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DECEMBER 1994

INCORPORATING ELECTRONICS MONTHLY

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MICROCONTROLLER DESIGN THAT REALLY PAYS OUT!

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over 20,000 possible combinations

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VIDEO MODULES

Horizontal and Vertical Wipers plus Audio Mixer

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THE No. 1 INDEPENDENT MAGAZINE for ELECTRONICS, TECHNOLOGY and COMPUTER PROJECTS

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

SINCLAIR C5 13" WHEELS Complete with centre bearing (cycle type), tyre and inner tube £6 ea ref MAG 6P10 Ideal go kart

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

MOD WIRE Perfect for repairing PCB's, wire wrap etc. Thin insulated wire on 500m reels. Our price just £9.99 ref APR10P8

12v MOVING LIGHT Controller Made by Hella. 6 channels rated at 90watts each. Speed control, cased £34.99 ref APR35

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 and straight from 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 seales 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

CLOCKMAKER KIT Hours of fun making your own clock, complete instructions and everything you need. £7.99 ref MAR8P2

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

IBM PC CASE AND PSU Ideal base for building your own PC. Ex equipment but OK. £9.99 each REF: JUN10P2

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

MULTICORE CABLE 300 metre reel of grey 8 core cable ideal for 'phones, intercomms, computers, alarms etc. Comes in specialdispensing container to avoid tangles £15 ref AUG15

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

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

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

GX4000 GAMES MACHINES returns so ok for spares or repair £9 each (no games) REF MAG9P1

C64 COMPUTERS Returns, so ok for spares etc £9 ref MAG9P2

FUSELAGE LIGHTS 3 foot by 4" panel 1/8" thick with 3 panels that glow green when a voltage is applied. Good for night lights, front panels, signs, disco etc. 50-100v per strip. £25 ref MAG25P2

ANSWERPHONES 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

360K 5.25 brand new half height floppy drives IBM compatible industry standard. Just £6.99 REF MAG7P3

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

TOWERS INTERNATIONAL TRANSISTOR GUIDE. A very useful book for finding equivalent transistors, leadouts, specs etc. £20 REF: MAG20P1

SINCLAIR C5 MOTORS We have a few left without gearboxes

NEW BULL ELECTRONICS STORE IN WOLVERHAMPTON

55A WORCESTER ST TEL 0902 22039

Spec is 12v DC 3,300rpm £25 ref MAG25.

••••••••••••••••••NEW PRODUCT••••••••••••••••••

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 shutdown (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 a very advantageous price!!! Price is £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 £15.99 Ref MAR16P2

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 2 kilometres in open country. Units measure 22x52x155mm. Complete with cases and earpieces. 2xPP3 req'd. £30.00 pair 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

SPEAKER WIRE Brown 2 core 100 foot hank £2 REF: MAG2P1

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 agendes. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER originally made to retail at £79 each, these units are designed to convert and 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

100 WATT MOSFET PAIR Same spec as 2SK343 and 2SJ413 (8A, 140v, 100w) 1 N channel, 1 P channel, £3 a pair REF: MAG3P2

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

PC CASES Again mixed types so you take a chance next one off the pile £12 REF: MAG12 or two the same for £20 REF: MAG20P4

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

PROXIMITY SENSORS These are small PCB's with what look like a source and sensor LED on one end and lots of components on the rest of the PCB. Complete with fly leads. Pack of 5 £3 REF: MAG: 3P5 or 20 for £8 REF: MAG8P4

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

SNOOPERS EAR? Original made to clip over the earpiece of telephone to amplify the sound-it also works quite well on the cable running along the wall! Price is £5 REF: MAG5P7

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 £3 REF: MAG3P8 5.25" 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

WINDUP SOLAR POWERED RADIO AM/FM radio complete with hand charger and solar panel! £14 REF: MAG14P1

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

FIRE ALARM CONTROL PANEL High quality metal cased alarm panel 350x165x80mm. With key. Comes with electronics but no information. sale price 7.99 REF: MAG8P6

REMOTE CONTROL PCB These are receiver boards for garage door opening systems. Another use? £4 ea REF: MAG4P5

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

LOPTX Line output transformers believed to be for IBM hi res colour monitors but useful for getting high voltages from low ones! £2 each REF: MAG2P12 bumper pack of 10 for £12 REF: MAG12P3

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

WATERPROOF JUNCTION BOX 65mm dia 33mm deep. Four cable entry exit points (adjustable for any size cable) snap fit lid. Ideal for TV, satellite use. £2 ea ref APR2 or 6 for £10 ref APR10P7

BOTH SHOPS OPEN 9-5.30 SIX DAYS A WEEK

INFRARED LASER NIGHT SCOPES Second generation 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 (all supplied) £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 UNDER QUALIFIED GUIDANCE. £349+Vat.

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IMMEDIATE SETTLEMENT. WE WILL ALSO QUOTE FOR COMPLETE FACTORY CLEARANCE

1994 CATALOGUE

3FT X 1FT 10WATT SOLAR PANELS 14.5v/700mA £33.95

(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. REF MAG34

PORTABLE RADIATION DETECTOR £49.99

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 MAG50.

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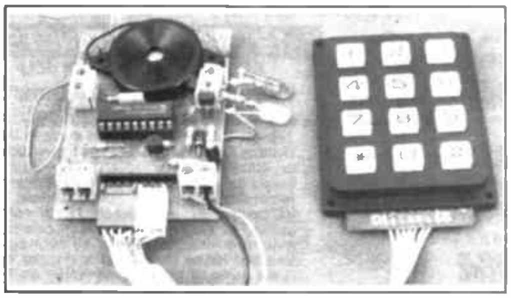
COMMENT . . . POPULAR FEATURES . . .

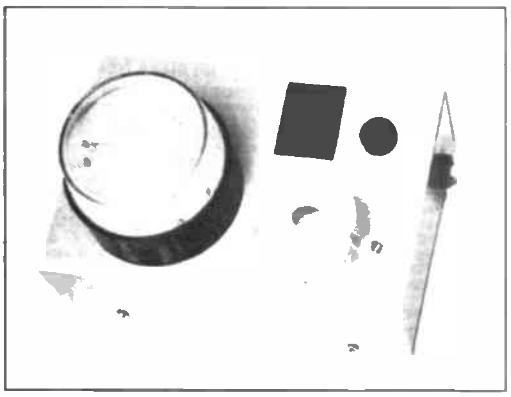
VOL. 23 No. 12 DECEMBER 1994

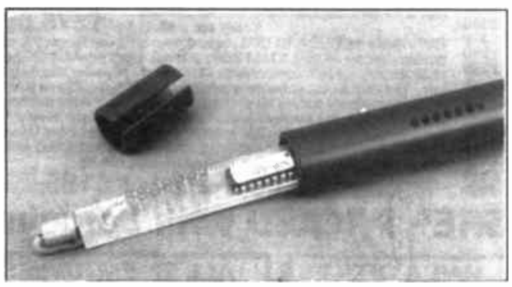
EVERYDAY WITH PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

The No. 1 Independent Magazine for Electronics, Technology and Computer Projects







Our January '95 issue will be published on Friday, 2 December 1994. See page 895 for details.

Projects

Series

Features

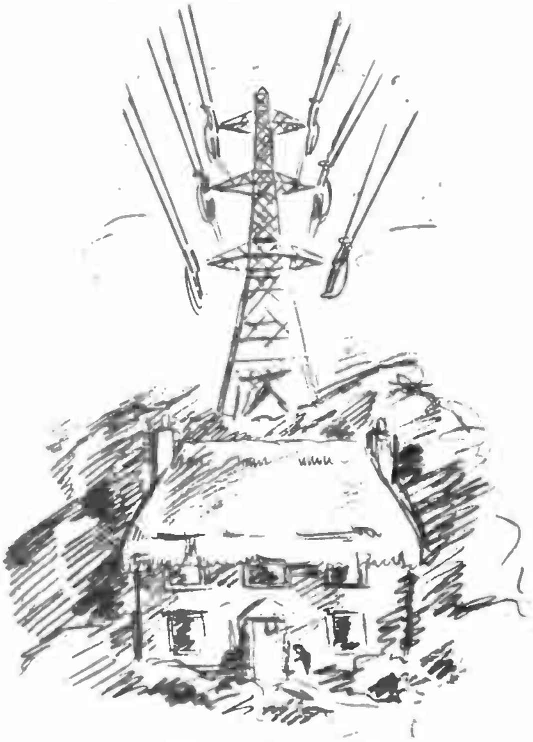
FREE
BULL ELECTRICAL 1995 CATALOGUE (96-pages)
BANDED WITH MAGAZINE

NEXT MONTH

MAGNETIC FIELD DETECTOR

Modern man is ever more often exposed to a variety of alternating magnetic fields of various frequencies, emanating from the huge variety of electrical and electronic devices which now form an integral part of life. Over the last few years these fields have become a source of concern to some people, who feel that constant exposure to them may constitute a hazard to health. A vast amount of research on this has been carried out, much of it by the electricity authorities who are understandably concerned about the safety of their product, but to date results have been inconclusive.

However, since these fields ccannot generally be seen, felt or heard, a means of detecting them may be useful to those who wish to minimise their exposure to this sort of risk. This relatively simple and inexpensive unit gives both an audible and visual (l.e.d. bargraph) indication of field strength.



ELECTRONIC TRACK CLEANER

Dirt on model railway track often produces erratic train speed and can cause a low speed train to come to a grinding halt. High quality controllers are less prone to this problem than very basic types, but if a significant length of track is affected, contact can be lost with the train, and it will come to a halt.

The best solution to the dirt problem is to simply keep the track scrupuously clean, but this can be quite difficult and time consuming. An alternative approach is to keep the track as clean as reasonably possible, and to use an electronic track cleaner to "zap" any remaining small amounts of dirt on the tracks.

This "zapping" is done by applying a high voltage across the tracks when the train goes out of electrical contact with the track. Although using a high voltage across the tracks might seem to be dangerous, this voltage is at a high impedance. The available current is therefore very low, and the equipment is incapable of giving even a moderate electric shock or of damaging the train.

MOVING DISPLAY METRONOME

The traditional mechanical metronome, with its weighted swinging-arm provides an audio and visual indication of beats per minute, but many simple electronic metronomes often overlook the visual aspect, with at best, a flash from an l.e.d. on every beat. This project fills this shortfall. It is based on a 4067 16-channel analogue multiplexer/demultiplexer with a ten l.e.d. display.

When the arm of a mechanical metronome swings from side to side it appears to slow down towards the end of its travel. Tc simulate this motion electronically, the outer l.e.d.s of the display stay on for longer. This produces an effecctive moving dot display similar to its mechanical counter-part. The metronome "clicks" are produced by a piezo electric buzzer.

EVERYDAY WITH PRACTICAL ELECTRONICS

OUR JANAURY '95 ISSUE WILL BE PUBLISHED ON FRIDAY, 2nd DECEMBER

HART AUDIO KITS – YOUR VALUE FOR MONEY ROUTE TO ULTIMATE HI-FI

HART KITS give you the opportunity to build the very best engineered hifi equipment there is, designed by the leaders in their field, using the best components that are available.
Every HART KIT is not just a new equipment acquisition but a valuable investment in knowledge, giving you guided hands-on experience of modern electronic techniques.
In short HART is your 'friend in the trade' giving you, as a knowledgeable constructor, access to better equipment at lower prices than the man in the street.
You can buy the reprints and construction manual for any kit to see how easy it is to build your own equipment the HART way. The FULL cost can be credited against your subsequent kit purchase.
Our list will give you fuller details of all our Audio Kits, components and special offers.

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!

RLH11 Reprints of latest articles £1.80
K1100CM HART Construction Manual £5.50

LINSLEY HOOD 1400 SERIES ULTRA HIGH-QUALITY PREAMP

Joining our magnificent 80 Watt power amplifier now is the most advanced preamplifier ever offered on the kit, or indeed made-up marketplace. Facilities include separate tape signal selection to enable you to listen to one programme while recording another, up to 7 inputs, cross recording facilities, class A headphone amplifier, cancellable 3-level tone controls and many other useful functions, all selected by high quality relays. For full details see our list.

LINSLEY HOOD 'SHUNT FEEDBACK' R.I.A.A. MOVING COIL & MOVING MAGNET PICKUP PREAMPLIFIERS

Modern, ultimate sound systems are evolving towards built-in preamplifiers within or near the turntable unit. This keeps noise pickup and treble loss to a minimum. We now offer two units, both having the sonically preferred shunt feedback configuration to give an accurate and musical sound, and both having the ability to use both moving magnet and moving coil cartridges.
Kit K1500 uses modern integrated circuits to achieve outstanding sound quality at minimal cost. The very low power requirements enable this unit to be operated from dry batteries and the kit comes with very detailed instructions making it ideal for the beginner. K1500 Complete kit with all components, printed circuit board, full instructions and fully finished case £67.99
Instructions only £2.80
Kit K1450 is a fully discrete component implementation of the shunt feedback concept and used with the right cartridge offers the discerning user the ultimate in sound quality from vinyl disks. Can be fitted inside our 1400 Preamp, used externally or as a standalone unit. It has a higher power requirement and needs to be powered from our 1400 Series preamplifier or its own dedicated power supply.
K1450 Complete Discrete Component RIAA Phono Preamp £109.58
Factory Assembled and Tested £159.58
K1565 Matching Audio Grade Power Supply with potted toroidal transformer and limited shift earthing system £79.42
Factory Assembled and Tested £118.42
U1115 Power Interconnect Cable £7.29

SPECIAL OFFER

PRECISION *Triple Purpose* TEST CASSETTE TC1D.

Are you sure your tape recorder is set up to give its best? Our latest triple purpose test cassette checks the three most important tape parameters without test equipment. Ideal when fitting new heads.
A professional quality, digitally mastered test tape at a price anyone can afford.
Test Cassette TC1D .... Our price only £10.99

DISK-COUNT *Classical* CD's.
Many New Titles This Month

Top quality, Full Digital (DDD) Compact Disks of the great classical favourites. Like everyone else we didn't like the idea of paying silly prices for CD's. After a long search we have now located a source of top quality classical recordings at prices that make you suspect the quality – until you try them! Send for our list of titles.

HART PCB SOLDERING PRACTICE KIT

Your chance to learn or try your soldering skills on a real Hart printed circuit board! This kit comes with a range of modern components, a typical Hart quality PCB, a roll of the correct grade of solder and your full learning guide. It enables the enthusiast who is uncertain of his, or indeed her, ability to put together and solder a printed circuit to try their hand first at minimum cost.
The instructions explain the right technique and guide even an absolute beginner through the seemingly daunting, but in fact very simple, art of making a good soldered joint.
The Hart **Printed Circuit Board Soldering Practice Kit** represents excellent value for money at only **£4.99.**

TECHNICAL BOOKSHELF

The Following are a Small Selection of the Books we Offer. Full Details are in our Free List.

"THE ART OF LINEAR ELECTRONICS", John Linsley Hood.
Just Out! Hot Off the Press, the definitive electronics and audio book by the renowned John Linsley Hood. This 300+ page book will give you an unparalleled insight into the workings of all types of audio circuits. Learn how to read circuit diagrams and understand amplifiers and how they are designed to give the best sound. The virtues and vices of passive and active components are examined and there are separate sections covering power supplies and the sources of noise and hum. As one would expect from this writer the history and derivation of audio amplifier circuitry have an entire chapter, as does test and measurement equipment.
Copiously illustrated this book is incredible value for the amount of information it contains on the much neglected field of linear, as opposed to digital, electronics. Indeed it must be destined to become the standard reference for all who work, or are interested in, this field.
SPECIAL OFFER. With each book purchased you may request a **FREE** extended index, written by the Author, exclusively from HART.
0-7806-0868-4 .... £16.95
Don't forget most of our kits have reprints of articles by John Linsley Hood that you can purchase separately.

"TOWERS' INTERNATIONAL TRANSISTOR SELECTOR". This will give you the specification, pin connections, case outline, manufacturer, equivalents and substitutes for over 27,000 European, American and Japanese transistors. Latest update 4 offers over 2,000 new entries plus surface mount cross index. 1990 432 Pages. 247 x 173.
0-572-01062-1 .... £19.95

"DIGITAL AUDIO AND COMPACT DISC TECHNOLOGY" 2nd Edition. Baert, Theunissen and Vergult. (SONY Europe).
A thoroughly well written book covering the whole field of recording media starting with the Phonograph right through to modern professional PCM digital recording systems with particular and extensive coverage on the compact disc. All aspects of the recording and reproduction processes are explained with separate chapters on such things as compact disc encoding and the use of cross interleave Reed-Soloman error correction code (CIRC). This book is of course essential reading for engineers and students involved in the field but its very low prices makes it ideal for the enthusiast of recorded music who wants to know more about the hidden processes going on in his CD player.
1992/94 248 Pages. 247 x 190.
0-7506-0614-2 .... £17.95

INTRODUCING DIGITAL AUDIO CD, DAT AND SAMPLING 2nd Edition. Ian R. Sinclair.
For enthusiasts, technicians and students.
Covers CD and DAT, Philips DCC and Sony Mini Disc, the digital techniques involved are explained non-mathematically.
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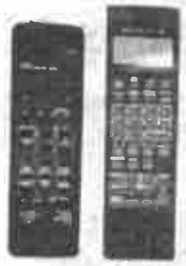

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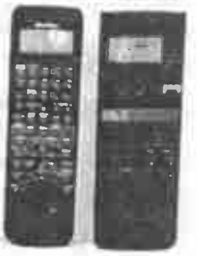

Just purchased a few thousand TV/VCR remote controls - and what a mixture they are. All brand new, they fall into three broad categories - (a) basic; (b) with LCD and (c) the bells and whistles brigade. Unfortunately, most manufacturers' seem reluctant to print their name on these handsets, so we haven't a clue for which machines they are intended. Hopefully, the table below will give some idea. Being realistic, we're aware not many of these will be wanted as replacements in any case, but just for the spare parts, and the low prices reflect this. In order to shift them fairly quickly, we've decided to offer them (wait for it, wait for it) in a PACK (What a surprise). Yes, another amazing GREENWELD offer. Enough buttons to zap the world!

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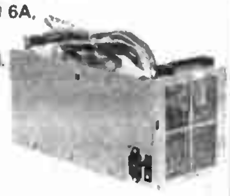

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STANDARDS

So many of us have been caught out when various standards fight it out in the market place. It happened with VHS and Betamax and I, for one, have an old Betamax recorder that still works well sitting in my loft. It is about to happen again with Digital Compact Cassette and Minidisc and it looks as though PCs are now winning over Apple Macs.

In *Fox Report* this month Barry Fox is fairly forthright on the possible imminent death of the Apple Mac. While it still reigns supreme in the publishing world (although all of our typesetting is done on PCs) it does appear to be on its way out elsewhere. Our recent free gift of *Electronics Workbench* software resulted in a couple of requests from colleges for a free Apple Mac disc – not available I'm afraid, although the full package is available in a Mac version.

On further investigation it appears that some colleges have equipped themselves totally with Apple Mac equipment – when I mentioned this to others in education and educational software suppliers the reaction was "are they in the real world?" Unfortunately it is a fact of life that out in the business world the PC is the *de facto* standard and while I can see that in the past Macs have been easier to use that does not help students when they need to work for a living.

GET REAL

"Dodo Apple", as Barry puts it, may not become a reality, only time will tell, but students must get to grips with the realities of DOS and Windows and possibly quite soon Chicago on a PC. It is time for our educational system to come to terms with educating students for the real world, particularly in the technological subjects, using the tools they will have to use in industry. Fortunately this is already happening in many areas but in some colleges it appears that the buying decisions are being made on ease of use in the classroom, rather than on criteria which will affect the ability of the student to function in the real world.

Mike Kenward

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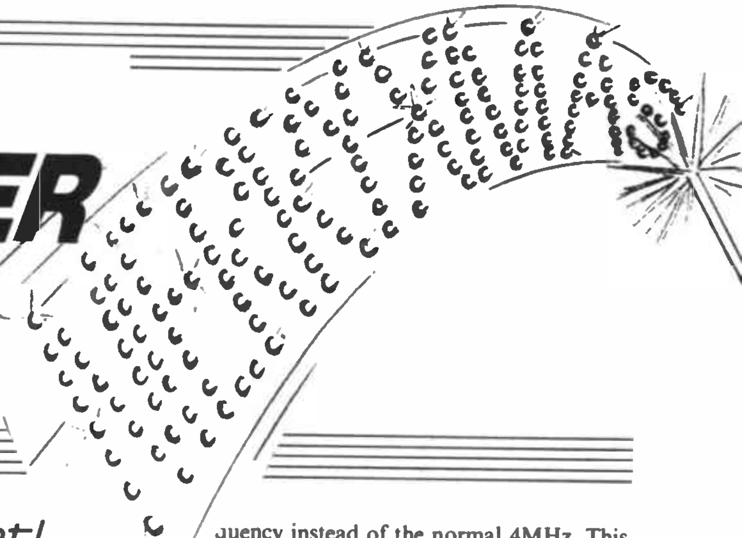


SPACEWRITER WAND

by MARK STUART

Sky writing with a Santalight!

THIS project follows the current vogue of optical effects and illusions such as the 3-D "Magic Eye" type currently featured in books and magazines worldwide. It uses the well known effect of "persistence of vision" to allow a single row of l.e.d.s to write words in the air. The effect is not difficult to view. With practised movement of a "wand" containing a row of seven l.e.d.s, an easily readable display is produced - especially in a darkened room.

PRINCIPLE

As the display relies on "persistence of vision" for its effect, if a bright light is moved quickly across the field of vision, a single continuous streak is seen. A row of seven bright l.e.d.s would produce seven parallel streaks. To write a message, the l.e.d.s are switched on and off rapidly during their travel so that the streaks become dashes. Timing the switching of each l.e.d. correctly allows dashes of different lengths and positions to be produced forming letters.

REALISATION

A microcontroller is ideal for this kind of job. A program containing all the necessary time delays for the pulses is relatively easy to produce, and the l.e.d.s can be driven directly from the microcontroller's output pins.

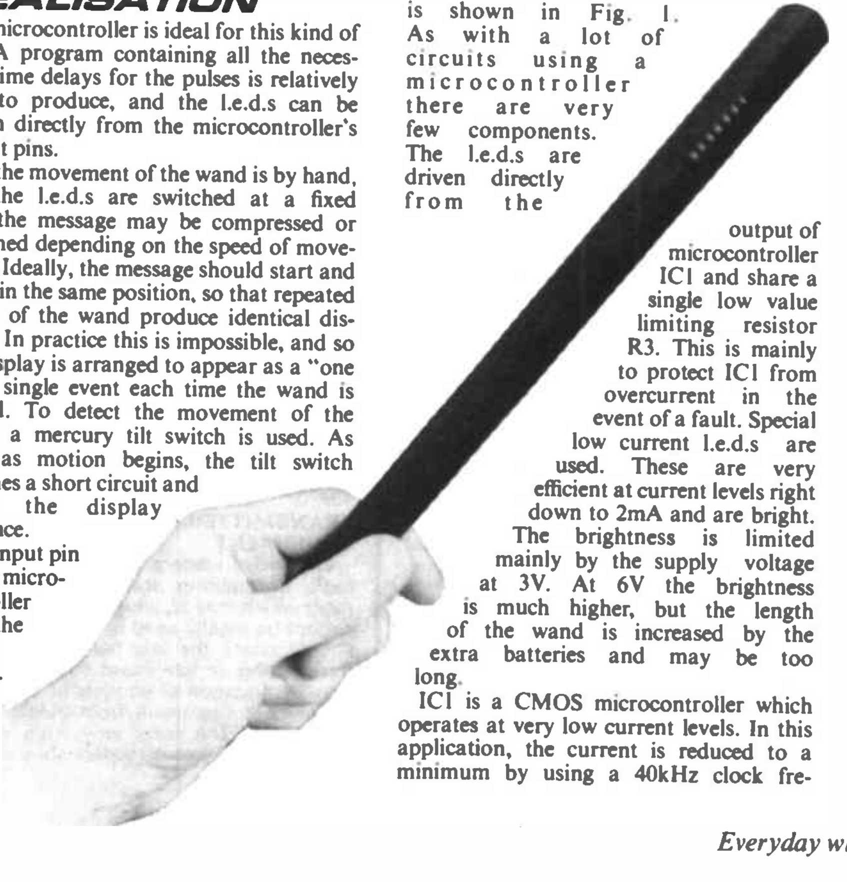
As the movement of the wand is by hand, and the l.e.d.s are switched at a fixed rate, the message may be compressed or stretched depending on the speed of movement. Ideally, the message should start and finish in the same position, so that repeated waves of the wand produce identical displays. In practice this is impossible, and so the display is arranged to appear as a "one shot" single event each time the wand is moved. To detect the movement of the wand, a mercury tilt switch is used. As soon as motion begins, the tilt switch becomes a short circuit and starts the display sequence.

An input pin on the microcontroller reads the the tilt switch. A second pin provides a serial input facility to allow user defined messages to be entered into memory.

The wand is tubular, being made from a short length of plastic electrical conduit. This is convenient as it is an almost ideal housing for the batteries, but construction is more complicated than just using a plastic box. An on/off switch is not required as the circuit drain is negligible provided the wand is stored with the tilt switch in the open circuit condition.

Other possible arrangements for the display suggest themselves, especially those which include some form of mechanical movement such as a turntable, pendulum, or rotating mirror, combined with a reed switch and magnet to produce a reliable and repeatable start position. The circuit is adaptable to all of these applications, and the tilt switch can be replaced by any appropriate type of switching device.

CIRCUIT DETAILS



The full circuit diagram for the Spacewriter Wand is shown in Fig. 1. As with a lot of circuits using a microcontroller there are very few components. The l.e.d.s are driven directly from the output of microcontroller IC1 and share a single low value limiting resistor R3. This is mainly to protect IC1 from overcurrent in the event of a fault. Special low current l.e.d.s are used. These are very efficient at current levels right down to 2mA and are bright. The brightness is limited mainly by the supply voltage at 3V. At 6V the brightness is much higher, but the length of the wand is increased by the extra batteries and may be too long.

