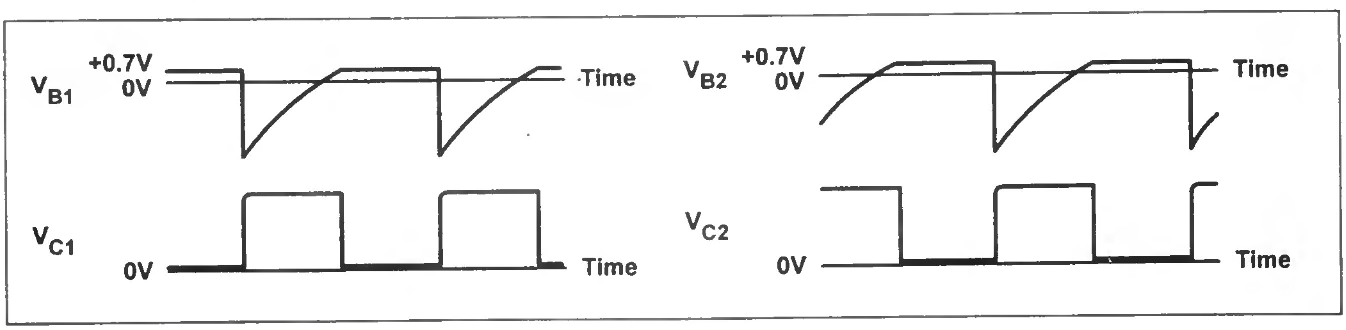
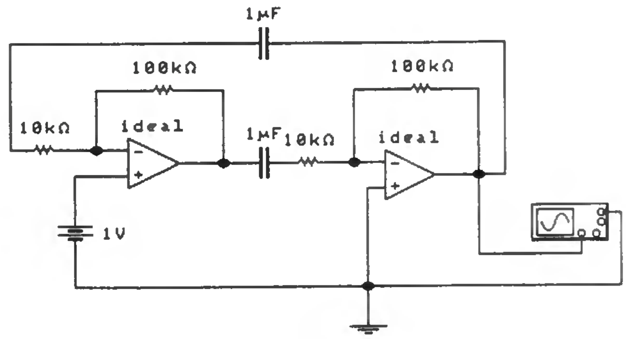


Fig. 6.6 Waveforms for the transistor astable multivibrator.



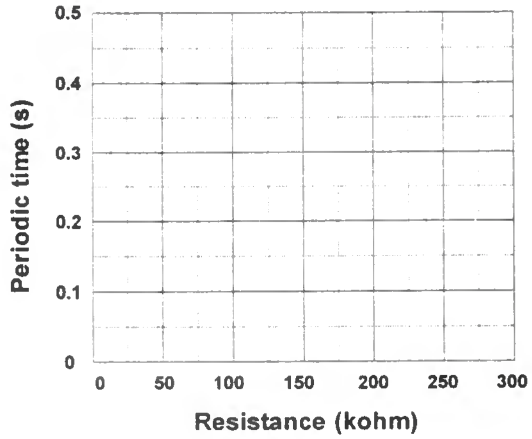


Fig. 6.8 (Above) Circuit for Assignment 6.1.

Fig. 6.9 (Below) Initial oscilloscope settings for Assignment 6.1.

Fig. 6.10 (Right) Results for Assignment 6.1.

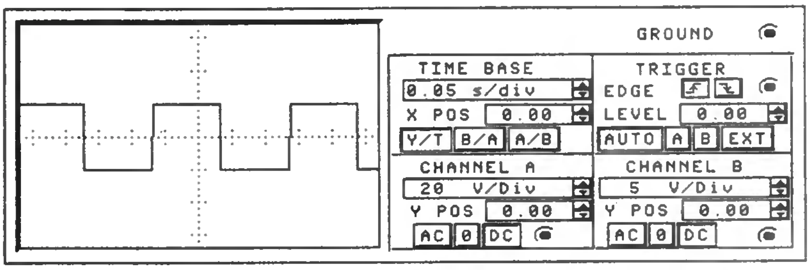


Table 6.1 Measured values for the simple astable multivibrator

Feedback resistance (kΩ)	100	200	50
Periodic time (s)			

4. Repeat step 3 for values of feedback resistor (both stages) of 50k**Ω** and 200k**Ω**. Again, record your results in Table 6.1.
5. Plot a graph (using the axes in Fig. 6.10) to show the relationship between periodic time and feedback resistance.

Conclusions:

To what extent have the objectives for this assignment been met? Comment on the shape of the graph. Can you explain why the periodic time should depend on the value of feedback resistance? What other component(s) determine the periodic time of the output? What value of feedback resistance would be required to provide an output frequency of exactly 4Hz?

OTHER FORMS OF ASTABLE OSCILLATOR

The circuit diagram of an alternative form of astable oscillator is shown in Fig. 6.11. This oscillator is ideal for producing a triangular wave output. IC1 forms an integrating stage whilst IC2 is connected with positive feedback to ensure that oscillation takes place.

Assume that the output from IC2 is initially at, or near, $+V_{CC}$ and the capacitor, C, is uncharged. The voltage at the output of IC2 will be passed, via resistor R, to IC1. Capacitor C will start to charge and the output voltage of IC1 will begin to fall. Eventually, the output voltage will have fallen to a value that causes the polarity of the voltage at the non-inverting input of IC2 to change from positive to negative.

At this point, the output of IC2 will rapidly fall to $-V_{CC}$. Again, this voltage will be passed, via resistor R, to IC1. Capacitor C will then start to charge in the other direction and the output voltage of IC1 will begin to rise. Eventually, the output voltage will have risen to a value that causes the polarity of the non-inverting input of IC2 to revert to its original (positive) state and the cycle will continue indefinitely.

The upper threshold voltage (the maximum positive value for V_{OUT}) will be given by:

$$V_{UT} = V_{CC} \times (R1/R2)$$

The lower threshold voltage (the maximum negative value for V_{OUT}) will be given by:

$$V_{LT} = -V_{CC} \times (R1/R2)$$

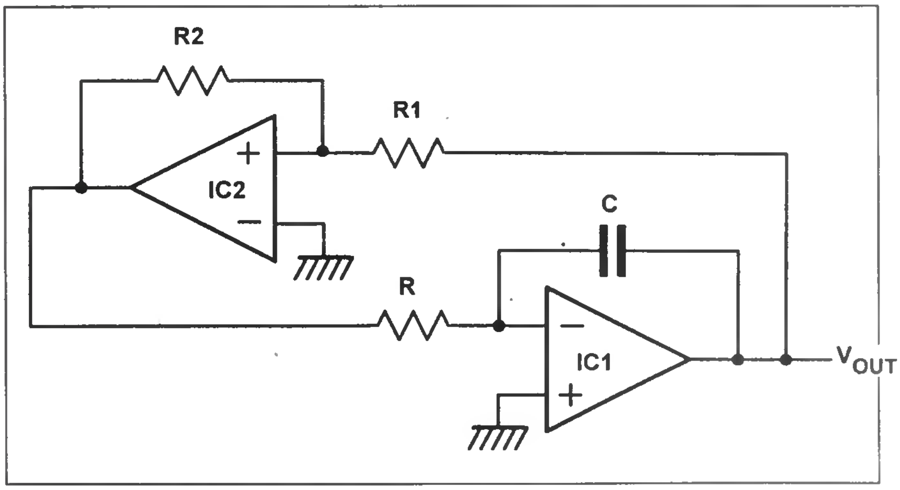


Fig. 6.11 Two-stage astable oscillator using operational amplifiers.