IC1 is a CMOS microcontroller which operates at very low current levels. In this application, the current is reduced to a minimum by using a 40kHz clock frequency instead of the normal 4MHz. This is possible because the amount of processing power needed is very small. Even at 40kHz there is plenty of time for the microcontroller to do its job.

Resistor R2, capacitors C1 and C2, and crystal X1 provide the clock frequency determining components. The oscillator circuitry is contained within IC1.

A single input pin (pin 6) is required for the tilt switch, S1. The input has a built in pull-up resistor so that the pin is normally held at logic 1 level. Closing the tilt switch pulls down the pin to logic 0 and starts the display sequence.

Two other input pins are used. Pin 18 allows data to be sent to the microcontroller from a computer serial (RS232) output. This allows a message to be loaded into RAM and displayed automatically. The message, once loaded, is maintained as long as the batteries are not removed. Resistor R1 and diode D1 protect the input from excessive voltage levels. Pin 17 is used to set IC1 to receive serial data. It is normally held at logic 1 by resistor R4 but must be shorted to 0V whenever data is being loaded.

CONSTRUCTION

A single printed circuit board holds all the components. This board is available from *EPE PCB Service*, code 921. The p.c.b. component layout and full size copper foil master track pattern is shown in Fig 2.

The board has been made as small as practically possible to fit into a piece of 20mm plastic electrical conduit. Alternative mounting arrangements such as cardboard tubes or plastic overflow pipes may, of course, be used. A transparent perspex tube would give a very interesting appearance. If the tubular form of construction is too fiddly, the display works quite well stuck on a strip of wood, using an ordinary 4 x AA battery holder, and a few rubber bands!

Whichever method of assembly is used, do not fit any components to the board until the drilling and mechanical work has been completed. The board is useful as a template, and is easier to handle before assembly.

For use in a tube, it is very important to set the l.e.d.s in the board to exactly the right height. This allows the board to be slipped into the tube and then pushed upwards so that the l.e.d.s locate into seven pre-drilled 3mm diameter holes.

The hole positions can be marked most accurately with a sharp needle using the unassembled board as a template. Stick the board to the outside of the tube with tape before marking the centres so that move-

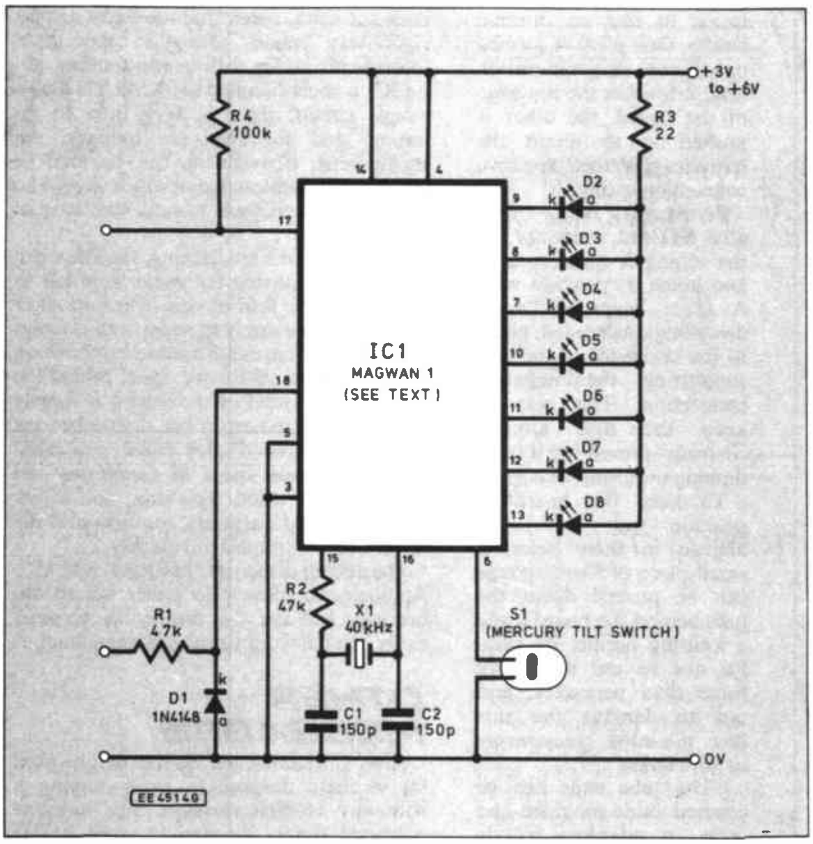


Fig. 1. Complete circuit diagram for the Spacewriter Wand.

COMPONENTS

Resistors
R1, R2 47k (2 off)
R3 22
R4 100k
All surface mount types

See SHOP TALK

Capacitors
C1, C2 150p sub.min ceramic (2 off)

Semiconductors
D1 1N4148 signal diode
D2 to D8 sub.min. high brightness l.e.d.
IC1 pre-programmed micrcontroller (see Shoptalk)

Miscellaneous
X1 40kHz crystal
S1 mercury tilt switch
Printed circuit board available from *EPE PCB Service*, code 921; length of 20mm plastic tubing 20mm diameter (see text); AA-type battery (3 off); connecting wire, solder, etc.

Approx cost guidance only **£17**

ment is minimised and the holes are aligned as well as they can be. Do this very carefully as the l.e.d.s cannot be adjusted easily if the holes are out of line. If alignment does cause problems, larger holes can be used to allow some slack.

The board should be positioned in the tube to allow for three AA type batteries to be fitted. It is permissible to use four batteries for a brighter display, but in most situations three are adequate.

The positive battery terminal connects to a thin piece of metal bent over the end of the board at the battery connection end. Make sure that the metal chosen can be soldered, and that it does not have a transparent plastic coating. Most tin cans are suitable and can be cut with strong scissors.

The tilt switch, S1, needs to be fitted "upside down" as shown in the component layout drawing. Two lengths of stiff wire are needed to extend the connections and should be insulated with short lengths of sleeving. Good quality silicon rubber sleeving was used in the prototype, it is flexible, and does not melt when soldered.

In use it was found that the initial "flick" as the tube was moved causes the mercury inside the switch to rise to the top, bridge the contacts, and start the display. This was contrary to the initial idea which was to use the switch conventionally and allow the mercury to roll over the contacts as the tube was tilted. It seems that the inertia and low viscosity of the mercury makes it respond quickly even to relatively slow movements (is that why it's called quicksilver?).

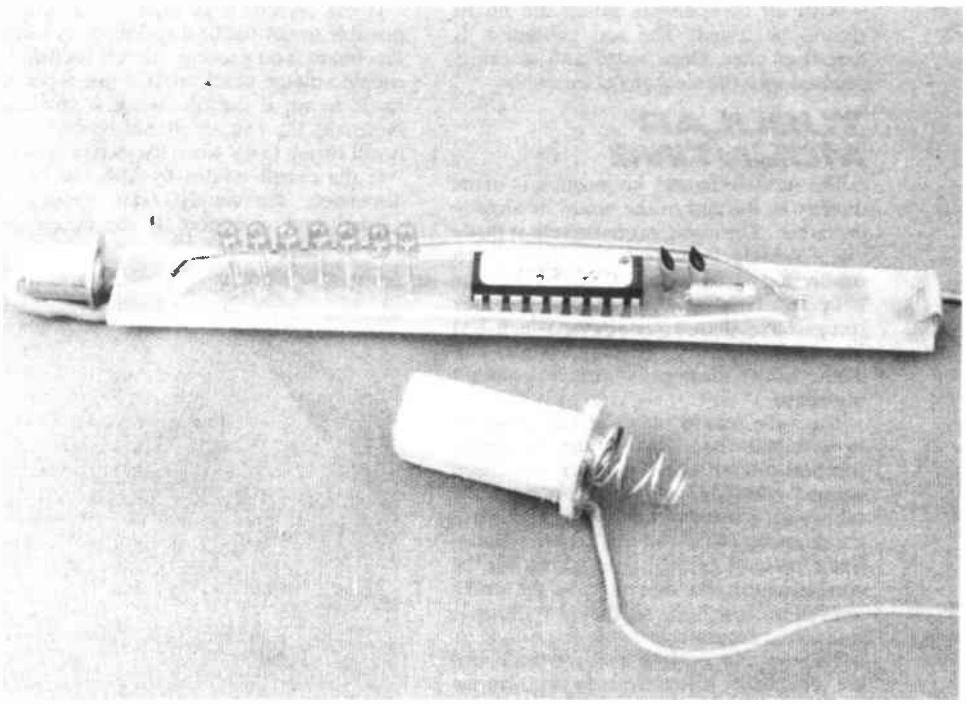
SOLDERING ON

The l.e.d.s must all be fitted the right way round. The long lead is normally the anode and goes to the long strip of track as shown in Fig 2. The height above the board is best determined by trial and error and should allow the board to be inserted and removed easily from the tube. Experiment with just one, and then mount the others at the same height. To aid alignment, the holes drilled in the tube can be used from the outside to hold the l.e.d.s in place whilst soldering. Use of sticky tape to hold the tube to the workbench is helpful, and allows the job to be done with just two hands.

Once the l.e.d.s have been fitted and the circuit board can be moved in and out of place, the remaining components can be added. The resistors are all miniature surface mount components. They are not difficult to solder, provided the pads onto which they sit have been tinned. Also, it is strongly recommended that a fine-tipped soldering iron is used.

A needle or other sharp instrument can be used to hold the resistor in position while one end is soldered. Once the solder has set, solder the other end. Be careful not to get both ends hot together, or the resistor will slide about all over the place. This can be turned to advantage to remove a resistor wrongly positioned. Simply heat both ends by moving the soldering iron from one to the other in quick succession. The resistor will loosen and can be lifted off with a needle.

There are four wire links which run from the holes at one end of the board to pads at the other. This is to allow the tilt switch and serial input connections to be at the top end of the board. There is not enough board space to allow proper tracks to be used. Ordinary thin solid core connecting



The assembled Spacewriter Wand p.c.b. showing "wood dowelling" battery connector.

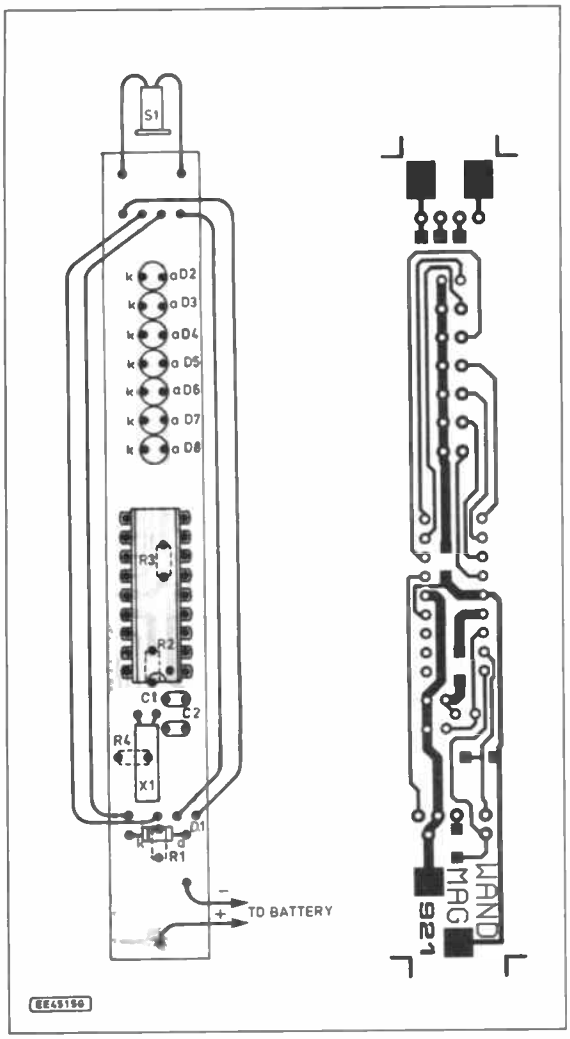


Fig. 2. Printed circuit board component layout and full size copper foil master track pattern.

wire can be used, and laid along the sides of the other components as shown.

To keep the board height low, IC1 must be soldered in position. Make sure it is the right way round! A mistake here will be difficult to put right.

With all components fitted, the board should be tested. The test procedure is described later. Once tested and working, proceed with the mechanical assembly.

TUBULAR MOUNTING

The positive battery connection is made directly to the end of the board as already explained. The negative connection is made via a flexible lead from the board to a connecting spring at the distant end of the batteries. This spring is held in place by being soldered to a metal disc which just fits inside the tube. A long flexible wire connects it to the negative contact point on the board.

The tube length must be cut carefully to give just the right amount of spring compression with the l.e.d.s on the board aligned correctly with their holes in the tube. This is done by setting up the board, the retaining plugs and the batteries alongside a piece of tubing and marking out the correct length. Be sure to have the l.e.d.s aligned in their holes so that everything is positioned accurately.

The top and bottom ends of the board are retained by a 30mm pieces cut from the end of a spare length of tube. Each piece is cut along its length and a section removed so that it closes down to become a tight inside fit like an internal circlip. One piece is pushed down over the tilt switch until it touches the top edge of the board, the other is pushed in to retain the batteries and their negative connection spring.

Permanent fixing with glue was not necessary, as the tubing is quite springy and holds its position well. A short length of wood dowelling was needed, glued to the underside of the disc supporting the negative connection. This was to keep the disc aligned correctly, preventing it from flipping over onto its edge.

To keep the board in position with the l.e.d.s aligned in their holes, a small piece of foam sponge can be pushed down the tube behind the board using a knitting needle. Be careful not to use any more force than necessary, and not to damage the surface mounted components or wire links.

The tube ends can be covered using moulded end caps, or adapting bicycle handlebar end plugs. This type of hardware can usually be found without too much difficulty.

TESTING

Assuming the assembly of the board is complete, the first thing to do is double check all of the soldering and the component identification. Once everything is in order, connect a 4·5V supply and check that the circuit does not draw excessive current. If a multimeter is not available, a small bulb in series with the supply will light if there are any bad short circuits.

If the current is in order, it should be possible to get the l.e.d.s to flash by tilting the board and closing the tilt switch. A simple voltage check at IC1 pin 6 can be made to see if the tilt switch is working. Normally the voltage should be 4·5V, and it will switch to 0V when the switch closes.

If the circuit refuses to flash the l.e.d.s, disconnect the supply, wait about one minute, and reconnect. If the circuit still does not work, check that the l.e.d.s are the right way round, and that they light individually when their corresponding pin on IC1 is short circuited to 0V. As it is such a simple circuit, there is very little to go wrong, and so faults are unlikely. An oscilloscope, if available, can be used to check the crystal oscillator which should be producing a 4·5V peak to peak sine wave at 40kHz.

Once the l.e.d.s are flashing, the effect can be tested by moving the wand from left to right across the field of view. The best effect is obtained in a dimly lit room, and is easier to see when the eyes are fixed in one position by looking at a stationary object behind the display. The speed of movement is largely down to trial and error, but should be easy to establish. The display speed is a compromise between speed of movement and persistence of vision. Too slow, and a row of moving l.e.d.s appears, too fast, and the wand has to be moved too quickly.

The default display is "MERRY XMAS". Apologies to those who prefer not to abbreviate, but for the display to be read easily, the full word *Christmas* is too long!

OTHER MESSAGES

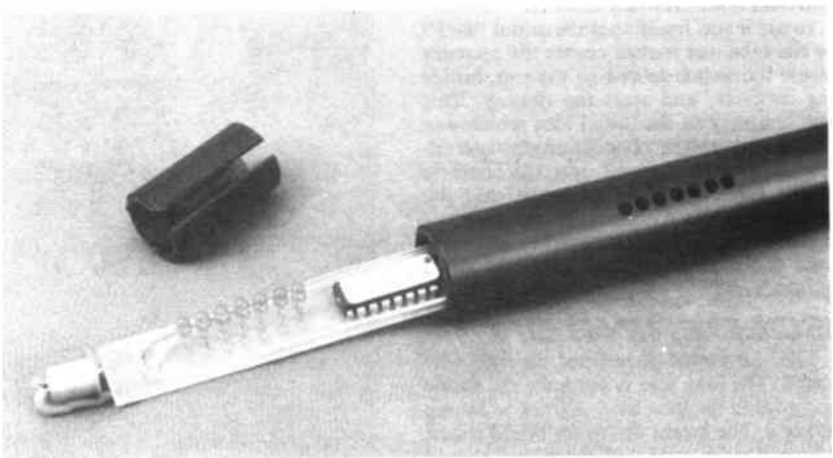
After Christmas, the display can be used for its main purpose by programming it with any 16-digit message. The message is loaded simply by sending serial ASCII code at 300 baud into pin 18 of IC1, whilst connecting pin 17 to 0V.

Any serial communication can be used, provided it sends data without handshaking, at 300 baud, no parity, eight bits and one stop bit. *Procomm* was used in the original, this has an ASCII download option and was configured as "300,N,8,1" according to the "Set Modem Parameters" screen. The first 16 codes to arrive are loaded, and everything else is discarded. Only capital letters, numbers, and spaces are available for display, others are ignored.

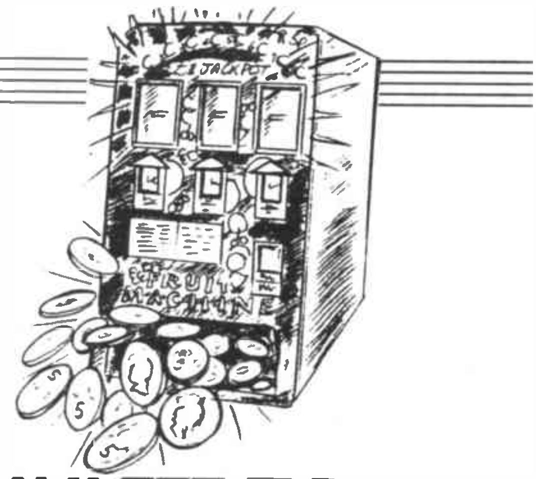
No handshaking or other reverse communication is used, because the message is so short and errors unlikely.

Three pads at the top of the board allow the serial connection to be made. A small 3-way 0.1 inch socket is suitable on a short flying lead. A special computer lead is then needed to pick up the computer 0V and TXD pins from the chosen serial port.

Finally, this is a novel display which must have a variety of interesting uses, about which we would be pleased to hear from you! □



Spacewriter board half-inserted into mounting tube. Note the holes for the l.e.d.s, and the retaining "plug".



EPE FRUIT MACHINE

BRETT GOSSAGE and JULYAN ILETT Part 1

A coin operated fruit machine that really pays out!

HAVING had a keen interest in fruit machines (also known as "slots", "automatics" or "one arm bandits") for as long as the authors can remember, they have always had it in mind to construct one. At a very early age, mechanical designs constructed using Meccano or Lego were attempted, but met with limited success, so an electronic machine was the obvious alternative.

Many years ago, an all TTL system was proposed, but if even the simplest of features were to be included, the circuitry would have been very complex. Some time later, a microprocessor design was considered, but it still would have involved considerable hardware and a hefty power supply.

PAYOFF

Now, finally, a design based around a single chip PIC16C57 microcontroller has become possible, and has resulted in a simple circuit, with battery power capability and plenty of space left for the single most important feature – *a real payout mechanism.*

This design, which it is believed fits into the "executive toy" category, makes use of two simple-to-construct plastic coin mechanisms, a coin detector and a coin payout mechanism. Both mechanisms are designed to work with the new small five pence piece. This coin was chosen for two reasons. First, the Fruit Machine had to be reasonably inexpensive to play while at the same time offering a high value jackpot. Second, since the five pence coin is the smallest, lower value coins will not fit through the slot, so no reject mechanism is required.

ANIMATED FRUIT

In order to minimise the number of mechanical components, large 7-segment displays are used instead of "reels" to reproduce the "fruit" symbols. Animation techniques have been used to give the "reels" a realistic spinning action, and software algorithms have been designed to simulate the inertia and friction of an equivalent mechanical system.

The fruit symbols are passed through the displays from top to bottom, quickly at first, then progressively more slowly until stationary. The three reels have been given different characteristics, so that the left reel stops first, followed by the centre reel and then the right reel.

To add further realism, the sound of the reels clicking against ratchets as they spin has been simulated too. Features including "hold" and "gamble" have been incorporated which appear at random introducing an element of skill into the game.

A mechanical arm, used to start the reels spinning, has been rejected in favour of a "start" button in line with the more up-to-date designs of fruit machine. Naturally, the machine cannot be started until at least one coin has been inserted. Several coins can be inserted if desired, and are registered as "credits" inside the machine.

A set of eight l.e.d.s called the *Feature l.e.d.s* are normally used to indicate the credits but are also used to liven up the machine by flashing various sequences prior to payout and when the machine is not being played.

PAYING OUT

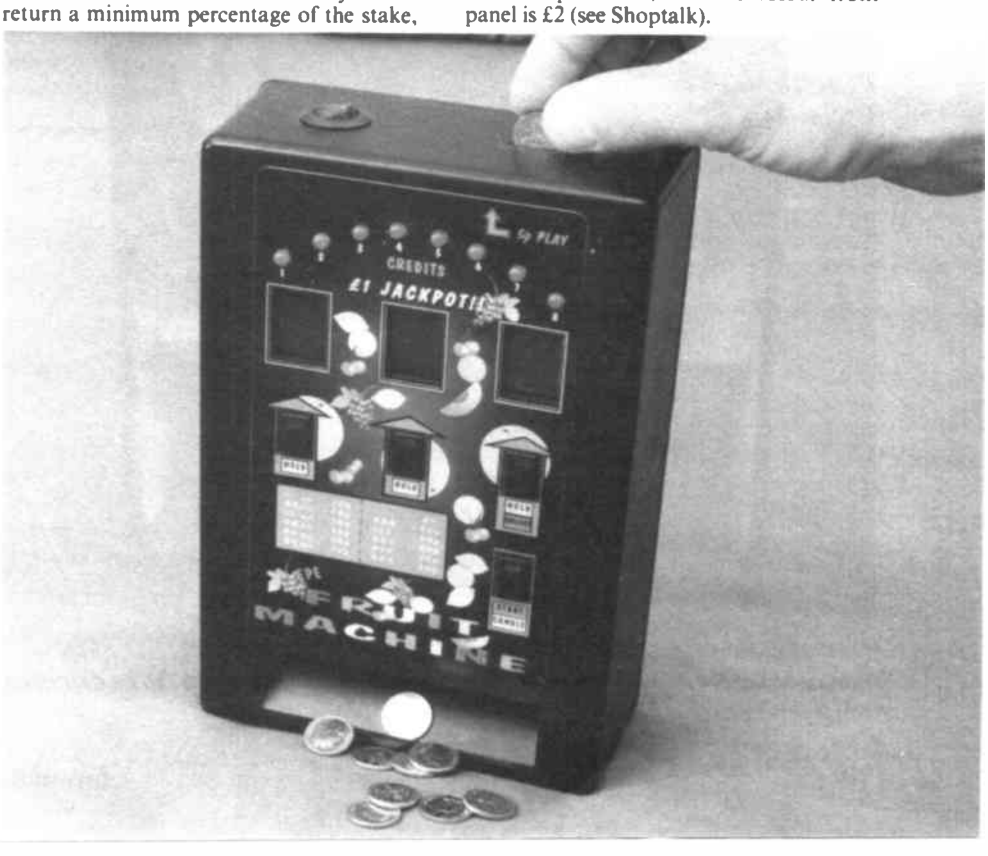
The Fruit Machine has an average payout of about 75 per cent and so is capable of making a profit. Interestingly, commercial machines are bound by law to return a minimum percentage of the stake, typically 70 per cent to 90 per cent, to the player. The exact value is indicated on the front of the machine. Since it does not make commercial sense to payout more than this, the odds are manipulated to maintain this percentage with great accuracy, it does not matter whether you play to win or lose.

This design does not monitor the payout, it is genuinely random and skilful play will increase the payout rate, although never above 100 per cent! For this reason, the Fruit Machine would make an ideal money box for a child who should ultimately discover the futility of gambling!

PROFESSIONAL PRESENTATION

The Fruit Machine is housed in a standard ABS plastic box measuring 220mm × 150mm × 60mm approx. A specially commissioned full-colour self-adhesive front panel is available which considerably enhances the machine's appearance. All the electronics including the displays and switches are mounted on a single sided p.c.b. measuring 100mm × 140mm approx. which is available from the *EPE PCB Service*, code 914.

The specially programmed PIC16C57 microcontroller is available from the authors, price £12, and the colour front panel is £2 (see Shoptalk).



MODE MANAGEMENT

The Fruit Machine's microcontroller continually manages a number of different tasks. These include multiplexing of the display matrix, monitoring the switches and coin detector, and controlling the piezo and servo outputs. In addition to this, "mode" control and the complex task of animating the three reels must also be carried out.

The program flowchart is shown in Fig. 1. At any one time, the Fruit Machine can be in one of seven different modes, *idle, sequence, spin, win, payout, gamble* or *nudge*. When the machine is first switched on, the *idle* mode is entered. If there are no credits, i.e. no coins have been inserted, the machine switches to the *sequence* mode after two seconds to encourage play.

Inserting a coin takes the machine back to the *idle* mode. In this mode, all three reels are stationary, and the program waits for the *start* button to be pressed. If the *hold* feature is active, the three *hold* lights will flash and the *hold* buttons will be active.

When the *start* button is pressed, the machine enters the *spin* mode. Next, a random number generator decides which combination of fruits the reels will stop at. Whether or not a win will be given and its value is decided even before the reels start spinning!

When all three reels have stopped, the winning line is analysed and the machine enters either the *win* mode, or returns to the *idle* mode if the game is lost. The *win* mode consists simply of a short sound and light sequence, after which the *payout* mode is entered. In the case of wins with three fruits the same, the *gamble* mode may be entered. Here, the win is either collected or gambled up or down. The *nudge* mode just steps all three reels forward or backward by one fruit.

In the *payout* mode, the "odds" table is read and a counter is set up to pay out the required number of coins. The servo motor is then moved to and fro and the counter decremented until it reaches zero. After payout, the Fruit Machine returns to the *idle* mode.

The random number generators, used to decide the winning line and to control the *hold* and *gamble* features, are simply fast counters which cycle continuously and are read each time the start button is pressed. It is impossible to anticipate the values of the counters, however, making it impossible to cheat!

IN A SPIN

A "mechanical analogy" of one of the Fruit Machine's reels is shown in Fig. 2. Although the system is essentially "all software", the algorithms of the *spin* mode were closely modelled on the equivalent mechanical system shown. The principles used are best described using this analogy, simply publishing parts of the source code would make very dull reading indeed!

The three reels each have six fruit symbols, but a total of 30 individual steps. This enables a reel to be displayed part way between two fruits for animation purposes, although the reel cannot stop in this position. Each reel has a speed parameter which is used to step the reel forward at a constant rate. Each time a reel is stepped, the piezo electric sounder output is toggled giving a "click" sound.

Initially, the reel is set spinning at a constant speed, then, after a short period, the speed parameter is decremented at a constant rate which slows the reel down. To ensure that the reel stops accurately on the fruit, rather than half way between two fruits, slowdown is delayed until the selected fruit passes through the win line. The complete slowdown process then takes exactly two revolutions until the speed parameter reaches zero and the reel stops.

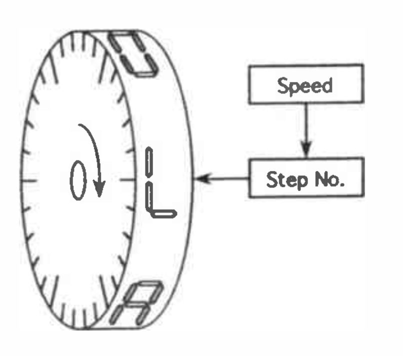
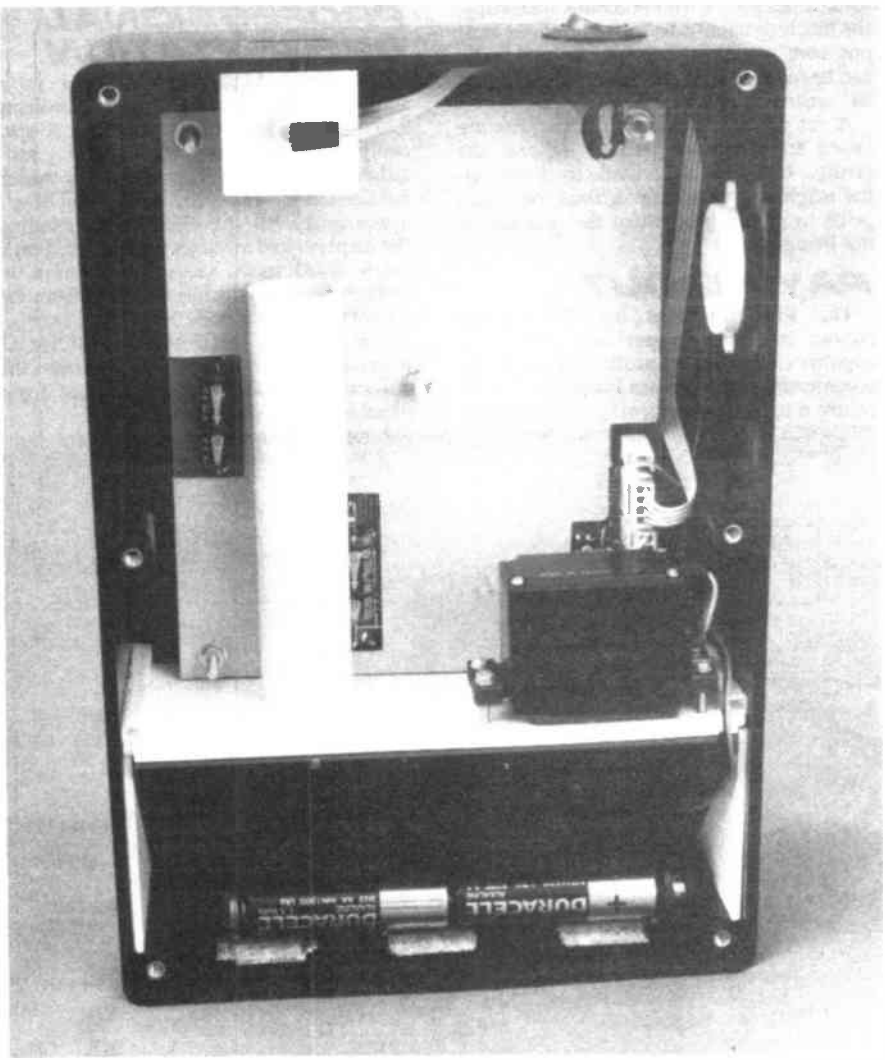


Fig. 2. Mechanical analogy.



Interior of the Fruit Machine showing the "mechanical mechanism" to be described next month.

MECHANICS

Since the Fruit Machine handles real coins, the job of getting them into and out of the machine requires a couple of mechanical devices.

Insertion of coins is handled by the coin detector mechanism. This uses a simple infra-red beam which is broken as the coin drops through. Whilst this design does not have any obvious security features, tampering is countered by measuring the time for which the beam is broken. Durations outside of a "window" value are rejected thereby ignoring the insertion of "inappropriate" objects.

Coins are payed out by the coin payout mechanism which uses a simple sliding tray to pull the coins, one at a time, from the bottom of the coin stack. It is driven by a servo motor, the type typically used in radio controlled models.

Both the coin detector mechanism and the coin payout mechanism are constructed, very simply, out of sheet plastic available from most model shops. A length of plastic pipe is required for the coin stack which is easily obtained in the form of overflow pipe for water tanks, available from builders merchants.

COMMERCIAL SCENE

The design of the Fruit Machine was, to a certain extent, inspired by the techniques used in commercial machines. For this reason, and by way of a small diversion, it may be interesting to take a look at the way these fascinating machines work.

Unlike early mechanical machines, which used electricity just to illuminate the front glass, modern machines are based entirely around complex microprocessor circuitry. The CPU board will typically contain a

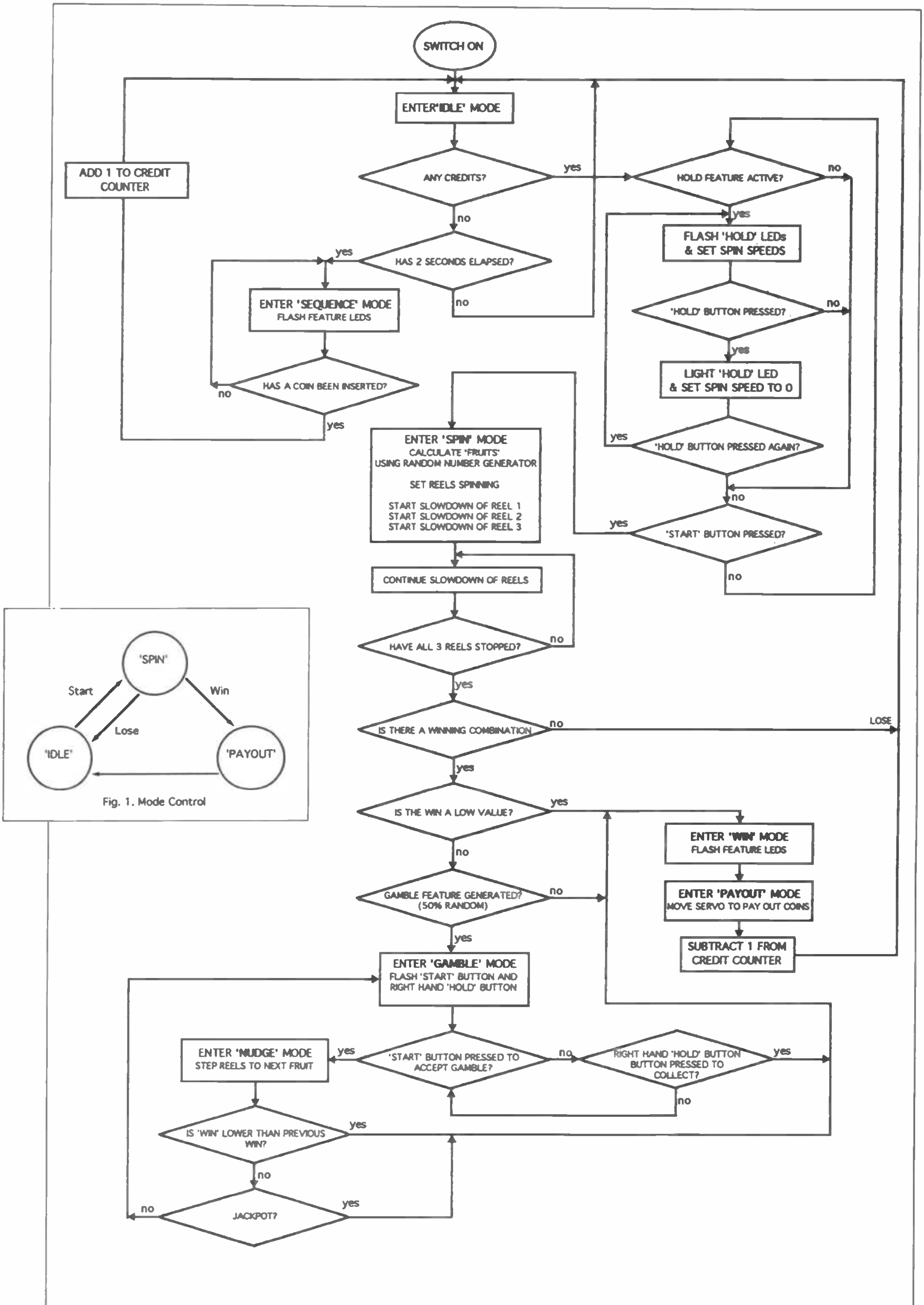


Fig. 1. Mode Control

Fig. 1. The EPE *Fruit Machine program flowchart*

Z80 or 68000 processor and the usual EPROM and RAM. Battery backed RAM or EEPROM may be used to maintain "odds" data during power off.

A large number of power transistors will be present to drive solenoids, stepper motors and the matrix of light bulbs which illuminate the reels and feature panels on the front glass. A sound effects chip may also be present.

The reels are, of course, mechanical, but being of an ultra light weight construction, have virtually no inertia and are controlled directly by the CPU using stepper motors. The speed of rotation and the point at which they stop is under CPU control. Any random behaviour here comes from random number generators in the software.

A large number of miniature filament lamps, which sit behind the front glass, are connected up in a matrix of rows and columns. Unlike l.e.d.s, these lamps conduct in both directions and therefore each lamp requires a series diode, which may be mounted in the lamp holder.

COIN DETECTION

Detecting the insertion of coins in commercial machines may be handled in two different ways.

The mechanical method uses an elaborate mechanism employing a counter-balanced cradle into which the coin drops, tipping the cradle over and sending the coin down a channel towards a microswitch which registers a credit.

Coins that are too small drop straight through the cradle and into the coin return chute, whereas large coins get stuck, requiring use of the coin reject lever. This forces open the whole mechanism allowing any large item to drop straight through. Additional safeguards include a magnet which attracts ferrous metal objects such as washers.

Modern coin detectors use a simple slide fitted with a number of coils through which a range of different coins can be passed. The coin changes the inductance of the coils as it passes, generating a unique signature for each coin.

Only coins with recognised signatures are accepted, a solenoid diverts alien devices to the reject chute. Once a valid coin has been detected, its signature is used to divert it down one of several different chutes.

A solenoid operated plastic paddle diverts the coin initially down one of two chutes, then two more paddles, mechanically linked and controlled by a further solenoid, split the two chutes into four. In this way, two solenoids operating in a binary fashion, can sort up to four different coins into four plastic tubes.

COIN PAYOUT

The coin payout mechanisms, of which there are likely to be four, are situated at the bottom of the tubes in which the coins stack. They are similar in design to the one used in this project, although they use a metal slide moved by a solenoid.

The solenoids are massive, each about the size of a mains transformer and are typically operated from 50 or 60 volts. Tremendous pulling power is required to slide a coin out from the bottom of a stack containing a couple of hundred coins.

All this gadgetry is housed in a tall cabinet made of chipboard with glass front panels. Several locks are employed to prevent access to a number of large plastic buckets sitting in the bottom of the machine which collect the coins that overflow from the coin stacks.

Commercial fruit machines are expensive items of equipment, although when situated in the right places, are capable of making a healthy profit.

CIRCUIT DESCRIPTION

The full circuit diagram for the *EPE* Fruit Machine is shown in Fig. 3.

A microcontroller is ideally suited for a project like this, to control the various Input and Output (I/O) devices found in the design. The amount and complexity of the software, and the memory required (2K), determine the specific controller, and this was chosen to be the 28-pin PIC16C57 manufactured by Arizona Microchip. The PIC16C57 (IC1) has three "ports" A, B and C, (one four-bit, A, and two eight-bit, B and C, where any bit can be configured as an input or an output) all of which are used (see Fig. 3).

The seven lines RB0 to RB6 are set up as outputs (port B), and drive the seven segments of each main "fruit" display, "a" to "g". The displays are multiplexed such that "segment" data is output via port B on lines RB0 to RB6. Then the appropriate "digit" drive bit on one of the four lines of port A (RA0 to RA3) switches transistors TR1 to TR4 in turn to sink current, lighting up the "digit" (the fourth digit corresponds to the "feature" l.e.d.s).

Segment drive "h" (RB7), which is usually the decimal point on 7-segment displays, is not connected as such, but is routed off to the l.e.d.s within the *hold* switches. Drive current to each of the segments is limited via resistors R1 to R8.

Each segment of the four displays is "overdriven" in turn by about four times its maximum rated current. This is acceptable and is done to increase the brightness of the displays. Because each segment is only on for a quarter of the time, there is no risk of damage to the displays or the drive transistors.

The clock circuit for IC1 uses a simple ceramic resonator for stability, and consists of components X4, C1 and C2. This generates a clock frequency of 1MHz.

The *start* and *hold* switches S1 to S4 "ground" the input lines RC4 to RC7 of port C (IC1) when pressed, and are otherwise pulled "high" by R32 to R36.

The servo requires two pulse trains of 1ms and 2ms at 50Hz for the "collect" and "payout" positions respectively, for the coin mechanism. These are generated using a CMOS 7556 dual timer chip (IC2).

The first timer in the chip (IC2a) is connected as an oscillator, generating the 50Hz via resistors R24, R25 and capacitor C3. This 50Hz output is connected to the trigger input of the second timer (IC2b), which

COMPONENTS

See SHOP TALK Page

Resistors

R1 to R8	56 (8 off)
R9 to R20	2k7 (12 off)
R21, R22	220 (2 off)
R23, R24, R28	4k7 (3 off)
R26, R29, R31	10k (3 off)
R30	15k
R25	100k
R27	150k
R32 to R36	4k7 (s.i.l. resistor pack)

Potentiometers

VR1, VR2	10k sub-min. preset (2 off)

Capacitors

C1, C2	22p disc ceramic (2 off)
C3, C9	100n disc ceramic (2 off)
C4, C5	10n disc ceramic (2 off)
C6 to C8	1000μ axial elect. 10V (3 off)

Semiconductors

D1	1N4148 signal diode
D2 to D5	1N4001 rectifier diode (4 off)
LED 5	min Infra red l.e.d.
LED 6 to LED 13	5mm l.e.d. std. (yellow) (8 off)
X1 to X3	0·8in. 7-segment display (common cathode) (3 off)
TR1 to TR5	BC548 *npn* silicon (5 off)
TR6 to TR13	BC558 *pnp* silicon (8 off)
TR14	min Infra red phototransistor
X4	1MHz ceramic resonator
IC1	PIC 16C57 (see text)
IC2	7556 dual CMOS timer

Miscellaneous

S1 to S4 (LED1 to LED4)	p.c.b. switch with internal l.e.d. (4 off)
S5	round rocker switch (black)
MO1	servo motor (Futaba FP.S14B)
PL1, PL2, PL4	p.c.b. 2-way plug (3 off)
PL5	p.c.b. 3-way plug
PL3	p.c.b. 4-way plug
SK1, SK2, SK4	p.c.b. 2-way skt (3 off)
SK5	p.c.b. 3-way skt
SK3	p.c.b. 4-way skt

28-pin i.c. socket; 14-pin i.c. socket; battery holder 4xAA (long type); battery clip (PP3 type); box ABS MB6; l.e.d. display filter (red); plastic sheet 0·060in. white; plastic sheet 0·080in. white; plastic sheet 0·080in. black; plastic tube 6mm diameter, 1 strip; plastic tube 21mm diameter, 100mm; plastic glue; paper clip; solder etc.; printed circuit board available from the *EPE P.C.B. Service*, code 914.

Approx cost guidance only **£65**

EPE MICROCONTROLLER FRUIT MACHINE - CIRCUIT DIAGRAM

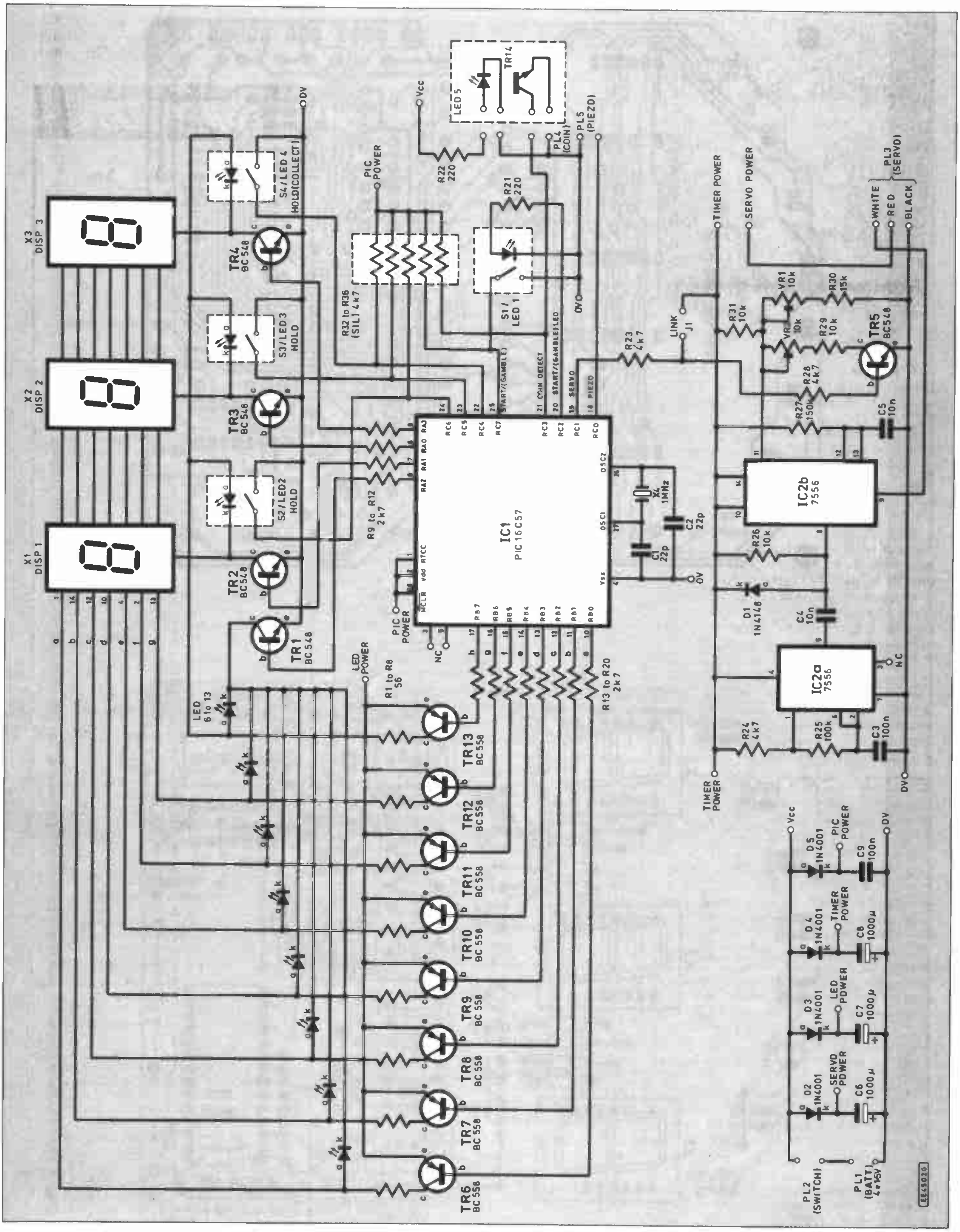


Fig. 3. Complete circuit diagram (less servo motor) for the EPE *Fruit Machine. Note that resistors R32 to R36 are contained in a single s.i.l. package.*

EPE MICROCONTROLLER FRUIT MACHINE – PRINTED CIRCUIT BOARD

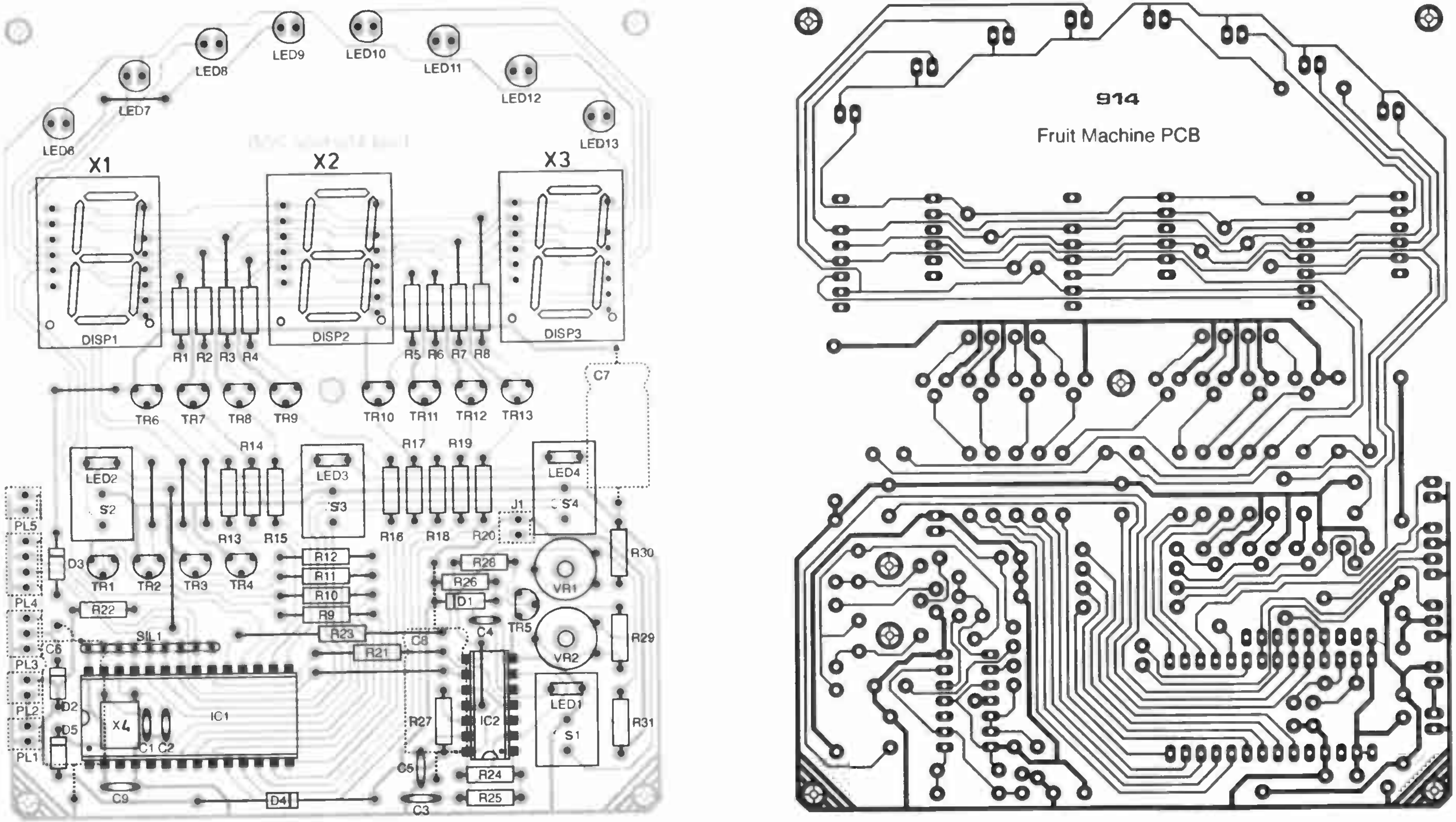
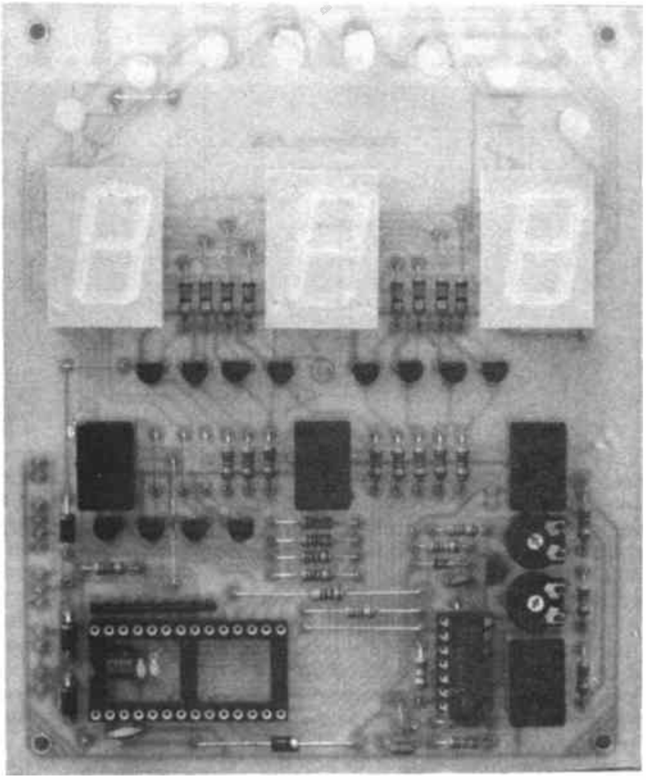
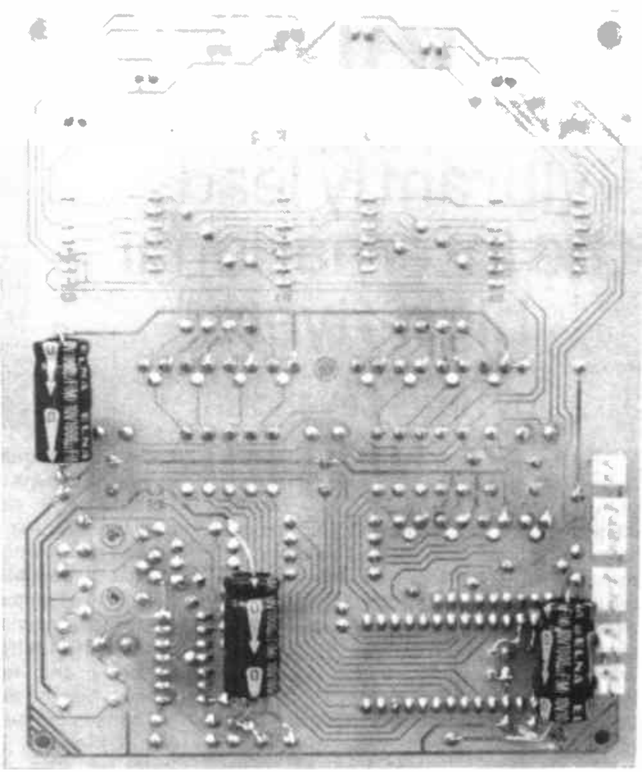


Fig. 4. Fruit Machine printed circuit board component layout and full size underside copper foil master pattern. This board is available from the **EPE PCB** Service, *code 914.*





Top and underside views of the completed p.c.b. Note the electrolytic capacitors and connectors on the underside.

is connected in monostable mode, giving the correct pulse width determined by resistor R27 and capacitor C5. The voltage at the reference pin (pin 11), is adjusted by preset VR1 to obtain the 2ms pulse. TR5 is switched on via link J1 to select a parallelled resistor pair which generates the 1ms pulse train, and this is adjusted using preset VR2 (see "Testing" – next month).