Practical assignment 6.2: Two-stage astable oscillator

In this practical assignment you will construct and test an astable oscillator that produces a triangular wave output. Once again, the oscillator is based on two op.amps.

Objectives:

6.2.1 To investigate the behaviour of a two-stage astable oscillator.

6.2.2 To determine the relationship between component values and output frequency for a two-stage astable oscillator.

6.2.3 To measure the threshold voltages for a two-stage astable oscillator and relate these to the component values.

Instructions:

1. Connect the circuit shown in Fig. 6.12. Once again, the 1V battery has been included in order to unbalance the circuit so that oscillation reliably commences.
2. Switch on the power to your circuit and display the output waveform using the oscilloscope. Recommended initial settings for this instrument are shown in Fig. 6.13.
3. Use the oscilloscope to accurately measure the periodic time of the output waveform. Record this together with the value of resistance (R in Fig. 6.11) in Table 6.2.
4. Repeat step 3 for values of R of 100k**Ω**, 200k**Ω**, 20k**Ω** and 10k**Ω**. Note that you will have to change the oscilloscope timebase setting in order to make accurate measurements of the periodic time. Add these results to Table 6.2.
5. Plot a graph (using the axes in Fig. 6.14) to show the relationship between periodic time and resistance.
6. Finally, measure the upper and lower threshold voltages (V_{UT} and V_{LT}). Compare the measured values with the calculated values.

Conclusions:

To what extent have the objectives for this assignment been met? Comment on the shape of the graph. Can you explain

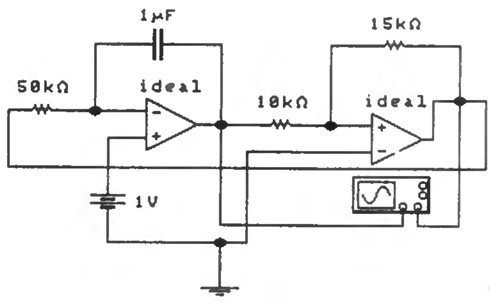
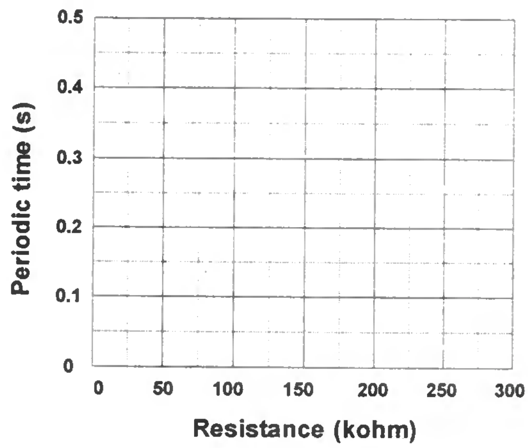


Fig. 6.12 (Above) Circuit for Assignment 6.2.

Fig. 6.13 (Below) Initial oscilloscope settings for Assignment 6.2.

Fig. 6.14 (Right) Results for Assignment 6.2.



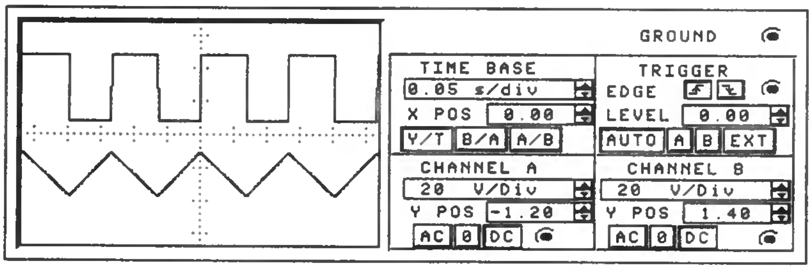


Table 6.2 Measured values for the two-stage astable oscillator

Feedback resistance (kΩ)	50	100	200	20	10
Periodic time (s)					

how the circuit operates? Which other component determines the periodic time of the output? What component values would be required to produce an output of 100Hz? Did the measured values of threshold voltage agree with those obtained from calculation? If not, why?

SINGLE-STAGE ASTABLE OSCILLATOR

A simple form of astable oscillator can be built using just one op.amp, as shown in Fig. 6.15. This circuit employs positive feedback with the output fed back to the non-inverting input via the potential divider formed by resistors R1 and R2.

Assume that capacitor C is initially uncharged and the voltage at the inverting input is slightly less than the voltage at the non-inverting input. The output voltage will rise rapidly to $+V_{CC}$ and the voltage at the inverting input will begin to rise exponentially as capacitor C charges through resistor R. Eventually, the voltage at the inverting input will have reached a value that exceeds that present at the non-inverting input.

At this point, the output voltage will rapidly fall to $-V_{CC}$. Capacitor C will then start to charge in the other direction and the voltage at the inverting input will begin to fall exponentially. Eventually, the voltage at the inverting input will have reached a value that is less than that present at the non-inverting input.

At this point, the output voltage will rise rapidly to $+V_{CC}$ once again and the cycle will continue indefinitely.

The upper threshold voltage (i.e., the maximum positive value for the voltage at the inverting input) will be given by:

$$V_{UT} = V_{CC} \times \frac{R2}{R1 + R2}$$

The lower threshold voltage (i.e., the maximum negative value for the voltage at the inverting input) will be given by:

$$V_{LT} = -V_{CC} \times \frac{R2}{R1 + R2}$$

Practical assignment 6.3: Single-stage astable oscillator

In this practical assignment you will construct and test a single-stage astable oscillator.

Objectives:

6.3.1 To investigate the behaviour of a single-stage astable oscillator.

6.3.2 To determine the relationship between component values and output frequency for a single-stage astable oscillator.

6.3.3 To measure the threshold voltages for a single-stage astable oscillator and relate these to the component values.

Instructions:

1. Connect the circuit shown in Fig. 6.16. Once again, the 1V battery has been included in order to unbalance the circuit so that oscillation reliably commences.
2. Switch on the power to your circuit and display the output waveform using the oscilloscope. Recommended initial settings for this instrument are shown in Fig. 6.17.
3. Use the oscilloscope to accurately measure the periodic time of the output waveform. Record this together with the value of resistance (R in Fig. 6.15) in Table 6.3.

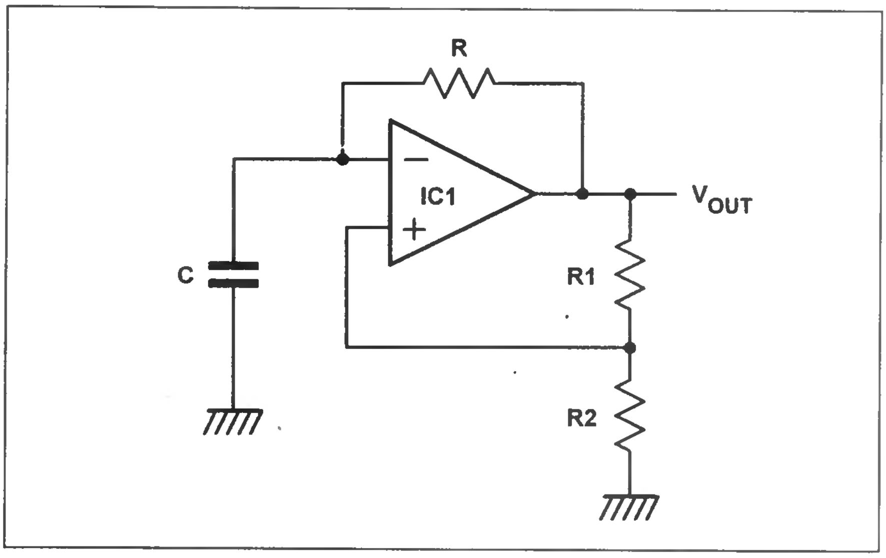


Fig. 6.15 Single-stage astable oscillator using an operational amplifier.