There are four isolated power supplies to power the l.e.d.s, servo, timer and microcontroller i.c.s. In each case, a diode "taps off" the battery supply (D2 to D5), isolating and localising any interference. Each supply is smoothed and decoupled with a capacitor (C6 to C9). The diode in the "PIC power" section (D5) reduces the maximum voltage for IC1 to a safer working level, as a new set of four batteries may exceed the 6V maximum supply rating for this i.c.

Sound is generated as a square wave, by toggling a bit (RC0) on IC1 at an appropriate frequency, (depending on the feature), and this signal is connected directly to the piezo electric sounder.

P.C.B. ASSEMBLY

The printed circuit board (p.c.b.) component layout and foil master pattern is shown in Fig. 4.

Due to the nature of construction, some of the components are not mounted flush on the p.c.b, notably the *feature* l.e.d.s. As a rough guide, the legs of these eight yellow l.e.d.s should be cut to a length of 16mm, and then should be soldered as high off the p.c.b. as possible.

The eight *feature* l.e.d.s, the three *hold* switches and the *start* switch all protrude from the front panel of the box, thus the cut-outs need to be quite accurately made so that the p.c.b. will make a snug fit. The main displays have a red filter fitted in front of them. This increases the contrast of the displays, and it really works! It fits in one piece behind the cut-outs in the front panel of the box. Note that these cut-outs are actually smaller than the displays themselves.

Construction proceeds by first fitting the seven links, and all the resistors including the presets. Then fit the capacitors, diodes and transistors, displays and l.e.d.s. Finally fit the switches, but note that the green l.e.d. in the *start* switch needs to be turned around. This can be done quite easily by disassembling the switch housing with a small watchmakers screwdriver, and it is easier than it sounds!

Note that some components are fitted underneath the microcontroller chip (IC1). Next fit the sockets for the microcontroller, and the 7556 timer (IC2). Finally, fit the three 1000µ capacitors on the back of the p.c.b. and fit the i.c.s when required, during testing.

The connectors are also mounted on the reverse side of the p.c.b, and because the p.c.b. is single-sided, care should be taken when soldering the plug pins to it. It may be easier to push the pins of the connector until they protrude equally from either side of the plastic mounting, and then solder them to the p.c.b, pushing the plastic part of the connector flush to the p.c.b. last.

Next Month: Mechanical assembly and testing.

ENHANCED AIR/SEA SAFETY

British enterprise vibrantly leads the international high-flyers

by Hazel Cavendish

LAST year the small Hampshire engineering firm of Stewart Hughes won a Queen's Award for Export Achievement by increasing its export sales from £266,000 to £2.71 million in three years. The increase was largely through their R & D into a method of detecting mechanical faults in helicopters at an early stage. This was an exercise which also won them the American Helicopter Society's Harry T. Jensen award for contributing towards the safety of aircraft.

The Company, established 14 years ago, originated as a department of Southampton University. Both Chairman Ron Stewart and his M.D. Tony Hughes had worked in the University's Institute of Sound and Vibration, specialising in the diagnosis of machinery faults by analysing vibration signals. Their development of this technique has resulted in the unique design of a box for helicopters to be used as part of the Flight Data Recorder which controls the Crash Protection Unit.

The approach they use is the HUMS system (Health Usage Monitoring Systems). Incorporating Inmos transputers, the latest generation of the system carries out continuous automatic vibration analysis of the components within the helicopter drive train, thereby helping to detect mechanical faults at an early stage.

A factor of considerable importance is the ability of the system to distinguish one gear from another. "It is important to know which gear is faulty," says Consultant Systems Engineer Max Hadley, "otherwise a signal indicating merely that the gearbox was faulty would mean having to change the whole box, dismantle it completely and inspect every gear. It is essential that aircraft are able to be turned around quickly, and with this system the faulty part can be identified instantly and replaced with minimum delay while the aircraft is in service."

The system uses software called the Flight Regime Recogniser which also looks at data signals from additional sensors throughout the aircraft. These too are recorded in the Crash Protection Memory, made by Penny and Giles of Dorset.

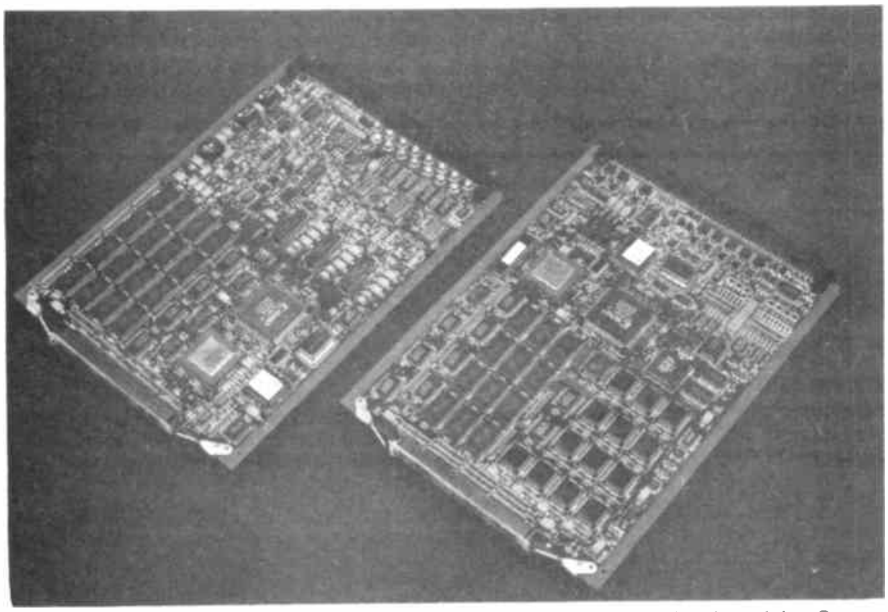
More advanced technology using Xilinx 4000 FPGAs (Field Programmable Gate Arrays) has been developed to meet military specifications for 100 systems supplied to the Canadian Defence forces for a fleet of helicopters ordered from Bell Helicopter.

"These FPGA devices are interesting because the data held within them can be readily reconfigured in situ," says Mr Hadley. "When the system is switched on, the first thing the software does is to load the hardware configuration into the FPGA which then starts the main software. It is a highly complicated system configuring from a common set of data which contains that for the FPGAs and the software for the Inmos processors. All this data can be uploaded into the box via a connector in the front panel from a special adapter card which can be plugged into a lap-tap PC. All the software and FPGA configuration is held in flash memory within the box.

"As far as I know, we are the first company anywhere to use transputers in a certified piece of civil avionics. The idea of systems being able to be programmed in the field without having to go back to manufacturers to have a chip removed and a new one soldered in, is just taking off."

This autumn the Company also landed a six-figure contract with the American Defence Department by designing "a little black box" the size of a standard pack of corn-flakes which will monitor the cooling system of a Spruce class destroyer, a task previously done by personnel.

Stewart Hughes beat off the competition from top US companies specialising in electronic technology with its Intelligent Sensor Interface, which Max Hadley, who directed the development, describes as "a complete Star-Trek type of automated maintenance."



Circuit boards showing the use of Xilinx FPGAs in Systems developed by Stewart hughes for use in helicopters servicing the North Sea oil rigs.

Handy Third Hand

The new Panavise JR is a vice that is more like a third hand than a tool. Work can be moved through three planes without removing it from the vice. The head is designed to rotate and swivel 360 degrees, and is able to pivot 210 degrees. One turn of the control knob, and you are able to securely position your work exactly where you want it.

The parallel closing jaws have an opening from 0mm to 730mm and are made of strong fibre reinforced thermal plastic for careful but firm holding of your work. The vice weighs in at only 567g, yet the body is made of cast zinc which provides a firm base that can also be bolted down. Its versatility makes it perfect for dozens of uses such as soldering, drilling, painting, gluing, assembling, fly-tying, repair, and even industrial use; ideal for the professionals, weekend professionals and do-it-yourselfers alike.

The Panavise JR has a retail price of £23.44 (including VAT) and is available from many hardware stores, hobby and model shops, or with £4.95 carriage from Longs Ltd., Dept EPE, Hanworth Lane Trading Estate, Chertsey, Surrey KT16 9LZ. Tel: 0932 561241.

AF PDM AMPLIFIER

The first in a range of modular PDM (Pulse Duration Modulation) audio frequency amplifiers for experimenters and systems engineers has been introduced by D-Systems.

The appeal of PDM modules lies in their versatility. They work by encoding the audio signal as a proportional variation in the mark/space ratio of a high frequency power switch and decoding passively at the output. The system encodes the whole audio signal without sampling.

The audio performance is up to the standards of the best hi-fi amplifiers available and distortion is almost completely second harmonic and mostly below 0·2 per cent. This generally excellent performance, and the high efficiency and low standby current consumption, makes the modules suitable for general purpose battery-powered monitoring use, possibly in remote locations using solar powered supplies. They can also be used as booster amplifiers for personal stereos.

The first of D-System's PDM modules is the PMI which operates on a single 9V or 12V rail with quiescent current drain of only 400 microamps. Full power bandwidth is 10Hz to 100kHz at 6W into 3ohms with a conversion efficiency of more than 90 per cent. Sensitivity is 0·7V r.m.s. input for full rated output. The price of the PMI is £14.35, inclusive of post and packing.

For further information contact D-Systems, Dept EPE, Moss Drive, Haslingfield, Cambridge CB3 7JB. Tel: 0223 871555.

Tactile Audio

A new radio cassette player-recorder has arrived onto the market designed specifically for those people with visual or physical disabilities who find consumer products complicated and difficult to operate.

Designed and manufactured by Clarke & Smith Industries and commissioned by the British Wireless for the Blind Fund, this user friendly product incorporates many special features which are of particular benefit to elderly, visually impaired and disabled people.

For example, the three waveband radio cassette – f.m., m.w. and l.w. – has a very simple operating layout. Its large, easy-to-grip operating controls in the high colour contrast of yellow on grey, are generously spaced to be easily distinguishable and carry tactile symbols for easy identification.

An audible rising/falling tuning tone on the digital push button indicates the radio band position, and an audible "cue" and "review" facility helps the user to locate a particular position on a cassette tape. In addition, a large yellow safety knob sits on the end of the aerial, a surprisingly common danger for those with failing sight or with young children.

Along with these special features, this hard-wearing radio cassette has all the facilities such as five preset stations for each waveband, allowing up to fifteen stations to be stored. It has a high quality four inch speaker, is mains or battery operated and is easily serviceable.

For further information contact: Jane Marren, Clarke & Smith Industries, Dept. EPE, Melbourne House, Melbourne Road, Wallington SM6 8SD. Tel: 081 669 4411.

TRY THE INTERNET!

You are sure to have heard about the Internet, the information highway and the global village, but do you really know what it means and how you can access it? You can find out more by going to the Christmas Computer Shopper Show at Olympia and visiting Carrera Technology who will allow you to access the network direct from their stand.

On their stand will be displayed the first Internet-ready PCs in the UK with Easynet software and a US Robotics Sportster modem pre-installed. Hooking up to the Net then becomes simply a matter of plugging the machine into a phone line.

As a special show promotion, Carrera Technology will also be offering free vouchers for use in the newly opened central London cafe, Cyberia – the UK's first cybercafe – which has a range of Internet-ready PCs.

To help you visit the show we are pleased to include above a special voucher which allows you £1.50 off the entry ticket price. The show is to be held at the Grand Hall, Olympia, London from the 1st to the 4th of December 1994.

For more information, please contact Helen Sheffield on 081 742 2828.

Lithium saves iceman!

Lithium cells supplied by Saft Nife helped the remarkable Rupert Hadow to return from the polar ice safely after the 32-year-old Scot failed earlier this year to walk 410 miles, unaided, to the North Pole. Temperatures of −45°C and two falls into arctic water ended this year's attempt after 24 days, but the long-life, low-temperature lithium cells, in battery packs assembled by Woolsery Electronics of Bideford, continued to power radiocommunications and satellite navigation equipment perfectly.

Not all applications are as gruelling as the Sector Ice Man Challenge, but Saft Nife's high energy density, lightweight and reliable LSH lithium cells are ideal power sources for emergency applications for medium and high drain use, and where high start-up voltages are required after long storage periods.

For further information contact: Antoinette Leach, Saft Nife Ltd., Dept. EPE, Station Road, Hampton, Middlesex TW12 2BY. Tel: 081-979 7755.

SHOP TALK
with David Barrington

EPE Fruit Machine

Apart from the pre-programmed microcontroller, several other components required to complete the *EPE Fruit Machine* need special mention and may not be obtainable locally.

Starting with the most important device first, the ready programmed PIC16C57 controller chip is available from the authors, price £12. The coloured, self-adhesive front panel overlay is also available from the same source for the sum of £2. Please add 50p for UK p&p and £2.50 for Overseas postage and packing. Orders should be sent to: **Dept EPE, 28 Blisworth Close, Yeading, Hayes, Middlesex, UB4 9RF.** *MAIL ORDER ONLY.*

The 0·8in. 7-segment displays must be the "common cathode" types. The ones used in the model are designated HDSP3405. An alternative type is the RS588-960 (code) stocked by **Electromail**, the RS mail order outlet.

The servo motor is the Futaba type FB.S14B and should be stocked by most good model shops. A range of low voltage servos are stocked by **Magenta Electronics** and one of these may work here but they have not been tried in the unit.

The switches with an integral l.e.d. are Maplin type JU04E (red) and JU05F (green). On/off switch also came from above, code JR96E.

The printed circuit board is available from the *EPE PCB Service*, code 914.

Universal Code Lock

The *Universal Code Lock* circuit has been designed to operate with virtually any keyboard as long as it has a matrix formation, i.e. rows and columns, and is not one with a common connection. Choice of keypad will, of course, depend on application.

The choice of small keypad is quite large and people like **Bull Electrical, Greenweld, Maplin**, in fact, most of our component advertisers should be able to offer a suitable type. The solenoid/lock mechanism may have to be purchased from your local hardware/DIY store, but someone like Bull or Greenweld may have one hidden away amongst their vast stocks of unusual items.

The custom programmed PIC1654RC microcontroller i.c. is available from the designer – Mail Order Only – for the sum of £9.50 including postage. Customers outside Europe are asked to add an extra £2 for postage. Orders should be sent to: **B. Trepak, Dept EPE, 20 The Avenue, London, W13 8PH.**

The printed circuit for the Code Lock is available form the *EPE PCB Service*, code 922 (See page 975).

Video Modules

All components listed for the Wiper modules and the Audio Mixer, this month's *Video Modules* projects, appear to be "off-the-shelf" items and should be obtainable from your regular component supplier/advertiser. The printed circuit boards are available from the *EPE PCB Service*, codes 916 (Horiz. Wiper), 917 (Vert. Wiper) and 918 (Audio Mixer).

The case shown housing the modules is not specified as it was felt readers may care to choose their own, also it usually sells for over £30. The one used by the author is known as a "1U" type and measures 432mm (W) x 45mm (H) x 254mm (D), the front plate is, of course, 19 inch (428mm) wide. This was originally purchased many months ago from **Rackz Products** (☎ *0749 840102*). Most of our advertisers will be able to offer something similar.

Rodent Repeller

The main outlay for constructors of the *Rodent Repeller* project will be the purchase of the Xenon flash unit. This was selected from the range of "burglar alarm accessories" stocked by **Maplin** and is the "clear" version of the low profile Xenon Flasher, code ZC16S (clear).

The "scare" buzzer was also obtained from the above source and is the High Power Buzzer, code FK84F. This has a claimed operating range of 3V to 24V d.c. and an output power of 103dB at one metre. One further point, the sounder must be the type with internal drive circuitry – other types will not work here.

It is important to use a good quality mains transformer which also has an adequate current rating. This will remain cool in operation during continuous use. Suitable transformers are listed by **Greenweld** (code 88-0255) and **Maplin** (code YN15R). The printed circuit board is available from the *EPE PCB Service*, code 913. Finally, pay special attention to the notes about **mains wiring**, its the unwanted visitors we want to remove!

Spacewriter Wand

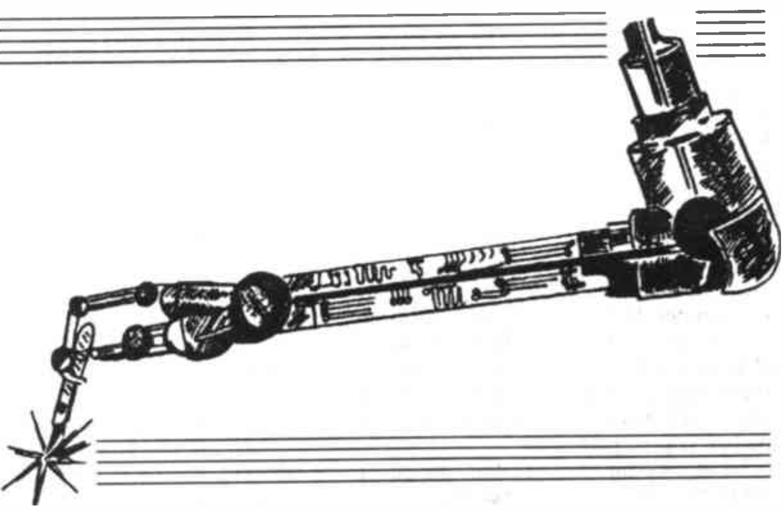
Another special pre-programmed chip is called for this month in the novel *Spacewriter Wand*, the first of our offerings for the festive season. This device is only available from **Magenta**.

A complete kit of parts, including p.c.b. and chip loaded with the message Merry Xmas, for the Spacewriter Wand is available from Magenta for the sum of £16.99 plus £3 post and packing. **Magenta Electronics, Dept EPE, 135 Hunter Street, Burton-on-Trent, Staffs, DE14 2ST.** Kitcode 849.

The printed circuit board is obtainable from the *EPE PCB Service*, code 921.

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY

Welcome once again to our popular column devoted to readers' problems and circuit suggestions. This month, we offer some advice to those constructors who fabricate their own printed circuits boards at home, and help with a query on winding your own inductors.

THIS month's edition of *Circuit Surgery* marks my first year at the helm of our "agony column" - I hope readers continue to find it varied, interesting and helpful. Remember, this is ***your*** column, so if you have any suggestions for circuit ideas which you would like us to investigate, or any topical comments which you would like to make, please write to *Circuit Surgery* at the editorial address.

All wound up

We have a mixture of both theoretical and practical topics this month, starting with a query from a budding radio amateur in South Africa. ***Mark Lamprecht*** of Durban, 4001 Natal posed a question relating to the techniques for winding simple coils.

I've just started a course in Amateur Radio and am really keen to build my own equipment. However, I've discovered a problem when trying to construct inductors and hope you can offer some advice. Suppose an inductor is, say, 100µH in value – then how many turns of wire is that? What gauge wire can I use? Is there a formula that one could apply or is it a case of hit and miss? I would be very grateful for any helpful suggestions you could offer.

There isn't a particular problem when winding inductors, thanks partly to the availability of ferrite core kits which permit you to custom-wind these components to a high degree of accuracy. For example the "RM" series or similar ferrite cores are available in kit form from several of our advertisers (see later).

The unit of inductance is the Henry, symbol H, named after the American physicist Joseph Henry who was credited with the discovery of the principle of self-inductance in 1832 (data: Microsoft Encarta™). The usual units of measurement of inductance are these:

milliHenry (mH, 1×10^{-3} Henrys)
microHenry (µH, 1×10^{-6} Henrys)
nanoHenry (nH, 1×10^{-9} Henrys)

The inductance of a coil is proportional to the *square* of the number of turns on the core, and it's desirable to use the largest diameter gauge of enamelled copper wire which can be accommodated on the chosen core. A larger diameter wire has a larger cross sectional area together with a lower electrical resistance than a narrower gauge. So it's best to wind on the thickest wire possible which the core will allow, for the specified number of turns.

This brings us to the next question, how many turns? The formula you need is the following:

$$N = \sqrt{\frac{L}{A_L}}$$

where N is the required number of turns, L is the desired inductance and A_L is the *specific inductance* of the ferrite core – in effect, a measure of the inductance per turn.

A useful data sheet no. K5774 is published by RS/ Electromail which describes their own product selection. If you know the number of turns required, the data sheet will help to choose the appropriate core and also the gauge of the wire.

Praying mantissa!

The parameter A_L is an inductance factor which is specific to each type of core. It could range typically from 160nH to 400nH or more. A particular trap in the above equation concerns the value of L which, if the data specifies A_L in nH, must be stated in *nanoHenrys* also. If for example Mark's coil is 100µH, you can convert this to nanoHenrys quite easily using "scientific notation" which saves having to write lots of noughts. Here's a quick reminder:

$L = 100\mu H = 100 \times 10^{-6}$ Henrys
$= 1 \times 10^{-4}$ Henrys in scientific notation. Convert this to nH.

Mathematicians will know that the "1" is termed the mantissa whilst the 10^{-4} is the exponent. In order to multiply numbers together using scientific notation, one multiplies the mantissas together whilst adding the powers (exponents). Recall that nanoHenrys are expressed as 10^{-9} Henrys. Working backwards from all this, a value of 1×10^{-4} Henrys equals $1 \times 10^{5} \times 10^{-9}$ Henrys – i.e. **1×10^{5} nanoHenrys.** The less academic conversion factor is simply 1nH = 0·001µH, implying that 100µH is equivalent to 100,000 nH (1×10^{5}). Take your pick, depending on your mathematical inclinations.

The choice of ferrite core may sometimes depend on the frequency of operation. In some applications (e.g. power supply filters), the d.c. current becomes relevant too and this also determines the wire gauge. For this example let's select the smallest pot core in the range, which has a value for A_L of 160nH.

To fabricate a 100µH inductor, we can use the above formula to calculate the required number of turns and we obtain a figure of just 25 turns (i.e. the square root of 625). Tables included in the data sheet tell us that the specified pot core (RS Order Code 228-214) will accept 25 turns of a maximum wire diameter of **0·56mm** (approximately 24 standard width gauge), so that's the optimum wire gauge to plumb for when selecting the enamelled copper wire.

Several of our regular advertisers stock a comprehensive range of inductors, ferrites and other r.f. components. In particular, ElectroValue Ltd (**☎ 0784 442253**) deserve a special mention because of their comprehensive range of Siemens ferrites whilst CirKit Distribution (**☎ 0992 448899**) are the UK stockists of Toko products.

Several others, including Maplin, also list a useful selection of components. You could possibly check out a modest book entitled *Coil Design and Construction Manual* published by Babani which is listed by our own *Direct Book Service* (code BP160), price £2.50 plus P&P. This might help further.

P.C.B. techniques

Back in the September issue I touched on the subject of making your own printed circuit boards (p.c.b.s) using the ultra violet system. Whilst the *EPE PCB*

Service is as popular as ever, we're of course well aware that many readers do prefer the satisfaction of etching and fabricating the boards for themselves at home. I've received several letters from readers asking for some advice on this topic.

If you decide to dabble with p.c.b. production yourself you can adopt one of two approaches. Either use a "direct etch" method, whereby etch resistant transfers are physically applied to the copper foil of a "blank" p.c.b. – then immerse the whole board in ferric chloride etchant for a period to remove the unwanted copper. Afterwards, polish off the etch resist transfers and then drill out the copper pads.

I can recommend the *Alfac* range of transfers, which are listed both by Greenweld (☎ **0703 236363**) and ElectroValue Ltd (☎ **0784 442253**). They are used exactly like rub-down lettering.

This method is fine for quicker one-off boards but there are several drawbacks: the artwork is destroyed each time after etching, so it's really irksome if you need to produce a small quantity of boards; if you find you've made a mistake, error correction is impossible after etching, so you have to start all over again – the same applies if you find that you want to modify the circuit after performing some circuit trials. You can't save the artwork for reference in the future, and it's extremely inconvenient if not impossible to originate the artwork if the circuit is complex.

To relieve this tedium you can use the ultraviolet (UV) technique, though it's more expensive and a little more complex. For the benefit of less experienced readers, Fig. 1 is a basic illustration showing how the UV system works.

The desired copper track pattern is first drafted onto a clear acetate or polyester film, again *Alfac* transfers are ideal here. This means that the artwork can be amended now or in the future, and can be re-used to produce more of the same design at a later date. You can also copy magazine artwork using the same system, by tracing it from the page.

A blank p.c.b. is used which has to be coated with a special UV photo-sensitive lacquer. Either buy pre-sensitised boards (which I much prefer to work with) or use a special aerosol spray-on coating. The next step is to place the artwork "positive" over the prepared board (right way round of course!) and then expose the board to an ultraviolet light source for a period of typically between ten to twenty minutes or so.

The exposed board is subsequently developed either using a proprietary developer or a weak solution of Sodium Hydroxide (domestic caustic soda). This will dissolve away the UV lacquer which has been subjected to UV light, so all that will remain is photo-resist lacquer which had been masked by the p.c.b. artwork. The lacquer is resistant to etchant and the board can be etched in ferric chloride in the usual way.

With the unwanted copper now removed, a quick swab of acetone (nail varnish remover) afterwards will dissolve away the lacquer to reveal the copper foil track pattern, and the board may now be drilled to obtain a really crisp, professional finish.

P.C.B.s exposed!

Of course, you need a UV light source for this technique and you might consider making your own. I previously suggested the *UV Exposure Unit* we published back in October 1991. Reader ***Frank Bagshawe*** of Buxton, Derbyshire had a few useful tips for those contemplating building an exposure unit for themselves:

The project you recommended for the construction of a UV light box is straightforward apart from the winding of the transformer. My difficulties with winding this led me to purchase a fluorescent tube driver from Maplin (Auto Light YZ35Q), similar types are also available from Greenweld as single or twin tube types L1652 or L1655.

The 8W UV tubes themselves were sourced from Maplin (FJ55K). This combination of parts works satisfactorily from a 12V mains power supply. However, I have come across boards which are said to react to daylight – could you give a few tips on exposure times for these boards?

Thanks for the information on your alternative approach to making a UV light unit. As far as timing's concerned, when you're exposing a photo-resist board to ultra violet light it's essential that the UV is allowed to penetrate through the entire depth of the lacquer so that it reacts thoroughly.

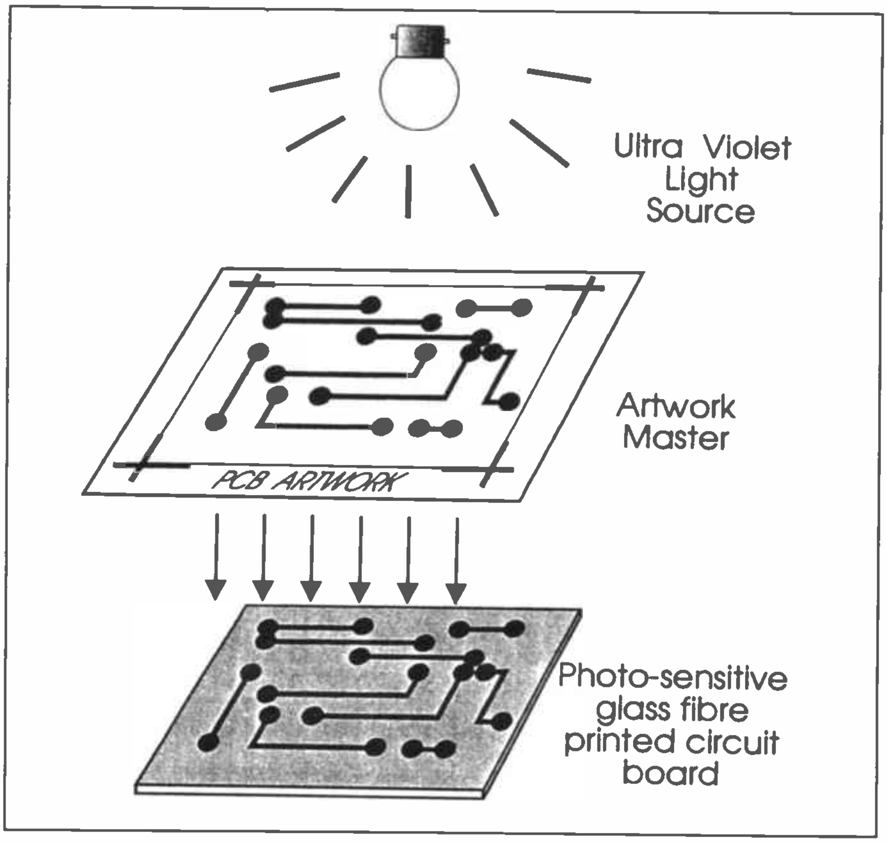


Fig. 1. Basic UV method of p.c.b. fabrication: 1 Expose to UV light through artwork. 2 Develop. 3 Etch.

Exposure value

Failure to expose for long enough will result in just the surface layer of the lacquer developing away, and a residue of resist will remain on the board rendering it useless for etching. It takes a little experience to familiarise oneself with the technique, and how long you expose for depends on the combination of UV power, the thickness of the photo-resist lacquer and the distance between the light source and the board.

Mr. Bagshawe mentioned that some boards are available which could be exposed using ordinary daylight. Perhaps so – but it's strictly a matter of trial and error as it relies on the UV content of natural daylight. It depends on the time of day (and year), the weather, and where you live!

I doubt if anyone will ever obtain consistent and repeatable results simply by using daylight, especially in the British climate where the only thing predictable about it is that it's unpredictable! Without a doubt an exposure unit will save a lot of heartache – and you can do it at night!

It's probably a good idea to err on the side of caution by over-exposing the board somewhat, to ensure that the photo-resist reacts all the way through. In theory, serious *over-exposure* will only cause problems when the UV light penetrates *through* the artwork if the light-proof symbols are not sufficiently opaque, or by undermining the transfers at their edges and affecting the lacquer underneath.

The latter is only likely to be a problem if your design has very fine copper conductors: they may then be etched away completely in places. Under-exposure is likely to be much more of a nuisance.

I find that etch-resistant aerosol sprays can cause a variety of problems. Because the coating on the p.c.b. may be considerably thicker (and not necessarily uniform), exposure times may be inconsistent and sometimes I find that I have under-exposed.

It's wise to experiment with some scrap board to find the optimum exposure times and generally become acquainted with the behaviour of the spray lacquer. A period of 20 to 30 minutes exposure has been known, but it depends on the power of your UV exposure unit. Sprays are handy though if you have ruined a pre-sensitised board for any reason, when at least you can try to re-use the blank board again.

My own UV unit has two 8W tubes which is fine for my needs, and a period of roughly 15 minutes seems average for ready-coated boards. Incidentally, I described a simple constructional project *UV Exposure Timer* in the July 1992 issue of *Everyday Electronics*. The mains-powered unit offers switched time delays between 2 to 24 minutes for your ultra violet light box and helps to ensure that you avoid accidentally under-exposing your boards. The circuit board (*only*) for this project is still available from the *EPE PCB Service*, Code No. 797.

Alternative UV unit

Steve Knight – author of the excellent *Calculation Corner* series which has been widely applauded by readers – dropped in and suggested an alternative for a DIY mains powered UV unit. Steve suggests:

I found the best bet is to get hold of an ordinary 300W UV Sunlamp from a chemists or wherever, and fit it in an open box as per the sketch of Fig. 2. The dimensions aren't critical and the box is made from odd pieces of chipboard.

Paint the inside matt black and off you go! I suggest give the lamp a few minutes to warm up, and with the board about 10 inches/ 25cms away, I find that five minutes is the required time.

It's worth investigating Steve's idea as the cost savings over a commercial unit are substantial. You *MUST* however take suitable precautions when dealing with ultra violet light. It can damage eyesight and therefore you should not gaze at the light with the naked eye. *(We strongly suggest that, for personal safety, a curtain or hinged flap is placed across the front opening of the unit. Ed.)*

I would also warn novices of the dangers of using ferric chloride etchant – please wear gloves and goggles and avoid splashing this corrosive fluid on anything.

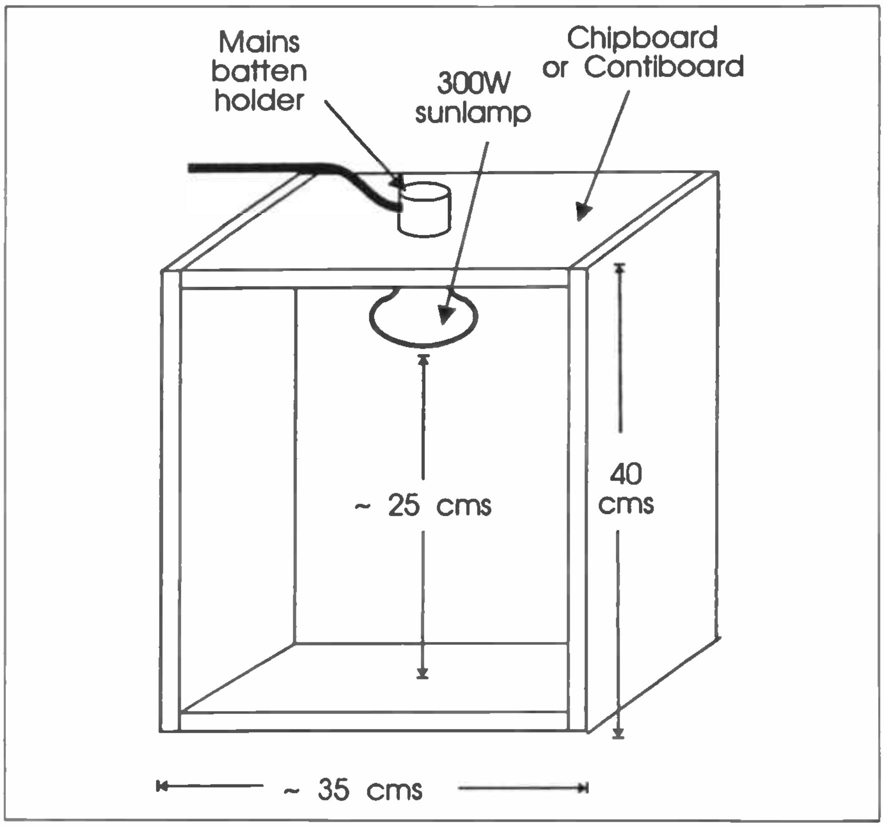


Fig. 2. UV exposure cabinet made with surplus chipboard and a 300W sunlamp. Take care not to view the UV light with the naked eye.

GCSE Support

Many GCSE Electronics/Design & Technology students write to the *Surgery* at this time of year seeking assistance with their chosen project. I'm only too happy to pass on a few pointers wherever possible, but *Circuit Surgery* does not provide *specific* circuits for projects as it is imperative that students research and develop the circuitry for themselves.

Our 12-part educational series *Teach-In '93* was specially written to support GCSE and Advanced Level Electronics, and as part of the course we designed the Teach-In *Mini Lab* and the advanced *Micro Lab* training units. We're pleased to say that because of demand we have now released the series as a complete book, available from your local *Newsagent* or from the *Direct Book Service*. Hobbyists and constructors will also find it useful for brushing up on theory, and the completed *Mini Lab* forms a complete test-bed to help you develop your own circuits.

Finally this month, don't forget our re-introduced *Ingenuity Unlimited* column – if you have any circuit ideas of your own for possible inclusion then please send a brief description (preferably typewritten or word-processed) with neat diagrams showing relevant component values, to myself at the following address. Ideas must be the readers' own work and we will pay between £10 to £50 for all circuits used depending on their length and technical merit. We will publish a selection at suitable intervals.

Send your circuit ideas to Alan Winstanley, *Ingenuity Unlimited*, Everyday with Practical Electronics, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. Or you can write to *Circuit Surgery* at the same address.

Next Time

In the next *Surgery*, I hope to look at regulated power supply design together with heatsink calculations, and more!

Electronics from the Ground Up

Mike Tooley, BA

Part 3

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 new software package that lets you use your PC to build and test a wide range of circuits. A special low-cost version of this software (with all the parts and test instruments needed to complete the series) is available to readers, see later for how to order.

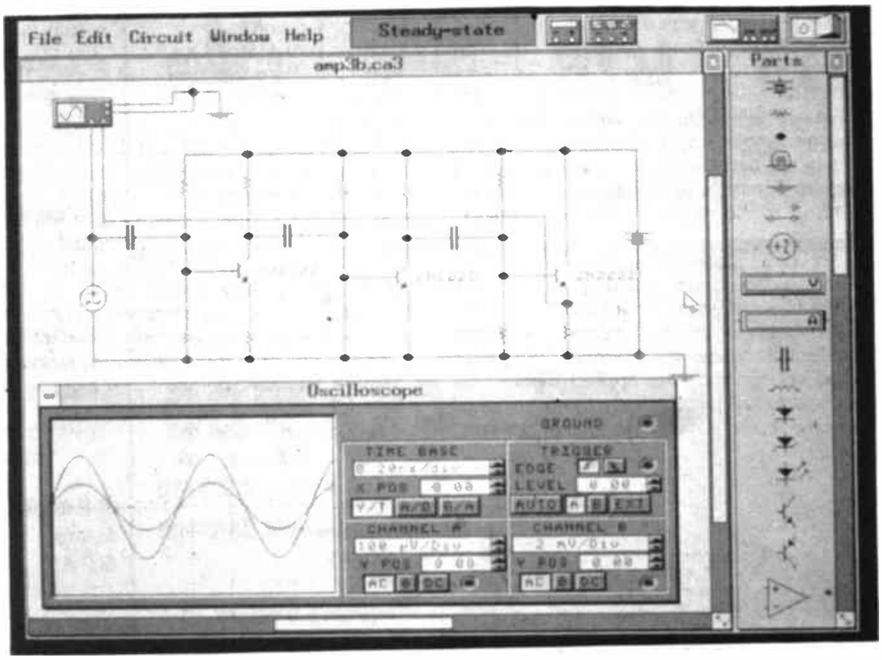
In this third part we introduce semiconductor diodes. We investigate the behaviour of half-wave and full-wave rectifiers and develop these into complete power supply circuits incorporating smoothing and voltage regulation.

SEMICONDUCTORS

Atoms contain both negative charge carriers (electrons) and positive charge carriers (protons). Electrons each carry a single unit of negative electric charge whilst protons each exhibit a single unit of positive charge. Since atoms normally contain an equal number of electrons and protons, the net charge present will be zero. For example, if an atom has eleven electrons, it will also contain eleven protons. The end result is that the negative charge of the electrons will be exactly balanced by the positive charge of the protons.

Electrons are in constant motion as they orbit around the nucleus of the atom. Electron orbits are organised into shells. The maximum number of electrons present in the first shell is two, in the second shell eight, and in the third, fourth, and fifth shells it is 18, 32, and 50 respectively. In electronics, only the electron shell furthermost from the nucleus of an atom is important. It is important to note that the movement of electrons only involves those present in the outer *valence shell*.

If the valence shell contains the maximum number of electrons possible the electrons are rigidly bonded together and the material has the properties of an insulator. If, however, the valence shell does not have its full complement of electrons, the electrons can be easily loosened from their orbital bonds, and the material has the properties associated with an electrical conductor.



An isolated silicon atom contains four electrons in its valence shell. When silicon atoms combine to form a solid crystal, each atom positions itself between four other silicon atoms in such a way that the valence shells overlap from one atom to another. This causes each individual valence electron to be shared by two atoms, as shown in Fig. 3.1. By sharing the electrons between four adjacent atoms, each individual silicon atom *appears* to have eight electrons in its valence shell. This sharing of valence electrons is called *covalent bonding*.

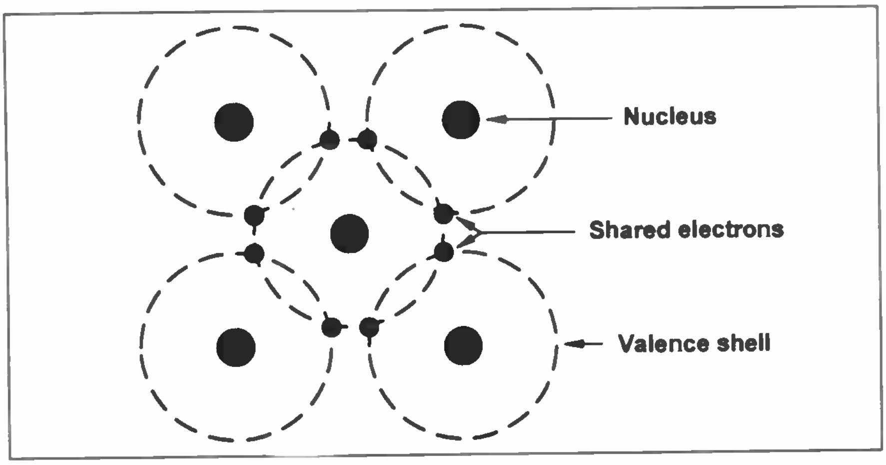


Fig. 3.1 Lattice showing covalent bonding.

In its pure state, silicon is an insulator because the covalent bonding rigidly holds all of the electrons leaving no free (easily loosened) electrons to conduct current. If, however, an atom of a different element (i.e., an *impurity*) is introduced that has five electrons in its valence shell, a surplus electron will be present. These *free electrons* become available for use as *charge carriers* and they can be made to move through the lattice by applying an external potential difference to the material.

Similarly, if the impurity element introduced into the pure silicon lattice has three electrons in its valence shell, the absence of the fourth electron needed for proper covalent bonding will produce a number of spaces into which electrons can fit. These spaces are referred to as *holes*. Once again, current will flow when an external potential difference is applied to the material.

Regardless of whether the impurity element produces surplus electrons or holes, the material will no longer behave as an insulator neither will it have the properties that we normally associate with a metallic conductor. Instead, we call the material a *semiconductor* – the term simply indicates that the substance is no longer a good insulator or a good conductor but is somewhere in between!

The process of introducing an atom of another (impurity) element into the lattice of an otherwise pure material is called *doping*. When the pure material is been doped with an impurity with five electrons in its valence shell (i.e., a *pentavalent impurity*) it will become an *n-type* material. If, however, the pure material is doped with an impurity having three electrons in its valence shell (i.e., a *trivalent impurity*) it will become *p-type* material. *N*-type semiconductor material contains an excess of negative charge carriers, and *p*-type material contains an excess of positive charge carriers.

DIODES

When a junction is formed between *n*-type and *p*-type semiconductor materials, the resulting device is called a diode. This component offers an extremely low resistance to current flow in one direction and an extremely high resistance to current flow in the other. This characteristic allows the diode to be used in applications that require a circuit to behave differently according to the direction of current flowing in it.

An ideal diode would pass an infinite current in one direction and no current at all in the other direction. In addition, the diode would start to conduct current when the smallest of voltages was present. In practice, a small voltage must be applied before conduction takes place. Furthermore a small *leakage current* will flow in the "reverse"

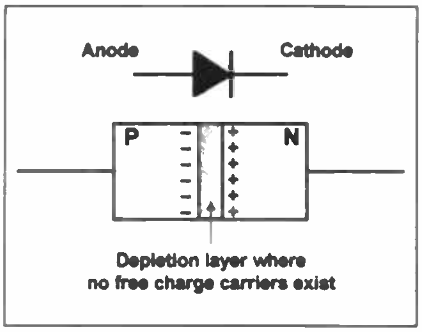


Fig. 3.2 P-N *junction diode.*

direction. This leakage current is usually a very small fraction of the current that flows in the "forward" direction.

If the *p*-type semiconductor material is made positive relative to the *n*-type material by an amount greater than its *forward threshold voltage* (about 0·7V if the material is silicon and 0·2V if the material is germanium), the diode will freely pass current. If, on the other hand, the *p*-type material is made negative relative to the *n*-type material, virtually no current will flow unless the applied voltage exceeds the maximum (breakdown) voltage that the device can withstand. Note that a normal diode will be destroyed if its *reverse breakdown voltage* is exceeded.

A semiconductor junction diode is shown in Fig. 3.2. The connection to the *p*-type material is referred to as the *anode* whilst that to the *n*-type material is called the *cathode*. With no externally applied potential, electrons from the *n*-type material will cross into the *p*-type region and fill some of the vacant holes. This action will result in the production of a region either side of the junction in which there are no free charge carriers. This zone is known as the *depletion region*.

A junction diode in which the anode is made positive with respect to the cathode is shown in Fig. 3.3. In this *forward-biased* condition, the diode freely passes current. A diode with the cathode made positive with respect to the anode is shown in Fig. 3.4. In this *reverse-biased* condition, the diode passes a negligible amount of current. In the freely conducting forward-biased state, the diode acts rather like a closed switch. In the reverse-biased state, the diode acts like an open switch.

If a positive voltage is applied to the *p*-type material, the free positive charge carriers will be repelled and they will move away from the positive potential towards the junction. Likewise, the negative potential applied to the *n*-type material will cause the free negative charge carriers to move away from the negative potential towards the junction.

When the positive and negative charge carriers arrive at the junction, they will attract one another and combine (recall that unlike charges attract). As each negative and positive charge carrier combine at the junction, a new negative and positive charge carrier will be introduced to the semiconductor material from the voltage source. As these new charge carriers enter the semiconductor material, they will move toward the junction and combine. Thus, current flow is established and it will continue for as long as the voltage is applied.

As stated earlier, the forward threshold voltage must be exceeded before the diode will conduct. The forward threshold voltage must be high enough to completely remove the depletion layer and force charge carriers to move across the junction. With silicon diodes, this forward threshold voltage is approximately 0·6V to 0·7V. With germanium diodes, the forward threshold voltage is approximately 0·2V to 0·3V.

Typical characteristics for small germanium and silicon diodes are detailed in Fig. 3.5. It is worth noting that diodes are limited by the amount of forward current and reverse voltage they can withstand. This limit is based on the physical size and construction of the diode.

In the case of a reverse biased diode, the *p*-type material is negatively biased relative to the *n*-type material. In this case, the negative potential applied to the *p*-type material

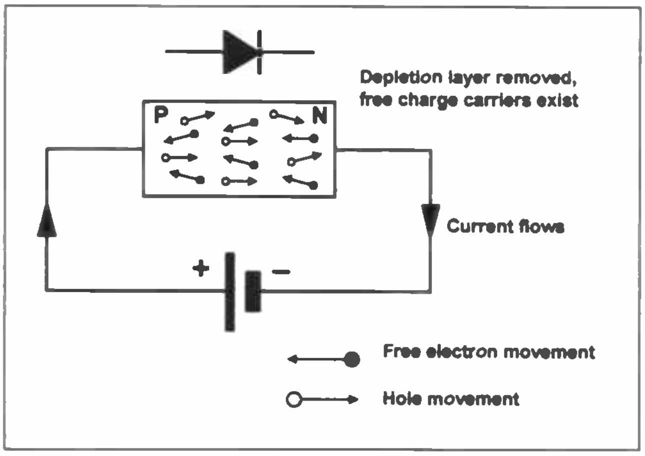


Fig. 3.3 Forward biased P-N *junction.*

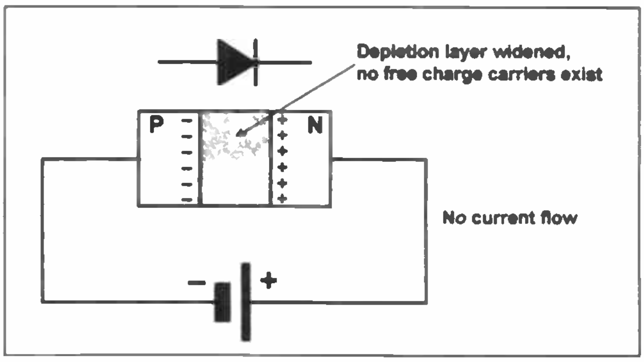


Fig. 3.4 Reverse biased P-N *junction.*

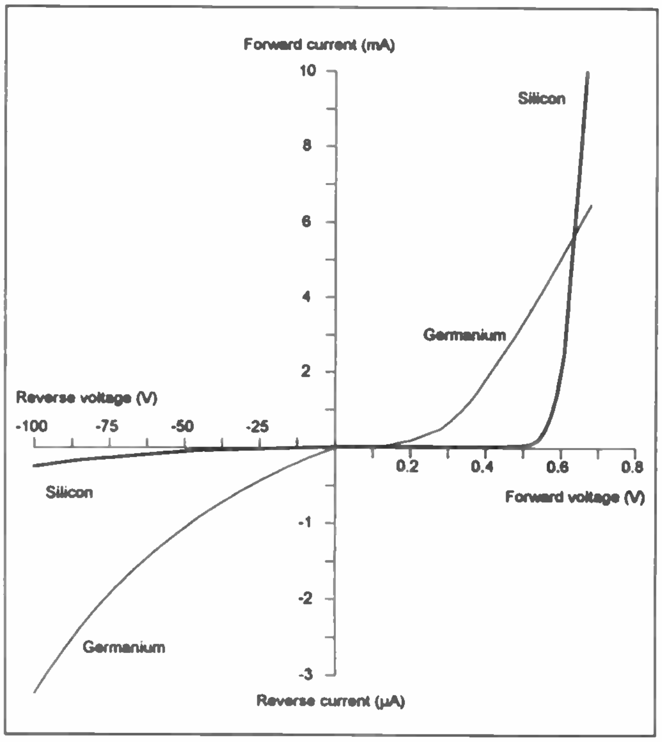


Fig. 3.5 Typical diode characteristics.

attracts the positive charge carriers, drawing them away from the junction. Likewise, the positive potential applied to the *n*-type material attracts the negative charge carriers away from the junction. This leaves the junction area depleted; virtually no charge carriers exist. Therefore, the junction area becomes an insulator, and current flow is inhibited.