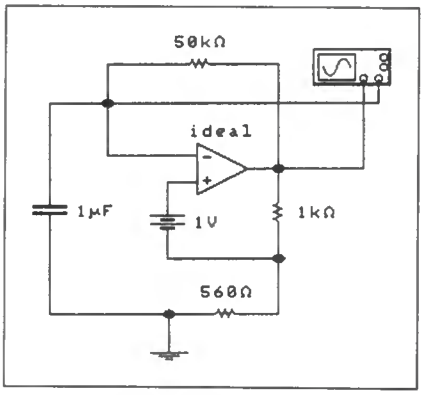
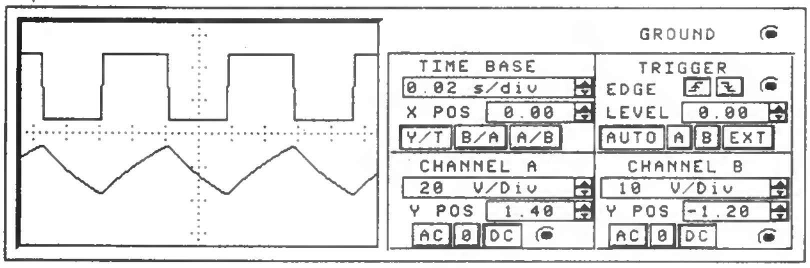


Fig. 6.16 Circuit for Assignment 6.3.

Table 6.3 Measured values for the single-stage astable oscillator

Feedback resistance (kΩ)	50	100	200	20	10
Periodic time (s)					



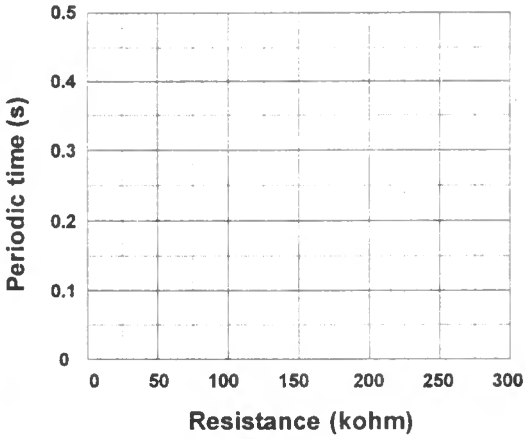


Fig. 6.17 (Left) Initial oscilloscope settings for Assignment 6.3.

Fig. 6.18 (Above) Results for Assignment 6.3.

4. Repeat step 3 for values of R of 100kΩ, 200kΩ, 20kΩ and 10kΩ. Note that you will have to change the oscilloscope timebase setting in order to make accurate measurements of the periodic time. Add these results to Table 6.3.
5. Plot a graph (using the axes in Fig. 6.18) to show the relationship between periodic time and resistance.
6. Finally, measure the upper and lower threshold voltages (V_{UT} and V_{LT}). Compare the measured values with the calculated values.

Conclusions:

To what extent have the objectives for this assignment been met? Comment on the shape of the graph. Can you explain how the circuit operates? Which other component determines the periodic time of the output? What component values would be required to produce an output of 100Hz? Did the measured values of threshold voltage agree with those obtained from calculation? If not, why?

SINUSOIDAL OSCILLATORS

Phase shift oscillators

Thus far, the oscillators that we have described have produced square, pulse, or triangular wave outputs. There are many occasions when we require a sinusoidal rather than a rectangular output. Sine wave oscillators are based either on tuned L-C circuits or on phase shifting networks.

A simple phase-shift oscillator based on a three-stage C-R ladder network is shown in Fig. 6.19. Transistor TR1 operates as a conventional common-emitter amplifier stage with resistor R1 and R2 providing base bias potential and resistor R3 and capacitor C1 providing emitter stabilization. Each C-R section of the ladder network (connected between collector and base) provides a 60° phase shift at the operating frequency. The total phase shift produced by the ladder network is thus 3 × 60° or 180°. The transistor provides the other 180° phase shift in order to realize an overall phase shift of 360° or 0°.

Wien bridge oscillator

The Wien bridge network (Fig. 6.20) provides a phase shift which varies with frequency. The input signal is applied to A and B whilst the output it taken from C and D. At one particular frequency, the phase shift produced by the network will be exactly zero (i.e., the input and output signals will be in-phase). If we connect the network to an amplifier (see Fig. 6.21), oscillation will result provided:

(a) the amplifier has sufficient gain to overcome the losses in the network (i.e., the loop gain is greater than one), and
(b) the amplifier provides a phase-shift of 0° (or 360°).

The minimum amplifier gain required to sustain oscillation is given by:

$$A_V = 1 + C1/C2 + R2/R1$$

and the frequency at which the phase-shift will be zero is given by:

$$f = \frac{1}{2\pi\sqrt{(C1\,C2\,R1\,R2)}}$$

In practice, we normally make R1 = R2 and C1 = C2 hence:

$$A_V = 1 + C/C + R/R = 1 + 1 + 1 = 3$$

and the frequency at which the phase-shift will be zero is given by:

$$f = \frac{1}{2\pi\sqrt{(C\,C\,R\,R)}} = \frac{1}{2\pi C R}$$

where R = R1 = R2 and C = C1 = C2.

Practical assignment 6.4: Wien bridge oscillator

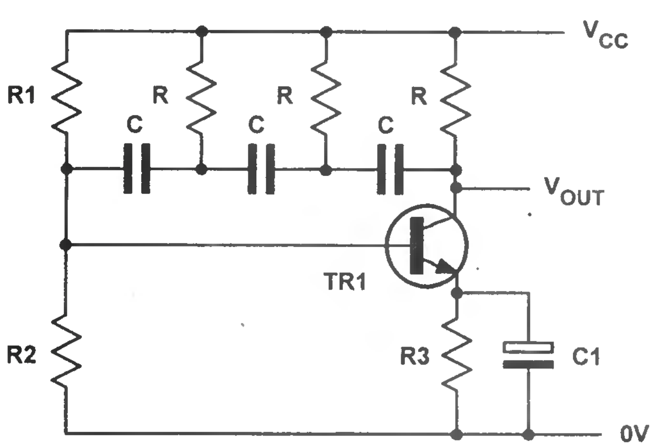
In this practical assignment you will construct and test a Wien bridge oscillator.