The reverse bias potential may be increased to the reverse breakdown voltage for which the particular diode is rated. As in the case of the maximum forward current rating, the reverse breakdown voltage is specified by the manufacturer. The reverse breakdown voltage is usually very much higher than the forward threshold voltage.

A typical general-purpose diode may be specified as having a forward threshold voltage of 0·6V and a reverse breakdown voltage of 200V. If the latter is exceeded, the diode may suffer irreversible damage. It is also worth noting that, where diodes are designed for use as rectifiers, manufacturers often quote peak inverse voltage (p.i.v.) or maximum reverse repetitive voltage rather than maximum reverse breakdown voltage.

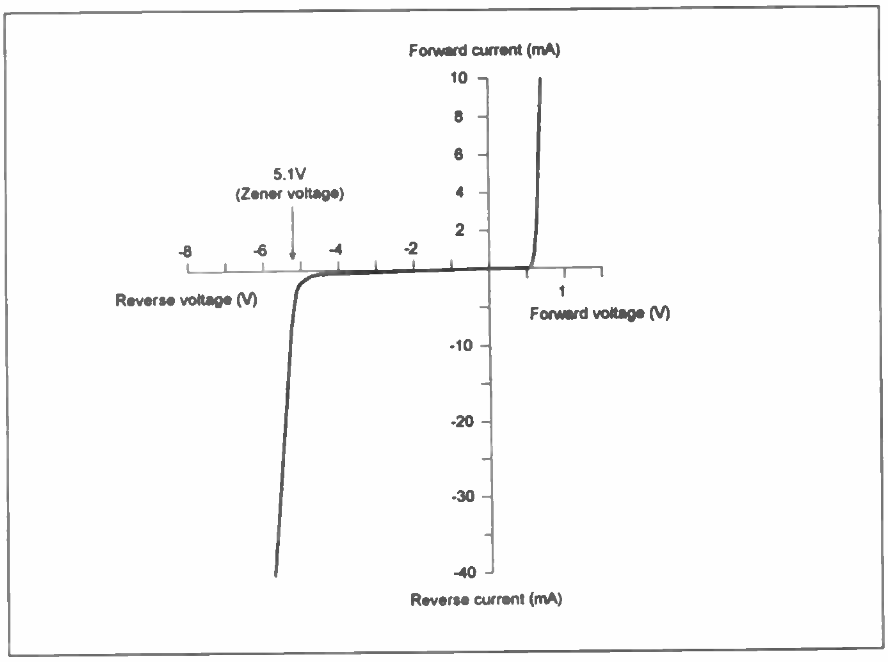


Fig. 3.7 Typical characterstics for a 5·1V Zener diode.

Practical assignment 3.1:
Diode characteristics

In this practical assignment you will investigate the characteristics of a typical silicon diode.

Objectives:

3.1.1 To plot the forward characteristic graph for a silicon diode

3.1.2 To estimate the forward voltage drop for a silicon diode at given values of current

Instructions:

1. Connect the circuit shown in Fig. 3.6 using a 0·6V battery.

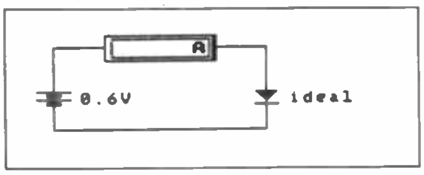


Fig. 3.6. Circuit for Assignment 3.1.

2. Switch on the power to your circuit and measure the current flowing. Record the value of current in Table 3.1.
3. Repeat steps 1 and 2 using battery voltages of 0·625V, 0·65V, 0·675V, 0·7V, 0·725V and 0·75V. Measure and record the current for each value of applied voltage.
4. Use the results from Table 3.1 to plot a graph showing forward current (mA) plotted against applied voltage (V).
5. Use the graph to determine the forward voltage drop for a current of (a) 1mA, (b) 10mA, and (c) 100mA.

Conclusions:

To what extent have the objectives for this assignment been met? Comment on the shape of the graph. Is the shape similar to the one you would expect? If not, why not?

Table 3.1 Measured values for Assignment 3.1

Voltage (V)	0V	0·6V	0·625V	0·65V	0·675V	0·7V	0·725V	0·75V
Current (A)	0							

ZENER DIODES

Zener diodes are heavily doped silicon diodes which, unlike normal diodes, exhibit an abrupt reverse breakdown at relatively low voltages (typically less than 6V). A similar effect occurs in less heavily doped diodes. These *avalanche diodes* also exhibit a rapid breakdown with negligible current flowing below the avalanche voltage and a relatively large current flowing once the avalanche voltage has been reached. For avalanche diodes, this breakdown voltage usually occurs at voltages above 6V. In practice, however, both types of diode are referred to as Zener diodes. A typical characteristic for a 5·1V Zener diode is shown in Fig. 3.7.

Whereas reverse breakdown is a highly undesirable effect in circuits that use conventional diodes, it can be extremely useful in the case of Zener diodes where the breakdown voltage is precisely known. When a diode is undergoing reverse breakdown *and provided its maximum ratings are not exceeded* the voltage appearing across it will remain substantially constant (equal to the nominal Zener voltage) regardless of the current flowing. This property makes the Zener diode ideal for use as a *voltage regulator.*

A simple voltage regulator is shown in Fig. 3.8. Resistor R_S is included to limit the Zener current to a safe value when the load is disconnected. When a load (R_L) is connected, the Zener current (I_Z) will fall as current is diverted into the load resistance. The output voltage (V_O) will remain at the Zener voltage until regulation fails at the point at which the potential divider formed by resistors R_S and R_L produces a lower output voltage that is less than V_Z. The ratio of R_S to R_L is thus important.

As the circuit begins to fail to regulate:

$$V_Z = V_{IN} \times \frac{R_L}{R_L + R_S}$$

where V_{IN} is the unregulated input voltage.

Thus the *maximum* value for R_S can be calculated from:

$$R_S max = R_L \times \left(\frac{V_{IN}}{V_Z} - 1\right)$$

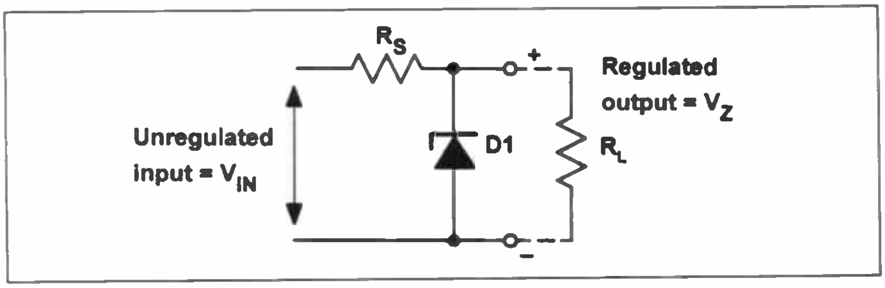


Fig. 3.8 Simple Zener diode voltage regulator circuit.

The power dissipated in the Zener diode, $P_Z = I_Z \times V_Z$, hence the *minimum* value for R_S can be determined from the "off-load" condition when:

$$R_S min = \frac{V_{IN} - V_Z}{I_Z} = \frac{V_{IN} - V_Z}{(P_Z max/V_Z)}$$

$$= \frac{(V_{IN} - V_Z) \times V_Z}{P_Z max}$$

$$\text{thus } R_S\text{min} = \frac{(V_{IN} \times V_Z) - V_Z^2}{P_Z\text{max}}$$

where $P_Z$max is the maximum rated power dissipation for the Zener diode.

Example

A 5V Zener diode has a maximum rated power dissipation of 500mW. If the diode is to be used in a simple regulator circuit to supply a regulated 5V to a load having a resistance of 400Ω, determine a suitable value of series resistor for operation in conjunction with a supply of 9V.

First we should determine the maximum value for R_S:

$$R_S\text{max} = R_L \times \left(\frac{V_{IN}}{V_Z} - 1\right)$$

$$\text{thus } R_S\text{max} = 400\Omega \times \left(\frac{9V}{5V} - 1\right)$$

$$= 400 \times (1{\cdot}8 - 1) = 320\Omega$$

Now to determine the minimum value for R_S:

$$R_S\text{min} = \frac{(V_{IN} \times V_Z) - V_Z^2}{P_Z\text{max}} = \frac{(9 \times 5) - 5^2}{0{\cdot}5}$$

$$= \frac{45 - 25}{0{\cdot}5} = 40\Omega$$

Hence a suitable value for R_S would be 150Ω (roughly mid-way between the two extremes).

Practical assignment 3.2:
Zener diode characteristics

In this practical assignment you will investigate the characteristics of a typical Zener diode.

Objectives:

3.2.1 To plot the characteristic graph for a Zener diode

3.2.2 To estimate the Zener voltage for a Zener diode

Instructions:

1. Connect the circuit shown in Fig. 3.9 using a 4V battery.

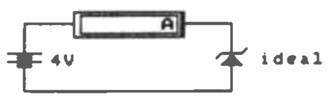


Fig. 3.9 Circuit for Assignment 3.2.

2. Switch on the power to your circuit and measure the current flowing. Record the value of current in Table 3.2.
3. Repeat steps 1 and 2 using battery voltages of 4·25V, 4·5V, 4·75V, 5V, 5·25V, 5·5V. Measure and record the current for each value of applied voltage.
4. Use the results from Table 3.2 to plot a graph showing reverse current (mA) plotted against applied voltage (V).

Table 3.2 Measured values for Assignment 3.2

Voltage (V)	0V	4V	4·25V	4·5V	4·75V	5V	5·25V	5·5V
Current (A)	0							

5. Use the graph to determine the Zener voltage at a nominal reverse current of 50mA.

Conclusions:

To what extent have the objectives for this assignment been met? Comment on the shape of the graph. Is the shape similar to the one you would expect? If not, why not?

RECTIFIERS

Diodes are commonly used to convert alternating current (a.c.) to direct current (d.c.), in which case they are referred to as *rectifiers*. The simplest form of rectifier circuit makes use of a single diode and, since it operates on only either positive or negative half-cycles of the supply, it is known as a *half-wave* rectifier.

The switching action of diode D1 results in a pulsating output voltage which is developed across the load resistor (R_L). Since the mains supply is at 50Hz, the pulses of voltage developed across R_L will also be at 50Hz even if only half the a.c. cycle is present. During the positive half-cycle, the diode will drop the 0·7V forward threshold voltage. However, during the negative half-cycle the peak a.c. voltage will be dropped across D1 when it is reverse biased. This is an important consideration when selecting a diode for a particular application.

Assuming that the secondary winding of transformer T1 provides 12V r.m.s., the peak voltage output from the tranformer's secondary winding will be given by:

$$V_{pk} = 1{\cdot}414 \times V_{r.m.s.} = 1{\cdot}414 \times 12V$$
$$= 16{\cdot}968V$$

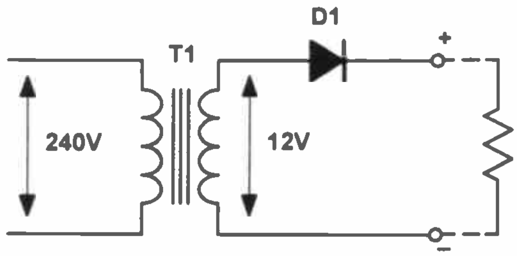


Fig. 3.10 Simple half-wave rectifier circuit.

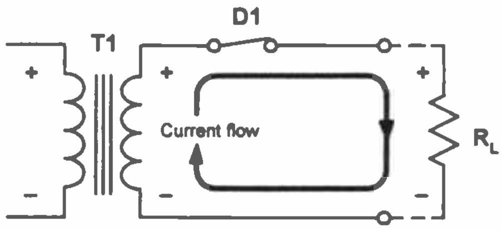


Fig. 3.11a Half-wave rectifier circuit with diode D1 conducting (positive going half cycles of secondary voltage).

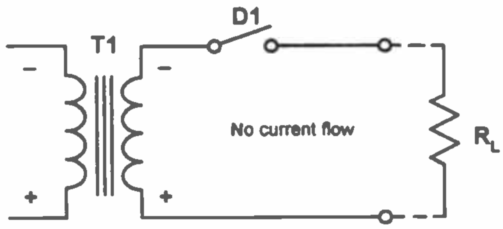


Fig. 3.11b Half-wave rectifier circuit with diode D1 not conducting (negative going half cycles of secondary voltage).

Fig. 3.10 shows a simple half-wave rectifier circuit. Mains voltage (240V) is applied to the primary winding of a stepdown transformer (T1). The secondary winding of T1 steps down the 240V r.m.s. to 12V r.m.s. (the turns ratio of T1 will thus be 240/12 or 20:1). Diode D1 will only allow the current to flow in the direction shown (i.e., from anode to cathode). Diode D1 will be forward-biased during each positive half-cycle (relative to common) and will effectively behave like a closed switch. When the circuit current tries to flow in the opposite direction, the voltage bias across the diode will be reversed, causing the diode to act like an open switch (see Fig. 3.11a and Fig. 3.11b respectively).

The peak voltage applied to diode D1 will thus be approximately 17V. The negative half-cycles are blocked by D1 and thus only the positive half-cycles appear across resistor R_L. Note, however, that the actual peak voltage across R_L will be the 17V positive peak being supplied from the secondary on T1, *minus* the 0·7V forward threshold voltage dropped by D1. In other words, positive half-cycle pulses having a peak amplitude of 16·3V will appear across resistor R_L.

Fig. 3.12 shows a considerable improvement to the circuit of Fig. 3.10. The capacitor, C1, has been added to ensure that the output voltage remains at, or near, the peak voltage even when the diode is not conducting. When the primary voltage is first applied to transformer T1, the first positive half-cycle output from the secondary will charge C1 to the peak value seen across R_L. Hence C1 charges to 16·3V at the peak of the positive half-cycle. Because C1 and R_L are in parallel, the voltage across R_L will be the same as that across C1.

The time required for capacitor C1 to charge to the maximum (peak) level is determined by the charging circuit time

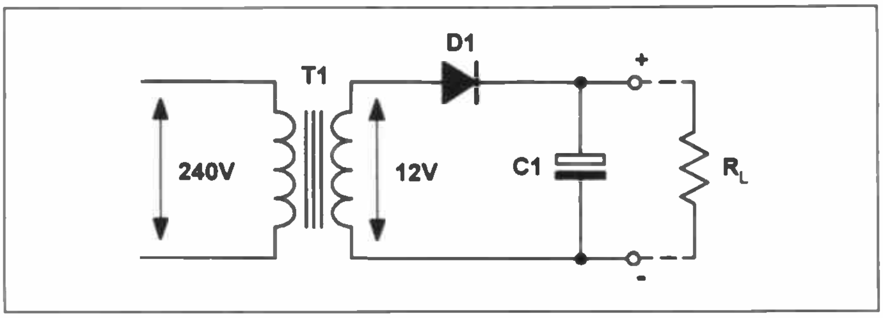


Fig. 3.12 Half-wave rectifier with reservoir capacitor.

constant (the series resistance multiplied by the capacitance value). In this circuit, the series resistance comprises the secondary winding resistance together with the forward resistance of the diode and the (minimal) resistance of the wiring and connections. Hence C1 charges very rapidly as soon as diode D1 starts to conduct.

The time required for capacitor C1 to discharge is, in contrast, very much greater. The discharge time constant is determined by the capacitance value and the load resistance, R_L. In practice, R_L is very much larger than the resistance of the secondary circuit and hence C1 takes an appreciable time to discharge. During this time, diode D1 will be reverse biased and will thus be held in its non-conducting state. As a consequence, the only discharge path for C1 is through R_L.

Capacitor C1 is referred to as a *reservoir* capacitor. It stores charge during the positive half-cycles of secondary voltage and releases it during the negative half-cycles. The circuit in Fig. 3.12 is thus able to maintain a reasonably constant output voltage across R_L. Even so, C1 will discharge by a small amount during the negative half-cycle periods from the transformer secondary. Fig. 3.13 shows the secondary voltage waveform together with the voltage developed across R_L with, and without C1 present. This gives rise to a small variation in the d.c. output voltage (known as *ripple*), as shown in Fig. 3.13.

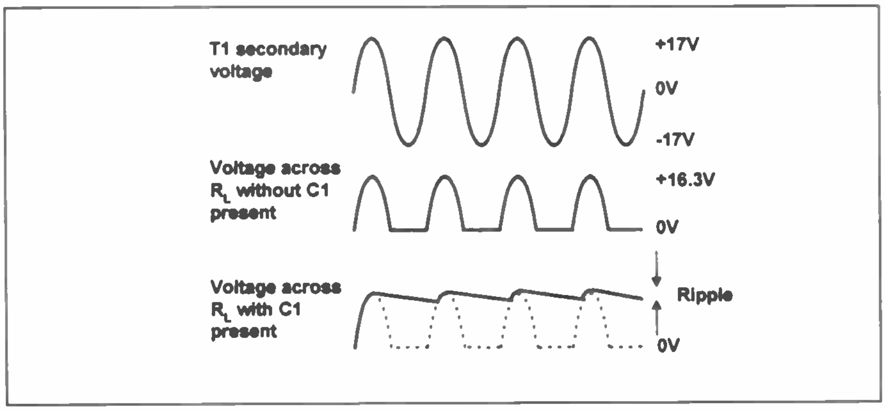


Fig. 3.13 Waveforms for half-wave rectifier circuits.

Since ripple is undesirable we must take additional precautions to reduce it. One obvious method of reducing the amplitude of the ripple is that of simply increasing the discharge time constant. This can be achieved either by increasing the value of capacitor C1 or by increasing the resistance value of R_L. In practice, however, the latter is not really an option because R_L is the effective resistance of the circuit being supplied and we don't usually have the ability to change it! Increasing the value of C1 is a more practical alternative and very large capacitor values (often in excess of 4700µF are typical).

A further refinement of the simple power supply circuit is shown in Fig. 3.14. This circuit employs two additional components, resistor R1 and capacitor C2, which act as a filter to remove the ripple. The value of C2 is chosen so that the component exhibits a negligible reactance at the ripple frequency (normally 50Hz). In effect, this circuit acts like a potential divider. The amount of ripple is reduced by a factor equal to:

$$\frac{X_C}{\sqrt{(R1^2 + X_C^2)}}$$

Example

The R-C smoothing filter in a 50Hz mains operated half-wave rectifier circuit consists of R1 = 100Ω and C2 = 1000µF. If 1V of ripple appears at the input of the circuit, determine the amount of ripple appearing at the output.

First we must determine the reactance of the capacitor, C2, at the ripple frequency from:

$$X_C = \frac{1}{2\pi f C} = \frac{1}{6{\cdot}28 \times 50 \times 1000 \times 10^{-6}}$$

$$= \frac{1000}{6{\cdot}28 \times 50} = \frac{1000}{314}$$

Thus $X_C = 3{\cdot}18\Omega$

The amount of ripple at the output of the circuit (i.e., appearing across capacitor C2) will be given by:

$$V_{ripple} = 1V \times \frac{X_C}{\sqrt{(R1^2 + X_C^2)}}$$

$$= 1V \times \frac{3{\cdot}18}{\sqrt{(100^2 + 3{\cdot}18^2)}}$$

$$= 0.032V = 32mV$$

A further improvement can be achieved by using an inductor (L1) instead of a resistor (R1) in the smoothing circuit. This circuit also offers the advantage that the minimum d.c. voltage is dropped across the inductor (in the circuit of Fig. 3.14, the d.c.

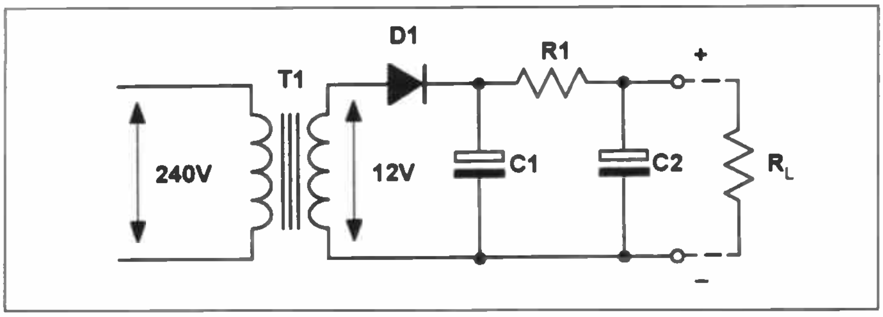


Fig. 3.14 Half-wave rectifier with R-C smoothing circuit.

output voltage is reduced by an amount equal to the voltage drop across R1).

The circuit of a half-wave power supply using L-C smoothing is shown in Fig. 3.15. At the ripple frequency, L1 exhibits a high value of inductive reactance whilst C1 exhibits a low value of capacitive reactance. The combined effect is that of an attenuator which greatly reduces the amplitude of the ripple whilst having a negligible effect on the direct voltage.

Example

The L-C smoothing filter in a 50Hz mains operated half-wave rectifier circuit consists of L1 = 10H and C2 = 1000µF. If 1V of ripple appears at the input of the circuit, determine the amount of ripple appearing at the output.

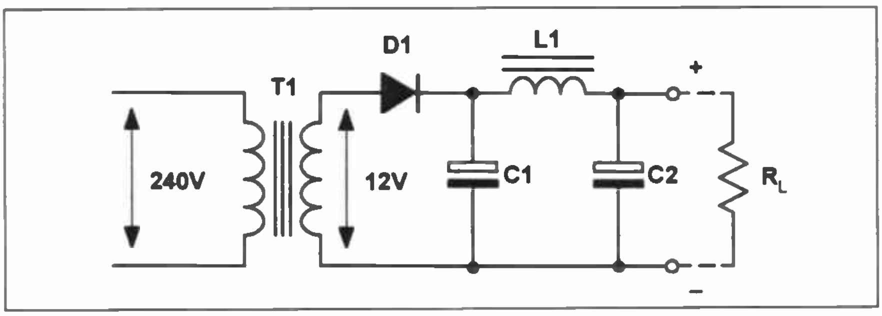


Fig. 3.15 Half-wave rectifier with L-C smoothing circuit.

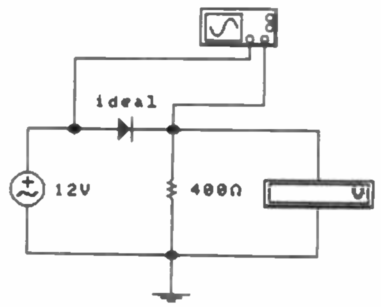


Fig. 3.16 Circuit for Assignment 3.3.

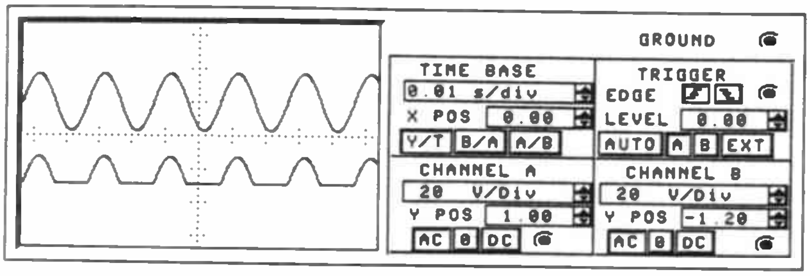


Fig. 3.17 Initial oscilloscope settings for Assignment 3.3

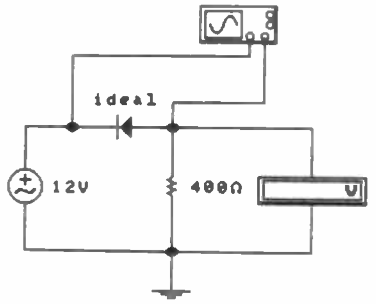


Fig. 3.18 Circuit of Fig. 3.16 modified for negative output.

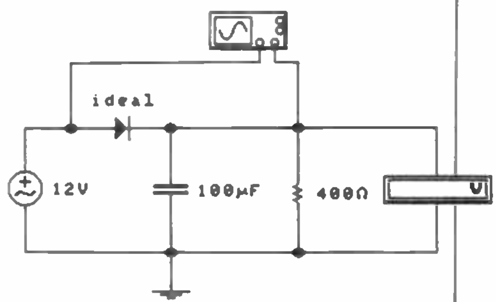


Fig. 3.19 Half-wave rectifier with reservoir capacitor (Assignment 3.3).

Once again, the reactance of the capacitor, C2, is 3·18Ω (see previous example).

The reactance of inductor L1 at 50Hz can be calculated from:

$$X_L = 2\pi f L = 2 \times 3{\cdot}14 \times 50 \times 10$$
$$= 3140\Omega$$

The amount of ripple at the output of the circuit (i.e., appearing across C2) will be given by:

$$V_{ripple} = 1V \times \frac{X_C}{\sqrt{(X_L^2 + X_C^2)}}$$
$$= 1V \times \frac{3{\cdot}18}{\sqrt{(3140^2 + 3{\cdot}18^2)}}$$
$$= 0{\cdot}001V = 1mV$$

It is worth comparing this value with that obtained from the previous example!

Practical assignment 3.3:
Half-wave rectifiers

In this assignment you will investigate the behaviour of half-wave rectifier circuits. You will also investigate the operation of simple smoothing and Zener diode regulator circuits.

Objectives:

3.3.1 To investigate the action of a half-wave rectifier.
3.3.2 To use an oscilloscope to obtain waveforms for a half-wave rectifier.
3.3.3 To determine the effectiveness of an R-C smoothing circuit.
3.3.4 To investigate the action of a simple Zener diode regulator.