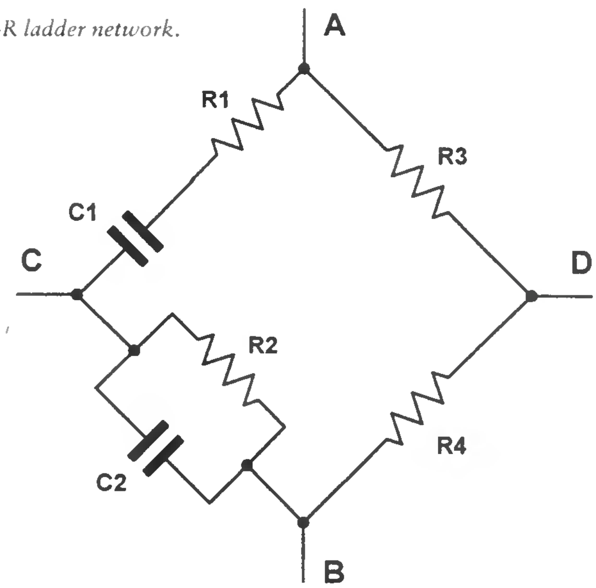
Objectives:

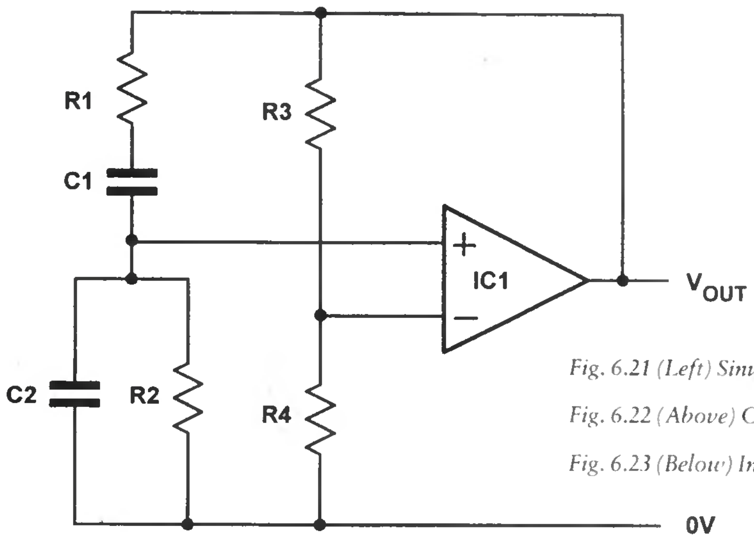
6.4.1 To investigate the behaviour of a Wien bridge oscillator.

Fig. 6.19 (Below) Sinusoidal oscillator based on a three-stage C-R ladder network.

Fig. 6.20 (Right) Wien bridge network.







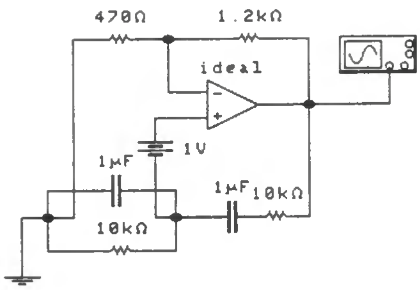
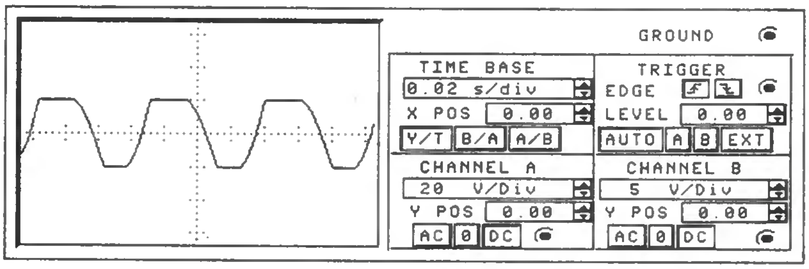


Fig. 6.21 (Left) Sinusoidal oscillator based on a Wien bridge network.

Fig. 6.22 (Above) Circuit for Assignment 6.4.

Fig. 6.23 (Below) Initial oscilloscope settings for Assignment 6.4.



6.4.2 To determine the relationship between component values and output frequency for a Wien bridge oscillator.

6.4.3 To observe the effect of different values of loop gain on the operation of a Wien bridge oscillator.

Instructions:

1. Connect the circuit shown in Fig. 6.22. Once again, the 1V battery has been included in order to ensure that oscillation reliably commences.
2. Switch on the power to your circuit and display the output waveform using the oscilloscope. Recommended initial settings for this instrument are shown in Fig. 6.23.
3. Use the oscilloscope to accurately measure the periodic time of the output waveform and use this to calculate the frequency of the output signal.
4. Note the distortion present on the output waveform (the peaks will appear to be "clipped"). Now change the value of the 470Ω resistor (R4 in Fig. 6.19) to 560Ω, 600Ω, and 680Ω. Note the effect on the output signal (oscillation will stop for larger values).

Conclusions:

To what extent have the objectives for this assignment been met? Compare the measured output frequency with that obtained by calculation. Explain why the value of R4 affects the output signal. Which value would you consider to be optimum? Why?

BRAIN TEASER

This month's challenge for those of you who are using the full *Electronics Workbench* package is to design a circuit that produces complementary square wave outputs with an amplitude of 1V and a frequency of 50Hz.

Answer to last month's Brain Teaser

Last month's Brain Teaser involved the design of a circuit based on a single op.amp that will perform according to the following specifications:

Voltage gain: 20
Frequency response: d.c. to 10kHz
Input resistance: 10kΩ
Phase-shift (mid-band): 180°

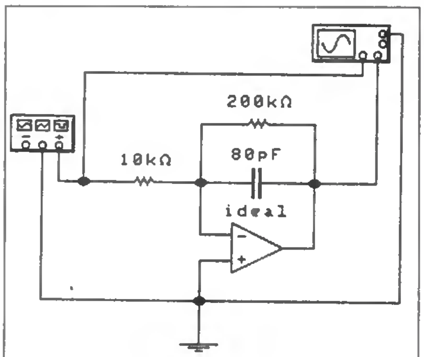
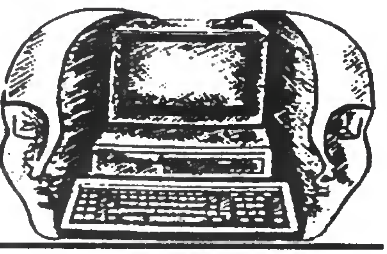


Fig. 6.24 Solution to last month's Brain Teaser.

Fig. 6.24 shows one solution arrived at using the full version of *Electronics Workbench.*

INTERFACE



Robert Penfold

THIS month we will continue to explore the general interfacing possibilities of the PC's printer ports. Last month's *Interface* article provided details of how to use four printer port handshake inputs plus a handshake output to provide an 8-bit input port. A single 8-bit port is adequate for many purposes, but what if you require two or more byte-size input ports?

The easiest solution is to use two printer ports, but in most cases this will be impractical as there will only be one spare printer port available. It is possible to use one printer port to provide two or more 8-bit inputs, but the more input ports you use, the less straightforward things become.

No Comparison

One way of tackling the problem is to effectively use the eight data outputs of the ports to act as an 8-bit input. This can be achieved in conjunction with an 8-bit comparator and a spare handshake input.

This is a ploy that can be used in any situation where you have eight outputs but require eight inputs, provided there is a spare input line available. The drawback of this method is that it is not particularly fast, although it is still faster than a normal serial port provided the control routine is written in a reasonably speedy language.

The basic scheme of things for an input port of this type is shown in Fig. 1. The 8-bit comparator has one set of inputs fed with the input signal, and the other set is fed from the eight data outputs of the printer port.