Instructions:

1. Connect the circuit shown in Fig. 3.16. The 400Ω resistor is used to simulate the load that would normally be connected to the power supply.
2. Display the input and output waveforms on the screen of the oscilloscope (see Fig. 3.17 for recommended initial settings for the oscilloscope front-panel). Note the shape of the output waveform (you might like to make a sketch of it) and measure its peak-peak voltage using the vertical scale.
3. Reverse the diode connections (see Fig. 3.18). Repeat step 1 and note the difference in the output waveform (once again, you might like to make a sketch of it). Measure the peak-peak voltage and check this is the same as before.
4. Reconnect the circuit as shown in Fig. 3.16. Connect the voltmeter across the 400Ω resistor in order to measure the output voltage. Record the measured value of the d.c. output voltage and the peak-peak ripple voltage (measured with the oscilloscope) in Table 3. 3.
5. Now add a 100µF smoothing capacitor (Fig. 3.19). Once again display the input and output waveforms. Note the shape of the output waveform. As before, record the measured value of d.c. output voltage and the peak-peak ripple voltage measured with the oscilloscope.
6. Replace the 100µF capacitor with a 470µF capacitor and repeat step 5.
7. Next, add an R-C filter to the circuit by connecting a 100Ω resistor in series with the d.c. output from the rectifier and a second 470µF capacitor in parallel with the output (as in Fig. 3.20). Once again, note the shape of the output waveform and record the measured value of d.c. output voltage and the peak-peak ripple voltage.
8. Finally, add a 5·1V Zener diode in order to regulate the output voltage (see Fig. 3.21). Record the measured value of output voltage and peak-peak ripple voltage.

Conclusions:

To what extent have the objectives for this assignment been met? Can you explain, in your own words, how each part of the circuit works? (Hint: divide the circuit into three parts; the diode rectifier, the smoothing circuit, and the Zener diode regulator). Can you explain why the d.c.

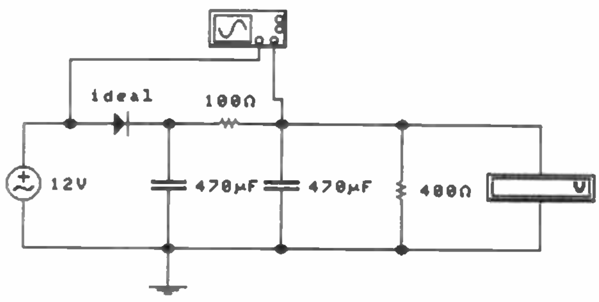


Fig. 3.20 Half-wave rectifier with smoothing filter.

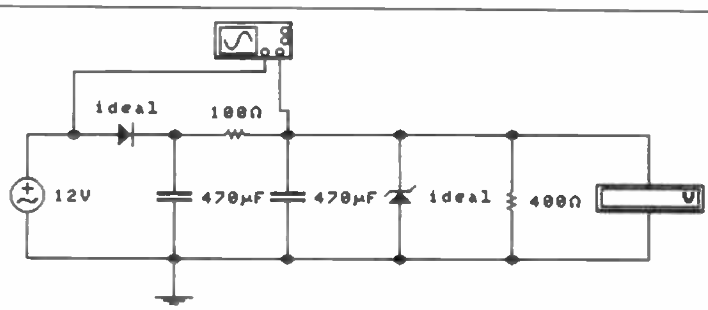


Fig. 3.21 Half-wave rectifier with smoothing filter and Zener diode regulator (Assignment 3.3).

Table 3.3 Measured values for Assignment 3.3.

Circuit under investigation	Measured voltage output	Measured voltage ripple
No reservoir capacitor (step 4)		
100μF reservoir capacitor (step 5)		
470μF reservoir capacitor (step 6)		
470μ reservoir plus 100Ω and 470μ smoothing filter (step 7)		
As above but with Zener diode regulator (step 8)		

output voltage was increased when the reservoir capacitor was fitted? Which circuit was most effective at removing the ripple? Why? Was the output voltage what you would have predicted? If not, why not?

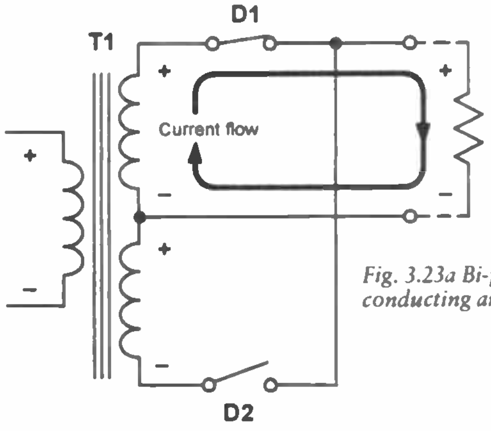


Fig. 3.23a Bi-phase rectifier with diode D1 conducting and D2 non-conducting.

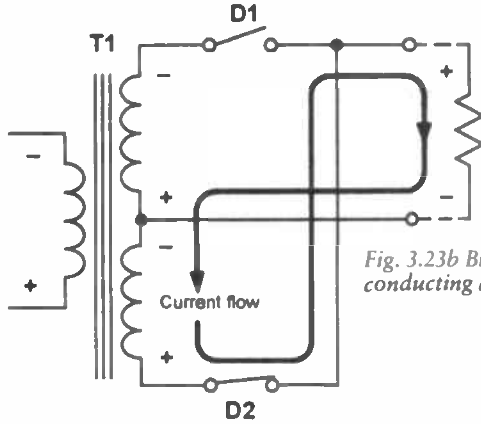


Fig. 3.23b Bi-phase rectifier with diode D2 conducting and D1 non-conducting.

FULL-WAVE RECTIFIERS

The half-wave rectifier circuit is relatively inefficient as conduction takes place only on alternate half-cycles. A better rectifier arrangement would make use of both positive *and* negative half-cycles. These full-wave rectifier circuits offer a considerable improvement over their half-wave counterparts. They are not only more efficient but are significantly less demanding in terms of the reservoir and smoothing components. There are two basic forms of full-wave rectifier; the bi-phase type and the bridge rectifier type.

BI-PHASE RECTIFIERS

A simple bi-phase rectifier circuit is shown in Fig. 3.22. Mains voltage (240V) is applied to the primary winding of a stepdown transformer (T1) which has two identical secondary windings, each providing 12V r.m.s. (the turns ratio of T1 will thus be 240/12 or 20:1 for *each* secondary winding).

On positive half-cycles, point A will be positive with respect to point B. Similarly, point B will be positive with respect to point C. In this condition diode D1 will allow conduction (its anode will be positive with respect to its cathode) whilst diode D2 will not allow conduction (its anode will be negative with respect to its cathode). Thus diode D1 alone conducts on positive half-cycles.

On negative half-cycles, point C will be positive with respect to point B. Similarly, point B will be positive with respect to point A. In this condition diode D2 will allow conduction (its anode will be positive with respect to its cathode) whilst diode D1 will not allow conduction (its anode will be negative with respect to its cathode). Thus diode D2 alone conducts on negative half-cycles.

The bi-phase rectifier circuit in Fig. 3.23 shows the diodes of Fig. 3.22 replaced by switches. In Fig. 3.23a diode D1 is shown conducting on a positive half-cycle whilst in Fig. 3.23b diode D2 is shown conducting. The result is that current is routed through the load *in the same direction* on successive half-cycles. Furthermore, this current is derived alternately from the two secondary windings.

As with the half-wave rectifier, the switching action of the two diodes results in a pulsating output voltage being developed across the load resistor (R_L). However, unlike the half-wave circuit the pulses of voltage developed across R_L will occur at a frequency of 100Hz (not 50Hz). This doubling of the ripple frequency allows us to use smaller values of reservoir and smoothing capacitor to obtain the same degree of

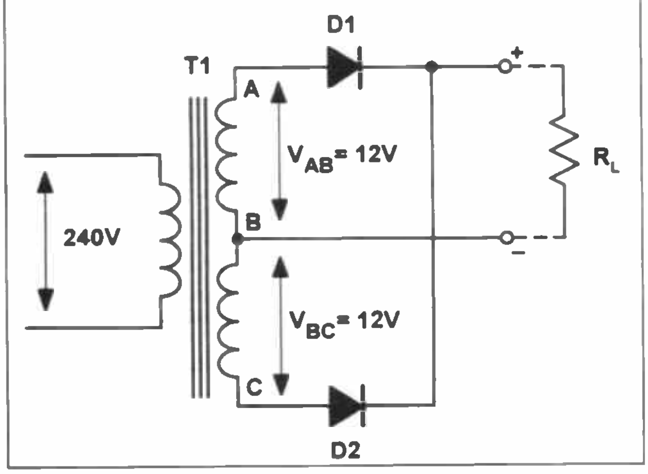


Fig. 3.22 Bi-phase rectifier.

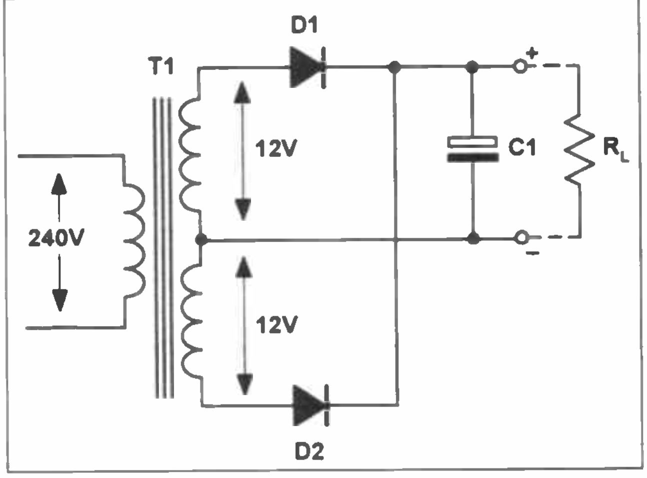


Fig. 3.24 Bi-phase rectifier with reservoir capacitor.

ripple reduction (recall that the reactance of a capacitor is reduced as frequency increases).

As before, the peak voltage produced by each of the secondary windings will be approximately 17V and the peak voltage across R_L will be 16·3V (i.e., 17V less the forward threshold voltage of about 0·6V to 0·7V dropped by the diodes).

Fig. 3.24 shows how a reservoir capacitor (C1) can be added to ensure that the output voltage remains at, or near, the peak voltage even when the diodes are not conducting. This component operates in exactly the same way as for the half-wave circuit, i.e., it charges to approximately 16.3V at the peak of the positive half-cycle and holds the voltage at this level when the diodes are in their non-conducting states.

The time required for capacitor C1 to charge to the maximum (peak) level is determined by the charging circuit time constant (the series resistance multiplied by the capacitance value). In this circuit, the series resistance comprises the secondary winding resistance together with the forward resistance of the diode and the (minimal) resistance of the wiring and connections. Hence capacitor C1 charges very rapidly as soon as either diode D1 or diode D2 starts to conduct.

The time required for capacitor C1 to discharge is, in contrast, very much greater. The discharge time constant is determined by the capacitance value and the load resistance, R_L. In practice, R_L is very much larger than the resistance of the secondary circuit and hence capacitor C1 takes an appreciable time to discharge. During this time, diode D1 and diode D2 will be reverse biased and held in a non-conducting state. As a consequence, the only discharge path for capacitor C1 is through R_L. Voltage waveforms for the bi-phase rectifier, with and without C1 present, are shown in Fig. 3.25.

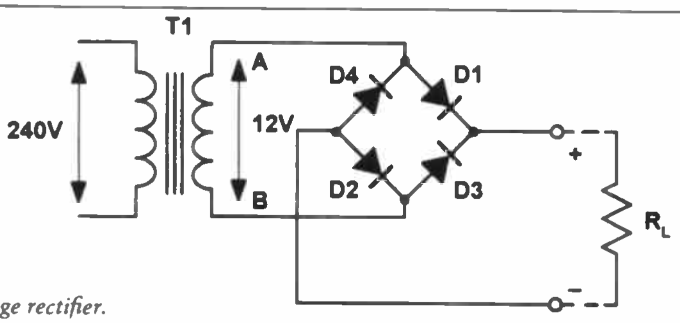


Fig. 3.26 Bridge rectifier.

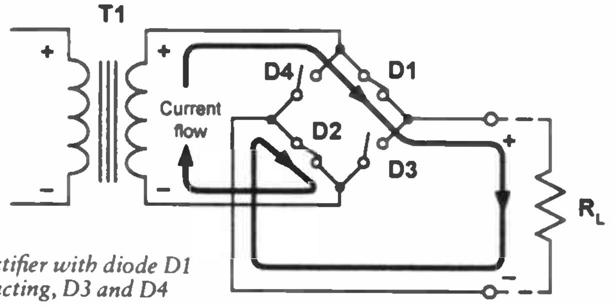


Fig. 3.27a Bridge rectifier with diode D1 and diode D2 conducting, D3 and D4 non-conducting.

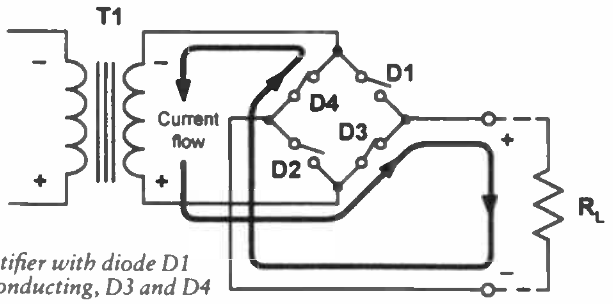


Fig. 3.27b Bridge rectifier with diode D1 and diode D2 non-conducting, D3 and D4 conducting.

BRIDGE RECTIFIERS

An alternative to the use of the bi-phase circuit is that of using a four-diode bridge rectifier (see Fig. 3.26) in which opposite pairs of diode conduct on alternate half-cycles. This arrangement avoids the need to have two separate secondary windings.

Mains voltage (240V) is applied to the primary winding of a stepdown transformer (T1). The secondary winding provides 12V r.m.s. (approximately 17V peak) and has a turns ratio of 20:1, as before. On positive half-cycles, point A will be positive with respect to point B. In this condition diodes D1 and D2 will allow conduction whilst diodes D3 and D4 will not allow conduction. Conversely, on negative half-cycles, point B will be positive with respect to point A. In this condition diodes D3 and D4 will allow conduction whilst diodes D1 and D2 will not allow conduction.

The bridge rectifier circuit in Fig. 3.27 shows the diodes of Fig. 3.26 replaced by switches. In Fig. 3.27a diodes D1 and D2 are conducting on a positive half-cycle whilst in Fig. 3.27b diodes D3 and D4 are conducting. Once again, the result is that current is routed through the load *in the same direction* on successive half-cycles.

As with the bi-phase rectifier, the switching action of the two diodes results in a pulsating output voltage being developed across the load resistor (R_L). Once again, the peak output voltage is approximately 16·3V (i.e., 17V less the 0·7V forward threshold voltage).

Fig. 3.28 shows how a reservoir capacitor (C1) can be added to ensure that the output voltage remains at, or near, the peak voltage even when the diodes are not conducting. This component operates in exactly the same way as for the bi-phase circuit, i.e., it charges to approximately 16·3V at the peak of the positive half-cycle and holds the voltage at this level when the diodes are in their non-conducting states. This component operates in exactly the same was as for the bi-phase circuit and the voltage waveforms are identical to those shown in Fig. 3.25.

Finally, R-C and L-C smoothing circuits can be added to both the bi-phase and bridge rectifier circuits in exactly the same manner as those shown for the half-wave rectifier arrangement (see Fig. 3.14 and Fig. 3.15).

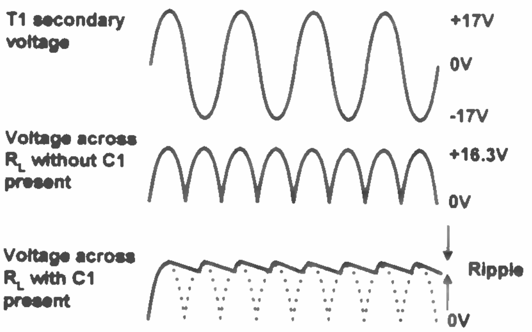


Fig. 3.25 Waveforms for the bi-phase rectifier.

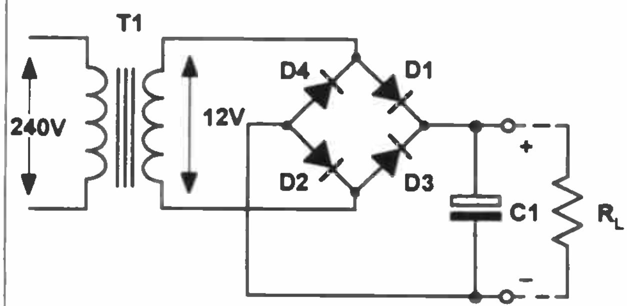


Fig. 3.28 Bridge rectifier with reservoir capacitor.

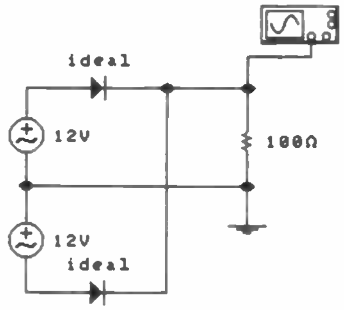


Fig. 3.29 Bi-phase rectifier circuit for Assignment 3.4.

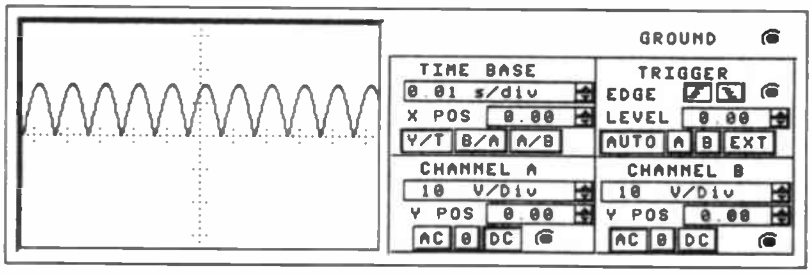


Fig. 3.30 Initial oscilloscope settings for Assignment 3.4.

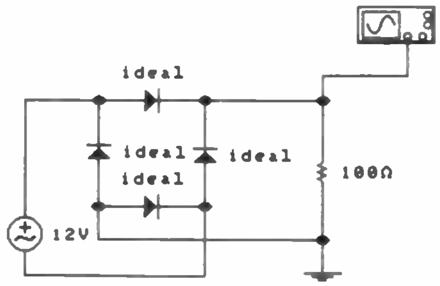


Fig. 3.31 Bridge rectifier circuit for Assignment 3.4.

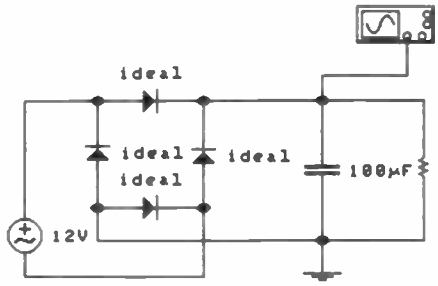


Fig. 3.32 Bridge rectifier with reservoir capacitor (Assignment 3.4).

Practical assignment 3.4:
Full-wave rectifiers

In this assignment you will investigate the behaviour of bi-phase and bridge rectifier circuits.

Objectives:

3.3.1 To investigate the action of full-wave rectifiers (both bi-phase and bridge types).

3.3.2 To use an oscilloscope to obtain waveforms for full-wave rectifiers (both bi-phase and bridge types).

3.3.3 To compare the effectiveness of R-C and L-C smoothing filters.

Instructions:

1. Connect the bi-phase rectifier circuit shown in Fig. 3.29. The 100Ω resistor is used to simulate the load that would normally be connected to the power supply. Note that this is a lower value of resistance (and thus a more severe load) than we used for the half-wave rectifier circuit. Note also that the transformer secondary windings are represented by two 12V 50Hz a.c. voltage sources.
2. Display the output waveform on the screen of the oscilloscope (see Fig. 3.30 for recommended initial settings for the oscilloscope front-panel). Note the shape of the output waveform (you might like to make a sketch of it) and measure its peak-peak voltage using the vertical scale. Record this measured value in Table 3.4.
3. Connect the bridge rectifier circuit shown in Fig. 3.31. Once again, the 100Ω resistor is used to simulate the load that would normally be connected to the power supply. This time you will only need a single 12V 50Hz a.c. voltage source.
4. Repeat step 2 (this time for the bridge rectifier).
5. Add a 100μF smoothing capacitor to the output of the bridge rectifier (as in Fig. 3.32). Once again display the output waveform and note its shape. Record the peak-peak ripple voltage in Table 3.4.
6. Replace the 100μF capacitor with a 470μF capacitor and repeat step 5.
7. Next, add an R-C filter to the circuit by connecting a 400Ω resistor in series with the d.c. output from the bridge rectifier and a second 470μF capacitor in parallel with the output (Fig. 3.33). Once again, note the shape of the output waveform and record the peak-peak ripple voltage in Table 3.4.
8. Finally, modify the filter circuit by replacing the 400Ω resistor with a 10H inductor (as in Fig. 3.34). Once again, note the shape of the output waveform and record the peak-peak ripple voltage in Table 3.4.

Conclusions:

To what extent have the objectives for this assignment been met? Can you explain, in your own words, how each part of the circuit works? Did the two rectifier circuits produce identical output waveforms? If not, why not? Which smoothing circuit (R-C or L-C) was most effective at reducing the ripple? Why? Can you suggest another advantage of the L-C filter when compared with the R-C filter?

BRAIN TEASER

This month's challenge for those of you who are using the full *Electronics Workbench* package is to design a full-wave power supply that provides equal but opposite output voltages with a common earth (0V) connection. The circuit is to incorporate smoothing and each output voltage is to be stabilised using a parallel-connected 5V Zener diode. Use *Electronics Workbench* to test your circuit and check that it works correctly!

Answer to last month's Brain Teaser

Each branch of the circuit will produce a phase shift. Since the component values

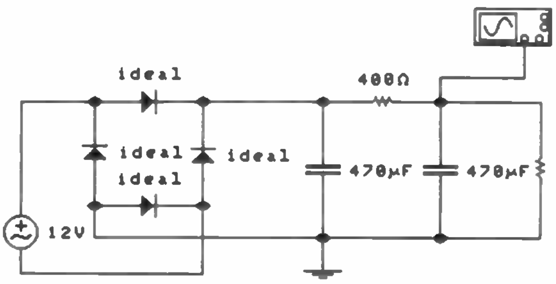


Fig. 3.33 Bridge rectifier with R-C smoothing filter.

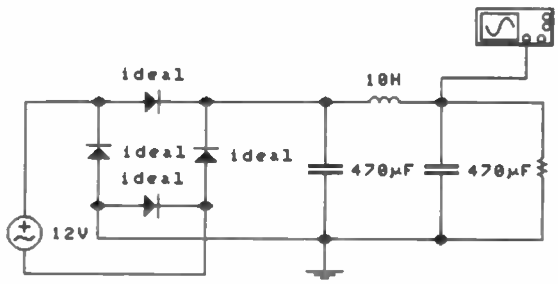


Fig. 3.34 Bridge rectifier with L-C smoothing filter.

Table 3.4 Measured values for Assignment 3.4.

Circuit under investigation	Measured ripple voltage
Bi-phase circuit without reservoir capacitor (step 2)	
Bridge circuit without reservoir capacitor (step 4)	
100μF reservoir capacitor (step 6)	
470μF reservoir capacitor (step 6)	
470μF reservoir plus 400Ω and 470μF smoothing filter (step 7)	
470μF reservoir plus 10H and 470μF smoothing filter (step 8)	

(1kΩ and 1μF) are identical but interchanged, an equal but opposite phase shift will be produced in the two branches. Thus, a 90° phase shift between A and B will be produced when each branch gives a phase shift of 45°.

The phase shift produced by a C-R circuit is given by:

$$\tan\theta = \frac{X_C}{R} = \frac{1/(2\pi f C)}{R} = \frac{1}{2\pi f C R}$$

Hence:

$$f = \frac{1}{2\pi C R \tan\theta}$$

Now when $\theta = 45°$, $\tan 45° = 1$ thus:

$$f = \frac{1}{2\pi C R}$$

$$= \frac{1}{6{\cdot}28 \times 1 \times 10^{-6} \times 1 \times 10^{3}}$$

$$= \frac{1000}{6{\cdot}28} = 159\text{Hz}$$

An easier way to solve the problem is to remember that a 45° phase shift will be produced at the frequency that makes $X_C = R$ (i.e., when the reactance is equal to the resistance). We can then say that:

$$X_C = R \text{ thus } \frac{1}{2\pi f C} = R \text{ or } f = \frac{1}{2\pi C R}$$

as before.

IMPORTANT NOTE:

If you have any problems installing *Electronics Workbench* please note the following points:

1. If you receive a "Mouse not installed" error message please ensure that you are using a Microsoft compatible mouse driver.
2. If you receive an "Incorrect registration" or "Access denied" error message please increase the FILES command in your CONFIG.SYS file by 20 (i.e., if the current setting of FILES is 20 you should increase FILES to 40).
3. If you receive a "Graphics card not recognized" error message and you are using an EGA monitor, you should edit the file EWB.OPT (using an ASCII text editor) and change the line "DISPLAY; VGA" to read "DISPLAY; EGA".

CORRECTION

In *Electronics from the Ground Up* Part 2 last month (*EPE* November 1994), at the bottom left of page 864, the capacitive reactance formula for X_C should read:

$$X_C = \frac{1}{2\pi f C} = \frac{1}{6{\cdot}28 \times 2 \times 10^{3} \times 10 \times 10^{-9}}$$

Techniques

ACTUALLY DOING IT!

by Robert Penfold

MOST hobbies are to some degree seasonal, and electronic project construction is no exception. No doubt there are many who follow the hobby all-year round, but for most it is a pastime that is pursued more avidly in the winter months.

By the time this piece gets into print we should be well under way with a new season of project building, and many potential "new recruits" will presumably be contemplating the construction of their first project. This inevitably gives rise to the question, "what is the minimum I need in order to get started?"

TOOLS FOR THE JOB

Even if you are in the fortunate position of having plenty of spare cash, it is probably not worthwhile going out and buying every tool and gadget you see. You will almost certainly end up wasting a lot of money on implements that you will rarely (if ever) use. It is much better to start with a fairly basic toolkit, and then add to it as and when the need arises. Start by building a couple of simple and straightforward projects from recent issues of *EPE*. It should be possible to construct these using just a few basic tools.

A lot of the tools you will require are the type of thing that is to be found in the average household toolbox anyway. These include such things as pliers, a hacksaw or junior hacksaw, screwdrivers, a centre punch, hammer, files, a hand or power drill, and a set of twist drill bits.