The output of the comparator is monitored via the spare handshake input. This output is normally high, but goes low when the two 8-bit input codes are the same.

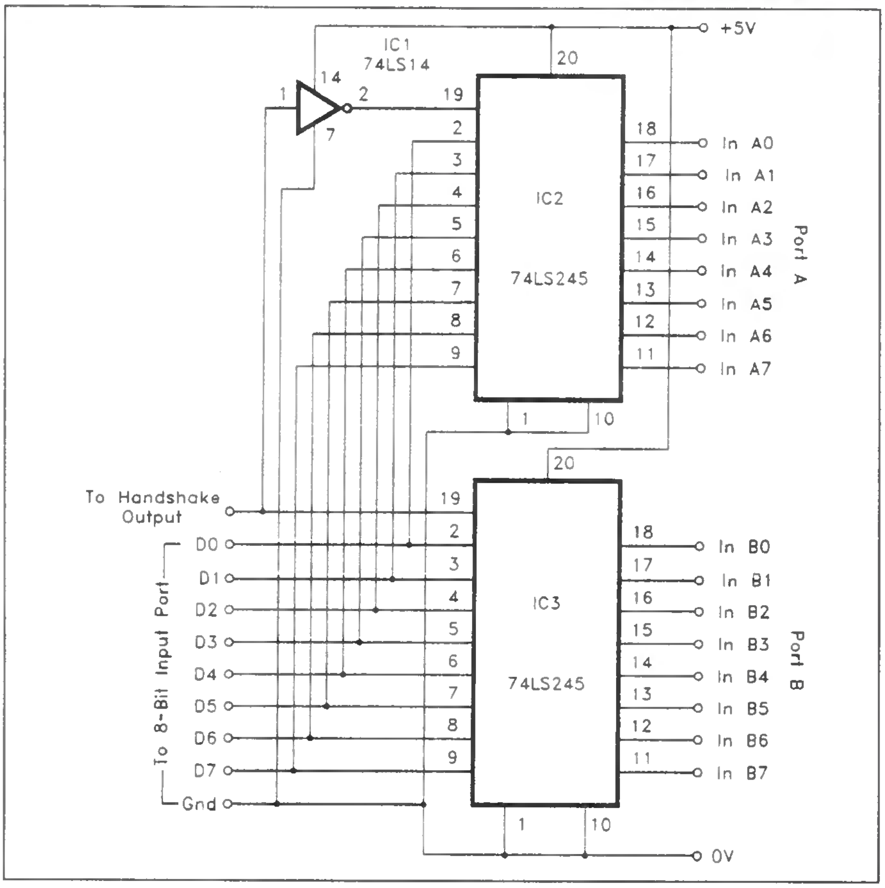


Fig. 2. An add-on circuit to provide two 8-bit input ports.

In order to take a reading a value of zero is output to the data lines, and the state of the handshake input is checked. While the handshake input is in the high state the two 8-bit codes to the comparator do not match, and the reading routine must continue. This means incrementing the value on the data output lines by one, and checking the handshake input again.

Eventually, the handshake input will be taken high by the output of the comparator. The last value written to the printer port's data lines is then equal to the value on the eight input lines.

This method has its limitations, the main one being that it can only be guaranteed to work if the input pattern remains unchanged while the reading routine is in progress. It is therefore unsuitable for use with rapidly changing input values, even if a fast machine code routine is used to take readings.

It is advisable to include a "catch" in the software routine that will repeat the process if the value on the output lines is incremented to 255 and no match is obtained. In many applications there will be a risk of this happening occasionally due to a change in the input value while a reading is being taken.

Four Into One

The input port described in last month's article reads each byte as two 4-bit nibbles. A handshake output is used to control which nibble of the input signal is connected through to the four inputs of the printer port. Some mathematics in the software then manipulates the two readings in order to reassemble the 8-bits of data and give the correct value.

An obvious way of providing more inputs is to take this a stage further, with two 8-bit inputs being multiplexed into eight output lines which can then be read by the circuit described last month. In other words, overall some 16 input lines are multiplexed down to four output lines that can be read by the printer port's nibble input.

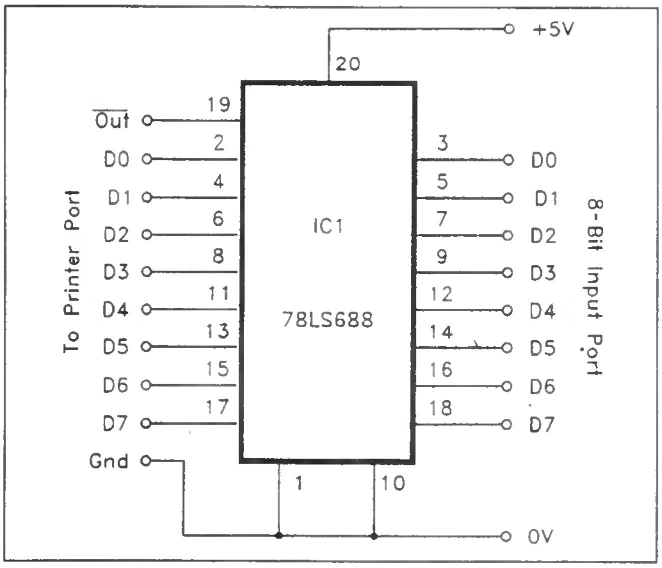


Fig. 1. A circuit which effectively converts an 8-bit output to an 8-bit input.

Of course, you do not get something for nothing in this world, and the extra multiplexing is only possible if an extra handshake output is available. However, there are four handshake outputs available on each printer port, and this will not normally be a problem. An obvious advantage of this method is that it leaves the eight data lines for use as outputs, and it should also permit readings to be taken at a substantially higher rate.

There is more than one way of providing the multiplexing, but the method described here uses the original input port circuit to provide eight input lines. The circuit of Fig.2 is added ahead of the original input port circuit, and provides two 8-bit input ports.

It is based on two 74LS245 octal transceivers, but in this case pin 1 of each transceiver is permanently wired low. Both devices are therefore held in the "receive" mode, and they act as straightforward octal tristate buffers.

The outputs of the buffers drive the data inputs of the 8-bit input port. The negative enable inputs of the buffers are controlled via one of the printer port's handshake outputs. IC2's enable input is controlled via an inverter (IC1), but the enable input of IC3 is controlled directly. Thus, IC2 and port A are enabled when the handshake line is high, while IC3 and port B are enabled when the handshake line is low.

This method of reading 16 lines via four inputs of the printer port obviously makes the software side of things a little involved. Matters are not made any easier by the fact that three of the four handshake outputs are inverted.

We will assume here that the "initialise" output at pin 16 of the port is used to control the basic 8-bit input port, and that the "strobe" output at pin 1 is used to control the circuit of Fig. 2. Using the GW BASIC routine provided last month will read port A.

In order to read port B it is necessary to set bit 0 at address &H37A to 1, which sets the "strobe" line low due to the built-in inversion on this line. This necessitates slight modifications at lines 10 and 40 of the program, where the "initialise" input is set to the correct states.

This is basically just a matter of adding one to the values output in the original program so that the "strobe" line is set low.

The modified routine needed to read port B is as follows:

```
10 OUT &H37A,1
20 X = INP(&H379) AND 120
30 X = X/8
40 OUT &H37A,5
50 Y = INP(&H379) AND 120
60 Y = Y * 2
70 Z = X + Y
80 PRINT Z
```

The multiplexing could be extended further, and with a total of four handshake outputs available it should be possible to have up to eight input ports, with some 64 lines in total. In practice I doubt if it would be worthwhile going this far, as the circuit and the software would both get rather convoluted. Also, there would be numerous 8-bit input ports available, but no handshake lines left to aid their use.

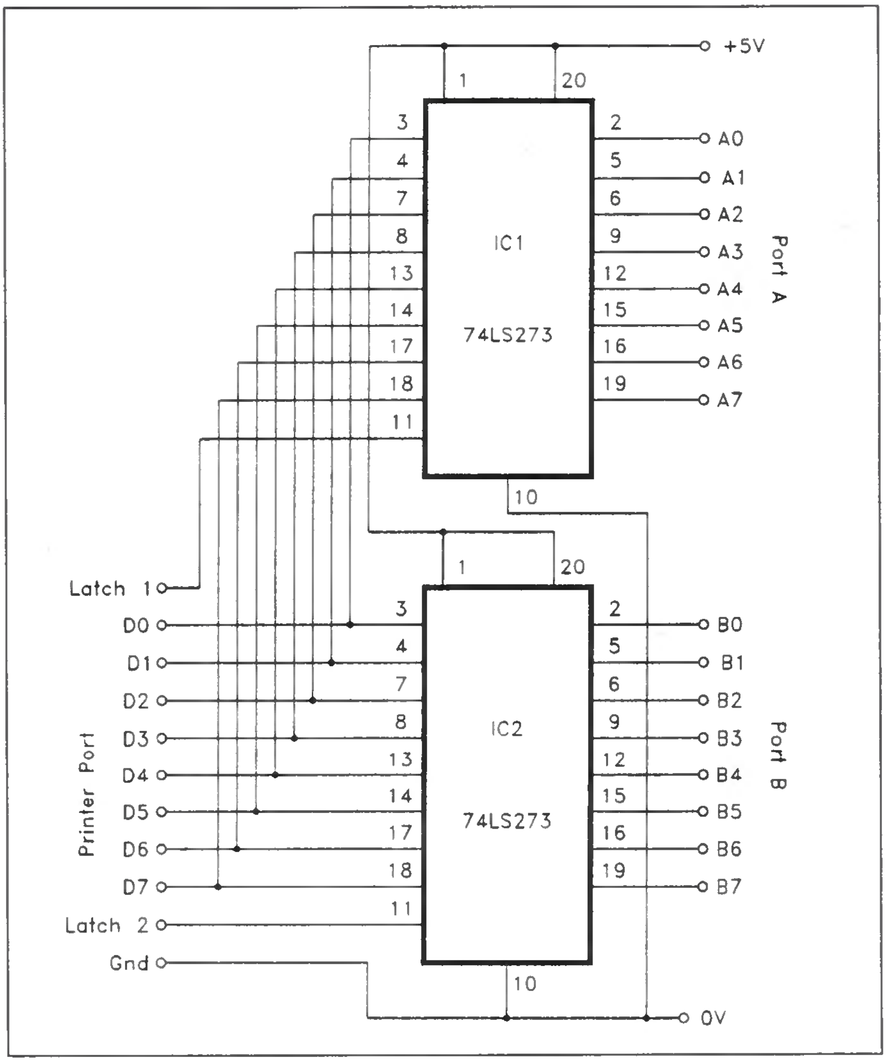


Fig. 3. A method for obtaining two 8-bit output ports.

This method represents a reasonably neat and practical solution if two 8-bit input ports are available, but if more input lines are needed it is probably better to opt for a proper PIA expansion card.

Dual Outputs

With the aid of two handshake outputs it is possible to make the eight data outputs of the port provide two 8-bit output ports. Fig. 3 shows how this can be achieved.

Two octal D-type flip/flops IC1 and IC2 are used, but in this circuit they are used as 8-bit data latches. The eight data outputs of the printer port are fed to the data inputs of IC1 and IC2.

The clock inputs of the flip/flops act as latch inputs in this case, and they should normally be held high. In order to latch data onto the Q outputs of a flip/flop, first the appropriate data should be placed on the data outputs of the printer port. Then the appropriate latch input is taken low, and immediately set high again.

It is on the low to high transition that the data is latched, and any subsequent changes at the data inputs will not affect the outputs of the flip/flop. This makes it possible to write new data to one output port without affecting the data already present at the outputs of the other port.

Suppose that "Latch 1" and "Latch 2" are respectively driven from the "auto linefeed" (pin 14) and "select out" (pin 17) handshake lines. These lines are at bits 1 and 3 at output address &H37A. This GW BASIC routine would write a value of 185 to port A.

```
10 OUT &H37A,0
20 OUT &H378,185
30 OUT &H37A,2
40 OUT &H37A,0
```

The first line simply sets both the latch lines high, which is their correct standby state. Bear in mind that both the "auto linefeed" and "select out" lines are inverted, and that this must be taken into account when writing software routines that utilize them. Line 20 writes a value of 185 to the data lines, and the next two lines pulse "Latch 1" low so that this data is latched on the outputs of port A.

This next program writes a value of 127 to port B, and it functions in the same basic fashion as the program for port A. The only difference is that the last two lines pulse the "Latch 2" input low, so that the data is latched onto the outputs of port B.

```
10 OUT &H37A,0
20 OUT &H378,127
30 OUT &H37A,8
40 OUT &H37A,0
```

Next month we will continue to delve into the PC printer ports, including their use with A/D and D/A converters.

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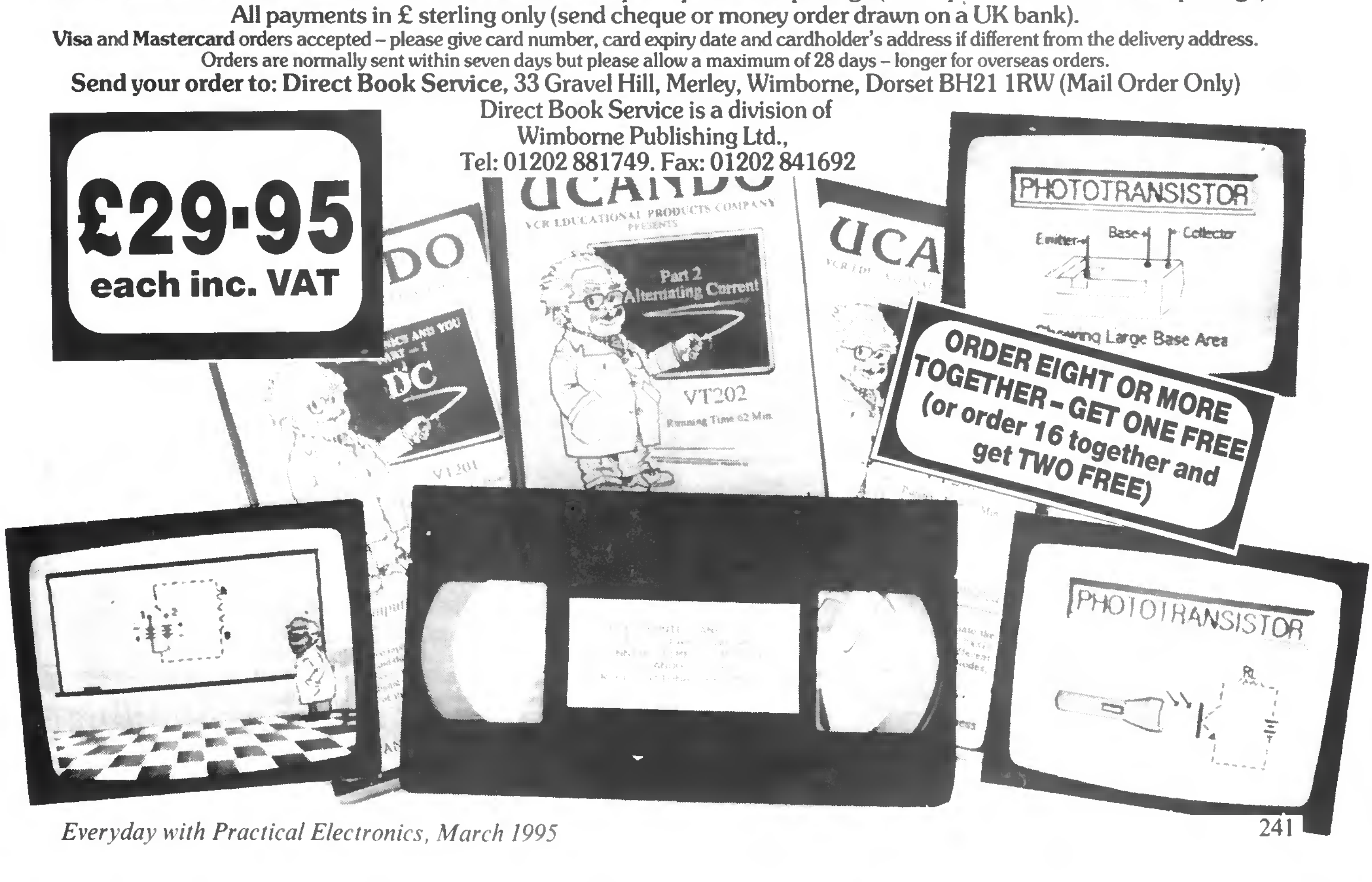

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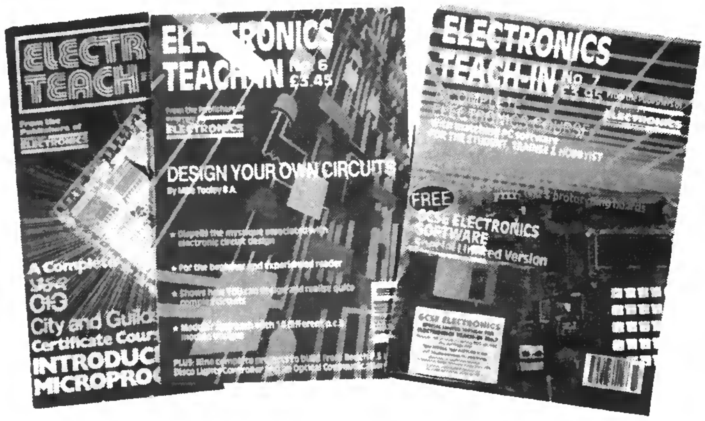

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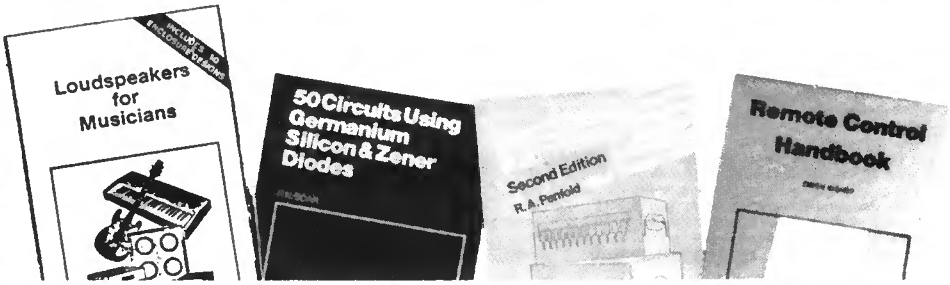

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REPORTING AMATEUR RADIO

Tony Smith G4FAI

OFFENDERS TO BE PUBLICISED

The Radiocommunications Agency (RA) has announced that in future details of the revocation of amateur and CB radio licences will be published where this is deemed appropriate.

Previously, says the Agency, it has not been able to inform the hobby radio community that a licence has been revoked as details about licensees have always been regarded as confidential between the Agency and the licensee. This has made it appear that the Agency has been too lenient with offenders.

The decision to publish this information will be based on the consideration that it is important to make other amateur and CB licensees aware of the revocation of a licence, and the ensuing ban on radio for the person concerned. This outweighs the normal rule that information about licensees should be regarded as private.

OCCASIONAL REVOCATIONS

Occasionally, says the Agency, there are cases of abusive behaviour on air, particularly in hobby radio. One or two of these per annum, following a prosecution, result in the revocation of amateur radio or CB licences, but it rarely needs to revoke other kinds of radio licence for misuse.

The latest figures available, in the Agency's report for 1993/94, show the number of prosecutions in that year as follows. As these were published under the previous rules, details of licence revocations, if any, are not given:

Prosecutions/Convictions – Amateur 4; CB AM 18; CB FM 19.

Forfeiture Orders – Amateur 2; CB AM 13; CB FM 8.

Warning Letters Sent – Amateur 4; CB AM 64; CB FM 371.

SSL CONTRACT RENEWED

The contract held by Subscription Services Ltd (SSL) for issuing amateur and CB radio licences on behalf of the Radiocommunications Agency is to be renewed for a further three years from 1 April 1995. In view of the delays experienced by many amateurs in renewing their licences, and various other problems encountered in the last three years, this news has not been received with much enthusiasm by the amateur community.

Readers may remember a letter from SSL, quoted in this column last September, in which they admitted "We have experienced a number of unique problems but have been working since Day One to iron them out, making a number of computer system revisions to achieve success. Ever since we took over the RA contract, in fact, we have been working hard to eradicate a number of extremely annoying and disruptive glitches."

BETTER PERFORMANCE PROMISED

The RA is aware of these difficulties and has felt it necessary to write a reassuring letter to all the licensees affected, both amateur and CB, to tell them that the new contract requires SSL to meet more demanding standards of performance which have been "specified clearly and in some detail".

In particular the practice of delaying issue of the licence validation document until the licence renewal date, even though payment may have been made weeks beforehand, is to stop and the document will be issued as soon as payment has been received.

Other changes are proposed, "with the aim of increasing efficiency", and we are all promised a further letter later explaining what these are.

I won't try to cost it out, but in these times of government economies I'm wondering about the expense of sending out a double mailshot totalling over 226,000 letters just to tell us that things will be more efficient in the future!

SPACE NEWS

A radio amateur has been appointed chief of the Johnson Space Center's Astronaut Office. He is Col. Robert D. Cabana, KC5HBV, a veteran of three Shuttle flights. Looking ahead, it is understood that negotiations are taking place to include an amateur radio station on the joint Russian-United States "International Space Station" due to orbit in 1995 or 1996. (W5YI Report).

Incidentally, all shuttle air-to-ground communications are re-transmitted on the amateur bands, as they happen. Using the callsign WA3NAN, the Goddard Amateur Radio Club, at the Goddard Space Flight Centre, Maryland, begins transmission about an hour before a launch and continues intermittently, depending on the astronauts' sleep/work schedules, until the mission ends.

There are also black-out periods of up to 30 minutes when no communications can be heard, but during loss of signal, audio from Mission Control may be transmitted.

The frequencies on which WA3NAN may be heard are 3·860MHz, 7·185MHz, 14·295MHz, 21·395MHz and 28·650MHz. The most likely frequency for reception in the UK is 14·295MHz, so if you hear on the news that a launch has taken place tune in to 20 metres on the WA3NAN frequency and leave the rig on.

Listeners' reports are welcomed and rewarded with the WA3NAN QSL card which is a photograph of a space shuttle in orbit. Reports should be sent to: *WA3NAN, Goddard Amateur Radio Club Inc., PO Box 86, Greenbelt, Maryland 20768-0086, USA.*

NEWS FROM THE RSGB

The VHF Committee of the Radio Society of Great Britain has published a discussion document on a number of matters on which comments are invited.

An IARU Region 1 Working Party, of which the RSGB is a member, is discussing possible changes to the lower half of the 144MHz band plan. The VHF Committee is considering making proposals for distinct sections to be allocated for CW/SSB EME (moonbounce); CW; CW/SSB; All Narrow-band Modes (narrow-band data modes as well as CW and SSB, with data communications strictly human-to-human, i.e., no computers, digipeaters or network nodes); Beacons; Data Communications; and All Modes.

It seeks comments on its suggestions, particularly on the relative amount of space for SSB/CW, All Narrow-band modes and Beacons. It wants also to investigate the possibility of adopting 12·5kHz channels for FM operation on 145MHz. Comments are welcome on the possibility of such a change, especially the time-scale that would be required for its implementation.

Consideration has also been given to the possibility of a Novice allocation on the 2m band. This could be restricted to certain frequencies and modes and, again, the Committee will welcome comments on this idea.

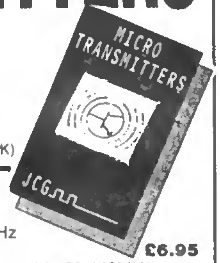
EXTRA SUB-BAND FOR PACKET?

It has also been considering proposals for an extra sub-band for packet radio use in the 432MHz band in order to relieve congestion and improve linking. Five alternatives have been proposed and it is the Committee's intention to allocate one of these for this purpose. Comments and alternative proposals are sought.

Comments should be sent to: *Peter Burden G3UBX, 2 Links Road, Penn, Wolverhampton WV4 5RF.* It is stressed, however, that the full text of the consultation document should be read first. This is printed in the December issue of *RadCom*, the Society's monthly journal.

According to the RSGB Press Bulletin, those wishing to submit comments may telephone RSGB HQ on 01707 659015 and ask for a complimentary copy of that issue. Please mention that you read about this invitation in *Everyday with Practical Electronics.*

The Bulletin also announces that purchasers of the 1995 RSGB Amateur Radio Diary have a chance to win an ICOM IC-728 transceiver worth nearly £1000. Just fill in a simple questionnaire, which comes with the diary, and send it to RSGB HQ in time for the free draw which takes place at the London Amateur Radio Show in March. The diary is available from RSGB Sales, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE, price £4.20 plus 50p post & packing.


MICRO TRANSMITTERS
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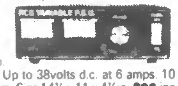

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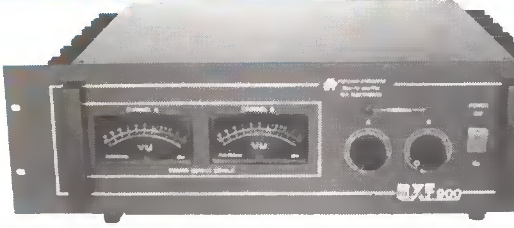

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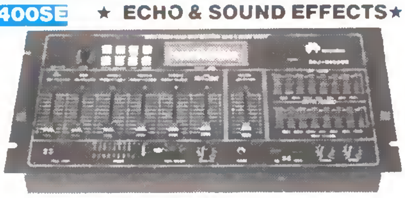

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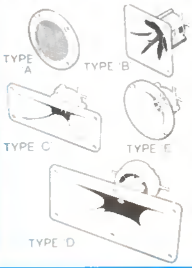

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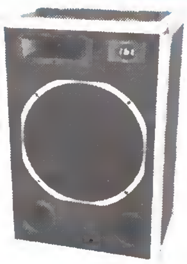

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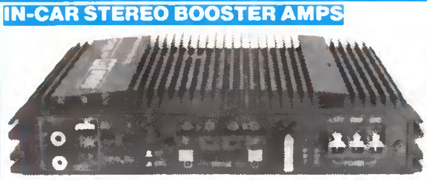

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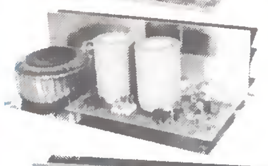
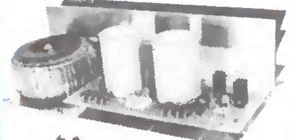


OMP/MF 200 Mos-Fet Output power 200 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 300 x 155 x 100mm.
PRICE £64.35 + £4.00 P&P



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. -110 dB. Size 330 x 175 x 100mm.
PRICE £81.75 + £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. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 385 x 210 x 105mm.
PRICE £132.85 + £5.00 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. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 422 x 300 x 125mm.
PRICE £259.00 + £12.00 P&P

NOTE: MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS: STANDARD - INPUT SENS 500mV, BAND WIDTH 100KHz. PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) - INPUT SENS 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC.

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12" 200 WATT R.M.S. ME12-200 GEN. PURPOSE, GUITAR, DISCO, VOCAL, EXCELLENT MID.
RES. FREQ. 58Hz, FREQ. RESP. TO 6KHz, SENS 98dB. PRICE £46.71 + £3.50 P&P
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RES. FREQ. 46Hz, FREQ. RESP. TO 5KHz, SENS 99dB. PRICE £50.72 + £4.00 P&P
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RES. FREQ. 39Hz, FREQ. RESP. TO 3KHz, SENS 103dB. PRICE £73.34 + £4.00 P&P

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10" 100WATT EB10-100 BASS, HI-FI, STUDIO.
RES. FREQ. 35Hz, FREQ. RESP. TO 3KHz, SENS 96dB. PRICE £30.39 + £3.50 P&P
12" 100WATT EB12-100 BASS, STUDIO, HI-FI, EXCELLENT DISCO.
RES. FREQ. 26Hz, FREQ. RESP. TO 3 KHz, SENS 93dB. PRICE £42.12 + £3.50 P&P
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6½" 60WATT EB6-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC.
RES. FREQ. 38Hz, FREQ. RESP. TO 20KHz, SENS 94dB. PRICE £10.99 + 1.50 P&P
8" 60WATT EB8-60TC (TWIN CONE) HI-FI, MILTI-ARRAY DISCO ETC.
RES. FREQ. 40Hz, FREQ. RESP. TO 18KHz, SENS 89dB. PRICE £12.99 + £1.50 P&P
10" 60WATT EB10-60TC (TWIN CONE) HI-FI, MULTI ARRAY DISCO ETC.
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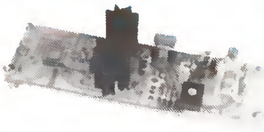

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PHOTO: 3W FM TRANSMITTER

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