Some of these may not be ideally suited to electronic project building, which is mainly a small scale affair. For example, large screwdrivers are of no use when you need to tighten the tiny grubscrew in a control knob. If you do not already have a couple of miniature electricians' screwdrivers you will certainly need to add them to your toolkit. The cost should be less than a pound for the two. It is also worth having a small cross-point (Phillips) screwdriver. Again, the cost of one these should be minimal.

Whilst in most cases I advocate purchasing the highest quality tools you can afford, this is not really essential in the case of twist drills. It is mostly soft plastics and aluminium that you will be working with, and even cheap drill bits should have a reasonably long life when used on these materials. If you have a set of HSS (High Speed Steel) drill bits with a good range of sizes from about 2mm to 10mm in diameter these should cover virtually all your needs.

If you have to buy the drill bits it would probably be better to obtain individual drills in the sizes you will need, rather than buying a large set which is likely to contain numerous drills you will never use. I find that the vast majority of project drilling can be handled by these four sizes:

3·3mm – for holes that will take metric M3 or 6BA screws (e.g. mounting circuit boards).

5mm – mounting holes for sub-miniature toggle switches

6·35mm (0·25 inches) – mounting holes for many push button switches, miniature toggle switches, miniature potentiometers, various sockets, etc.

10mm – the standard mounting hole size for potentiometers, rotary switches, and many other controls.

In due course you will probably find the need for several other sizes, but provided you steer clear of unusual switches, sockets, etc., these drills should suffice initially.

Power drills are all right for project work, but I find them a bit awkward to use. When drilling soft materials such as plastics and aluminium there is a tendency for power drills to rip straight through almost instantly in a rather uncontrolled fashion. Particularly when drilling larger holes, there is a definite advantage in using a drill that can be set to a slow speed. These days I rarely use power drills when building projects. My preference is for a heavy duty hand drill for the small and medium sized holes, and a brace for the larger ones.

CLEAN CUT

For holes larger than 10mm in diameter a chassis punch is my preferred tool. A chassis punch is basically just a large nut and bolt, but the nut is also a circular cutting blade. First a hole of suitable diameter for the bolt is drilled. Then the bolt is fitted into the hole, and the nut is fitted onto the bolt and tightened. With the aid of an Allen key the nut is tightened so much that it is forced through the panel, punching a hole on its way. Although this sounds like a very crude way of tackling the problem, it actually produces very high quality results very quickly. Even a well worn chassis punch seems to provide "cleaner" holes than any drill. Although only intended for use with metals such as steel and aluminium, chassis punches seem to work quite well with any non-brittle plastic.

Chassis punches having diameters of 12·5mm and 16mm are very useful for electronics work. These are suitable for punching the mounting holes for larger switches (especially toggle types) and DIN sockets respectively. Unfortunately, chassis punches are relatively expensive, so it is probably not worthwhile buying one unless you really need it, and are likely to go on using it. When only used on aluminium and plastics a chassis punch has an extremely long life, and is not expensive in the long term.

Probably the most useful type of file to have is a large half round type. A small flat type is also more than a little useful. In due course I would recommend buying a set of miniature files (needle files) as these are useful for correcting small errors, making irregular shaped cutouts, etc. An "Abrafile" is a good low cost alternative.

The type of pliers I find most useful are, not surprisingly, electricians' pliers. Virtually any type of pliers will do initially, provided you use them carefully, but it is a good idea to invest in a good pair of electricians' pliers before too long.

HOT STUFF

While a lot of the tools needed for electronic project construction are general purpose tools which you may have already, there are a few which do not form part of the average toolkit. The most obvious of these is the soldering iron. Most electronic component catalogues list a few soldering irons having ratings from about 12W to 50W.

For project construction an iron having a rating of about 17W to 25W is the most suitable. There is no need to bother with expensive temperature controlled irons. Something like an Antex model CS will provide very good results, will only set you back about £10, and (with occasional bit replacement) should last many years.

A soldering iron stand is an essential extra. It provides somewhere safe to keep the hot iron between soldering operations, and it also helps to remove excess heat from the iron during periods of inactivity. A matching stand for your particular soldering iron should cost no more than about £4.

You will also need some solder. Only use a 60 per cent tin/40 per cent lead solder containing a non-corrosive flux. This is listed in most catalogues in two thicknesses, which are 18 and 22 s.w.g. For modern project construction the 22 s.w.g. solder is the easier to use, and it is a good idea to buy a decent sized pack of this, or even a large reel. Buying solder in very small quantities is likely to be rather expensive in the long term, and you will inevitably find that you keep running out when projects are 99 per cent complete! It is useful to have some 18 s.w.g. solder for larger joints, such as when wiring-up controls and sockets, but you can get by without it.

It is possible to buy soldering kits which consist of an iron, a matching stand, some solder, and a booklet on soldering techniques. At about £14 these offer good value for money, and are ideal for beginners.

A SNIP

Wire cutters and insulation strippers are tools that should be regarded as essential items. It is possible to improvise using scissors or a modelling knife, but the end result is usually a minor disaster. Scissors will soon be ruined if you cut wire with them. Also, they are simply too large and clumsy for a lot of wire cutting work.

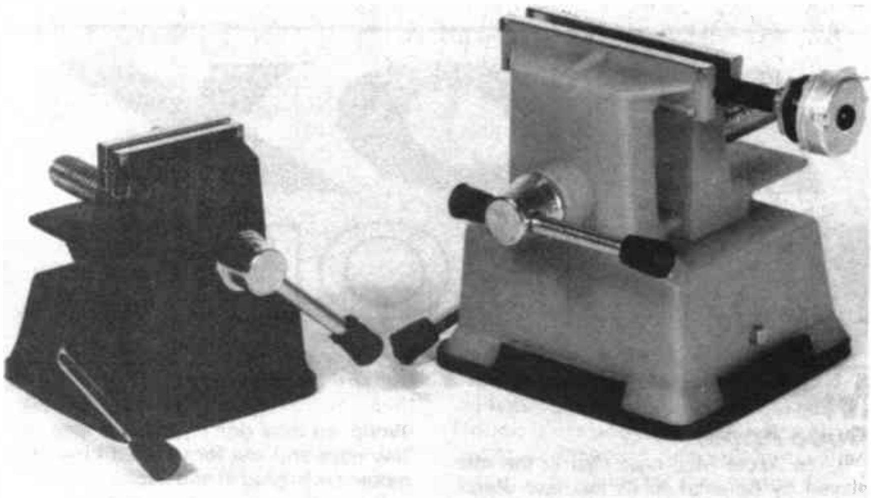
Using a knife is likely to almost instantly ruin the blade, and there is a strong risk of cutting yourself. With both methods it is likely that the wire core or cores will be nicked and seriously weakened. Even with only a small amount of flexing the wire will almost certainly break.

A pair of combination wire strippers and cutters should only cost a pound or three, and can be adjusted so that they will not cut so deeply that the wire becomes damaged. I find that these combination tools are very good as wire strippers, and I actually prefer them to expensive wire stripping tools. As wire cutters they are perhaps less than ideal, but they are more than good enough to get you started.

In due course I would recommend purchasing a pair of "side cutters". Although miniature cutters might seem to be the most apposite for modern electronic work, I find a relatively substantial pair of six inch cutters much easier to use.

THE REST

In due course you will certainly need to add to your toolkit, but initially only a few other odds and ends are required. If your nails are cut (or bitten!) quite short you will probably find it very difficult to pick up small pieces of wire, and the smaller components such as resistors. This may also be difficult if your fingers are not quite as nimble as they once were. A pair of tweezers should make life a lot easier when dealing with the more fiddly items.



Little and large "Hobby" vices. They are fixed in place via a suction cup.

Some sort of vice is more than a little useful. Even something as basic as a "hobby vice" will do to start with. In fact I find these unlikely gadgets to be extremely useful. A vice of this type is basically just a scaled-down version of a normal bench vice, but it is made of plastic with metal inserts on the jaws.

It is fixed to the worktop via a large suction clamp which provides a more secure fixing than you might expect. A vice of this type is very useful if you have to borrow the kitchen table for use as a temporary work-space when constructing projects.

A printed circuit work frame (also known as a mounting frame or a solder frame) is a worthwhile addition to the electronics workshop if you get involved in building fairly large printed circuit boards. The basic idea is to fit all the components in place on the board, and then clamp it into the frame. The frame is then clipped in the closed position, which presses the component side of the board into a thick piece of heat-resistant foam material. This holds all the components in place while the leads are trimmed and the soldered joints are completed. Particularly with larger boards, this method is very much quicker and easier than dealing with the components one or two at a time.

As a good quality printed circuit frame costs about £40 or more it is probably not worth buying one initially, but for regular project builders it represents a sound investment.

Last but by no means least, no creative hobby can be pursued without some plasticine or Bostik Blu-Tack. This is useful for all manner of things, such as holding components in position while they are soldered in place, and generally sticking down anything that has a tendency to "walk" away.

Although electronics is sometimes accused of being an expensive hobby, it is difficult to justify this claim. Even if you have to start virtually from scratch when assembling a toolkit, I would guess that it would be possible to obtain the basic requirements plus the components for a small project, and still have change from £50. I doubt if it is possible to get started in many hobbies these days for this sort of money.

FOX REPORT

by Barry Fox

Dodo Apple

Is the Apple Mac now cast in the role played by Betamax in its last few years? Great picture, great sound, great features, but with a future as secure as a Dodo.

Do those who now buy into the Mac world risk becoming the victim of friends who joke about their being "the man who bought Mac when everyone else was buying PCs?"

Journalists like me, who kept banging on about Beta's superior benefits, finally had to face reality. When does the Mac press own up?

Even by now the Mac zealots amongst you will be be fuming at the very suggestion of a parallel with Betamax. So will Apple's staff. But there is clear writing on the wall and there is no sign of Apple's top management addressing the problem.

Of course, lower and middle management make all the right reassuring noises. But without a sign from Apple's powermasters it means nothing. Frankly, just as when the Beta manufacturers like Toshiba and Sanyo started to make VHS recorders as well, it is hard to see what can now be done to halt the death spiral.

Consider the Facts

A few weeks ago, and for the first time since the Mac was launched, I was loaned a Mac (portable) to try for myself. Never in ten years had anyone from Apple ever said, "I've seen all the rude things you keep writing about the compatibility mess in PC World, so why don't you try a Mac for a few days and see for yourself how much easier it is to plug in and use?".

Gradually it now seeps out that Apple has had an economy policy of restricting the number of Macs available for review. So they have been shuttled round bona fide reviewers, rather than journalists with a much more general approach. I was only loaned the portable, because I was involved with a highly respected, wide circulation, magazine's comparative review of portables.

Given the chance to use a Mac, I was struck immediately by the fact that using it was an easy pleasure. Five years ago it would have made a glorious change from struggling with early versions of Windows. But in those five years, the PC Windows world has aped the Mac world so effectively that the look and feel of the two worlds is now almost identical.

Multiply this situation across the board, and through the ranks of non-specialist journalists writing for just the kind of real world people the Mac is aimed at, and you have a massive missed opportunity.

Even semi-specialists like me who have invested tens of thousands of pounds into buying PC hardware are hardly going to pay the even higher price of Mac hardware and software just to give it a try.

If Microsoft gets its new Windows-style operating system, called Chicago, right and brings plug-and-play convenience to the PC world, what has the Mac world got left to offer the customer?

Certainly not chip speed, because both PCs and Macs are already running so fast that most of the time they just sit idle while their owners perform routine tasks.

The people who love their Macs are the people who have always used Macs. But the bridges that are now being built between Mac and Windows software will let corporate purchasing departments look only at price when the time for the next hardware update comes round. This will suck Apple ever deeper into a price war it can never win.

How can Apple compete on price against the mass manufacturing might of Korea, Taiwan and Mainland China? How can Apple compete on the size, weight and compactness of portables from miniaturization masters like Toshiba, Sharp, Sony and the clone manufacturers making for Gateway and Dell?

Apple can sub-contract, as it already does to Sony and Sharp, but this shaves the profit margins even tighter. Newton was a flop, with early models now being offered for sale at £100. The parallel with BetaMovie, the world's first genuinely portable camcorder, is inescapable.

Licence to Kill

This whole scenario is the direct cause of Apple's consistent refusal to license Mac technology to other companies. Initially this kept profits high. But it restricted sales volume and gave the PC World and Microsoft all those years it took them to get Windows working, and Chicago planned.

Remember how in the early days Sony was reluctant to license Betamax technology, while JVC threw VHS licences around like confetti? The parallels stack up.

From the outside looking in, there is only one way for Apple to stop the Mac becoming another Betamax. That is to move fast and license the technology to clone makers who could then offer a cheap alternative to the Pentium PC and Chicago. Apple would then become a licensing company.

There is no shame in this. Dolby Laboratories have very wisely never made a single piece of consumer equipment in their life, but grown rich on the licence fees paid by those who do. Microsoft has never made any consumer equipment either (except for a few sub-contracted mice etc). They grow fat on royalties from software.

With the launch of Chicago imminent, I'd say that Apple has just about six months left in which to shape its final future. And my bet is that Apple will do nothing, and sink into irreversible decline.

Date with the Future

I have been working on a feature for these pages which deals with the whole issue of data storage cards like smart cards. How they work, how much information they can store, what they can do with it and the security implications. One point that emerged early and clearly is that some people are very worried about any plan to bring in Identity Cards, especially using cards which can store very large volumes of information.

Witness the recent fuss about the government's scheme for a photo driving licence. This reminds one of the fuss which preceded launch of the licences currently in use.

After complaints about loss of privacy, age and sex were not listed. But when I hired a car in the US last year, the counter clerk wished me happy birthday. Date of birth and sex, the clerk pointed out, are buried in the innocent-looking six-figure Driver Number which is printed over the driver's name.

Since then I have found friends and work colleagues split between those who say "Oh everyone knows that" and those who say "I never knew that". Even those who do know, do not know how to read the numbers.

Although it is easy to decode the date when you know the tricks, you first have to know the tricks. The date code varies with the month and is further disguised by the code used for sex. I checked a collection of friends' licences and birthdates to be sure I had fully cracked the code.

The first and last digits tell the year of birth. The third digit gives single figure months (January – September). But double figure months (October – December) use the second and third digits. The second digit has 5 added where the driver is female. The fourth and fifth digits give the day of the month.

So number 359149 tells that the holder is female and was born on 14 September 1939. Number 306107 tells that the driver is male and born on 10 June 1937.

Did you know that this information is available to any police officer who asks to see your driving licence? Does it bother you?

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EMBEDDED CONTROLLERS

JOHN DAVIES B.Sc.

From fly-by-wire aircraft to automobiles and home control-systems, the applications for embedded controllers are increasing in number and complexity.

THESE days most people are familiar with personal computers in one way or another. They may use them at work, see them while shopping or, more often than not, play games on them. There is, however, another type of computer which is becoming more and more common and which comparatively few people are aware of. This other type is the *embedded controller* which usually has no human interface other than maybe a few flashing lights.

Before embarking on a tour of embedded controllers it is worth defining a few points. Firstly for the purposes of this article, the author has defined an embedded controller as a computer which is dedicated to one task only.

This task may be to control a washing machine a TV, or the ignition system of a car, as will be seen the possibilities are endless. Secondly, because the microprocessors used in embedded controllers contain many peripheral devices (interrupt controllers, memory, serial interfaces etc.) they are generally called microcontrollers.

The rest of this article looks at where and why embedded controllers are used, what the differences are between them and the average PC (Personal Computer) and what design problems are faced.

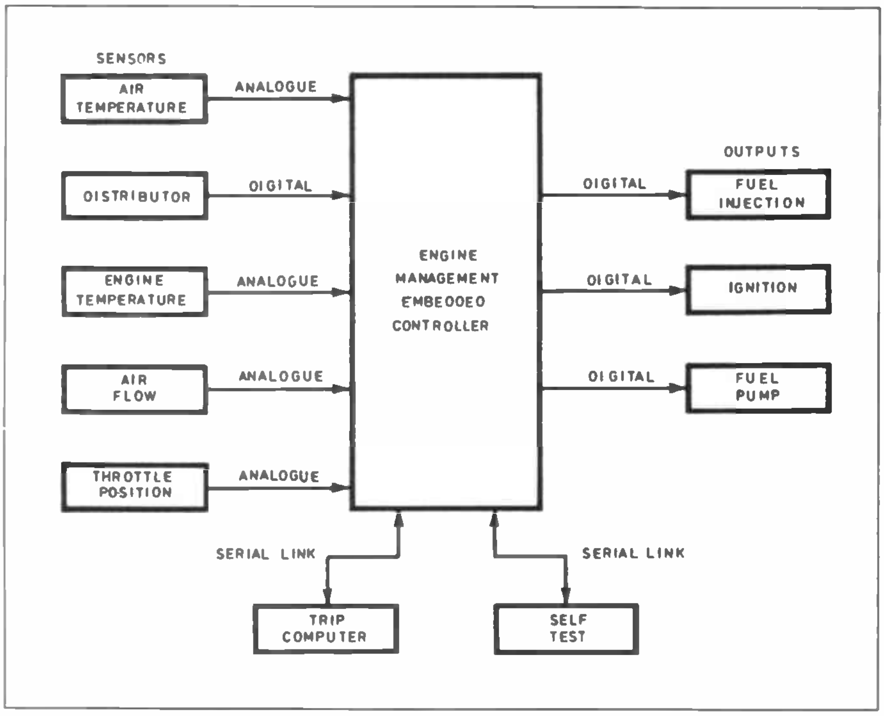


Fig. 1. Typical engine management system.

APPLICATIONS

The earliest application of an embedded controller that the author has discovered is the small computer developed for the *Apollo* Lunar Programme of the 1960s. This computer was designed to take control of the Lunar Module while it orbited behind the Moon and was thus unable to communicate with the computers on Earth.

Since then embedded controllers have been used in aircraft, initially for navigation and then for weapons control, and latterly for fly-by-wire systems whereby the entire aircraft is controlled by computer. Similar applications have been found in the shipping world and the latest P&O liner being built in Germany at the moment will be steered into port by means of a small joystick on the bridge.

One of the largest and most obvious applications, however, is in the car market. These applications were instigated by the demands of the motorsport industry for more and more power from existing engines and these developments have now spilled over into normal road cars. It is now very unusual for even middle of the range cars not to have an engine management system based on an embedded controller.

The boom over the past few years in the home entertainment industry has also seen the introduction of embedded controllers into televisions, video recorders etc.

Another area which has also been revolutionised by the availability of cheap embedded controllers is the design and application of alarm systems (both fire and intruder systems). Even cheap domestic alarm systems costing less than £100 will probably have a small microcontroller inside them. More sophisticated systems will even go to the length of having a microcontroller inside each sensor.

The smallest embedded controllers in use at the moment are the credit card sized "smart cards". They are used for a variety of applications, e.g. high security identification cards, rechargeable cards for electricity meters etc., and usually contain a simple microcontroller and a small amount of memory.

MOTIVATION

There are three main reasons for introducing computer control. First, an improvement in performance in the equipment being controlled can usually be expected. The major boost in power and handling obtained by Formula One racing cars is due in no small part to the skill of the engineers who designed the on-car electronics. Indeed the power increase is so great that many of the electronic aids are now being banned.

Applications in road cars have also resulted not only in power increase but also more importantly in economy. Recently, however, the reduction in exhaust emissions has become essential and embedded controller applications are the only real way to make progress. Fig. 1 shows the way in which a typical engine management system would work.

Phenomenal increases in speed and performance have also been obtained in modern warplanes which now have very sophisticated weapon systems which allow the attacking of multiple targets simultaneously.

The second reason for using embedded controllers is to provide features that could not be provided using conventional analogue based systems. Formula One cars' active suspension and traction control systems, for example, could not realistically be implemented any other way. Similarly, the sophisticated video recorder programming methods using on-screen menus, barcodes and code numbers could not be done without embedded controllers.

Finally, embedded controller based systems are usually more reliable and need less calibration than their analogue counterparts. Self test and diagnostic software can be built in to ease repair work and self calibration features can be used to minimise any adjustments required for measurement systems.

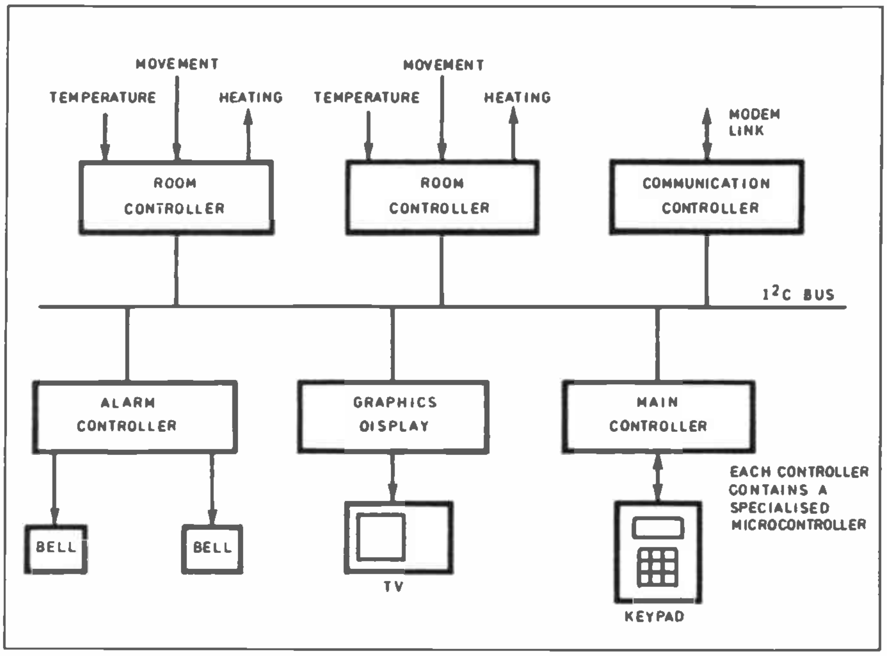


Fig. 2. Future home control system.

PC COMPARISON

The first and most obvious difference between a PC and an embedded controller is the lack of a keyboard or screen. The embedded controller's view of the world is obtained via analogue or digital signals. The digital signals can be represented by one bit of information, either on or off. An analogue signal, however, is slightly more complex in that it theoretically has an infinite range of values.

To simplify matters an analogue voltage is converted into a digital number before being read by the microcontroller. The resolution of the conversion process depends on the application. A simple volume control for a hi-fi may only need six bits of resolution, where one bit represents 1/64th of the maximum voltage.

High performance measuring equipment, however, may need up to 16 bits of resolution where one bit represents 1/65536th of the maximum voltage. Needless to say the more resolution needed the more expensive the analogue to digital converter devices and the more susceptible the circuit is to noise.

An average PC usually has at least 640Kbytes of RAM and more often anything up to 4Mbytes of RAM. The average embedded controller application, however, usually uses only hundreds of bytes of RAM with possibly a few Kbytes of EPROM for program storage. In addition, the average microprocessor chip used in embedded controllers packs in far more interfaces and peripheral devices than does say an 80386 or 80486 as used in many PCs.

Embedded controllers are also generally more rugged than the average PC, and this is discussed in more detail later.

PROBLEMS

The first and most obvious embedded controller problem is that of programming. How do you program a computer which has no keyboard, screen or disk drive and whose program is stored in an EPROM? Early embedded controller applications were programmed by hand coding the assembler software and entering it byte by byte into an EPROM programmer which was then used to program the EPROM. The controller was switched on and more often than not didn't work.

These days the software is written and assembled or compiled on a separate computer (usually a PC), traditionally in assembler but more and more in high level languages such as C. The PC is then normally attached to a separate piece of equipment called an emulator which has a pod which can be plugged into the circuit board in place of the microcontroller chip. The programmer can then download the software into the emulator and can control the operation of the microcontroller by single stepping through the program or setting breakpoints in much the same way as developing software to run on a PC

Emulators for a simple microcontroller chip cost a few hundred pounds whereas emulators for specialist complex chips used for telecommunications applications can cost upwards of ten thousand pounds. When the program is running satisfactorily the emulator is removed, the microcontroller replaced and the software programmed into an EPROM.

The second major problem is that while the average PC will operate in a relatively benign office environment the average embedded controller application will face a more hostile climate. An engine management controller in a car, for example, will face an ambient temperature of −30°C in Norway in mid-Winter and an ambient temperature of +50°C in southern Spain in mid-Summer.

Very careful thermal design of the equipment and the use of rugged, almost military specification chips are needed to ensure reliable operation. The use of CMOS based low power devices is very important and most manufacturers of microcontrollers offer this option. Vibration can be a problem with extra restraints needed for any large components, e.g. capacitors, mounted on the printed circuit board (p.c.b.).

A less obvious problem is that of humidity and heat cycling. An alarm system in a warehouse, for example, can be quite cold overnight then warm up rapidly during the day as the heating is switched on and then cool down again overnight. This sort of heat cycling can lead to condensation forming on p.c.b.s and components usually with dire results. To overcome this problem the p.c.b.s may need to be sprayed with a waterproof coating.

LEGISLATIVE IMMUNITY

A further design problem which has only really been highlighted recently with European and worldwide legislation is that of Electromagnetic Compatibility or EMC. There are two main aspects to this legislation, namely susceptibility and emissions.

Susceptibility means that your embedded controller application must not be affected by other electrical equipment. Usually this means that the circuit must be unaffected by large voltage transients occurring in the vicinity. These can be the ignition system in a car, lightning strikes, switched mode power supplies or even the EHT in a television. The voltage transients may be conducted through the air or induced onto wires connecting to the equipment.

Emission legislation means that your application must not emit voltages such that it would be hazardous to other equipment. This may not seem to be a major problem for embedded controllers but there are two main areas of concern.

Firstly microcontrollers will operate at clock speeds up to 10MHz and the harmonics from digital signals at this frequency are large enough to interfere with radio equipment. Secondly, switched mode power supplies are usually used to reduce size and increase efficiency and these also radiate at high frequency, especially onto the mains power input which is usually run all around a building.

Compliance with the various new bits of legislation is now essential as from 1996 no new electrical equipment may be sold in Europe unless it passes the relevant EMC tests.

RUN-TIME ERRORS

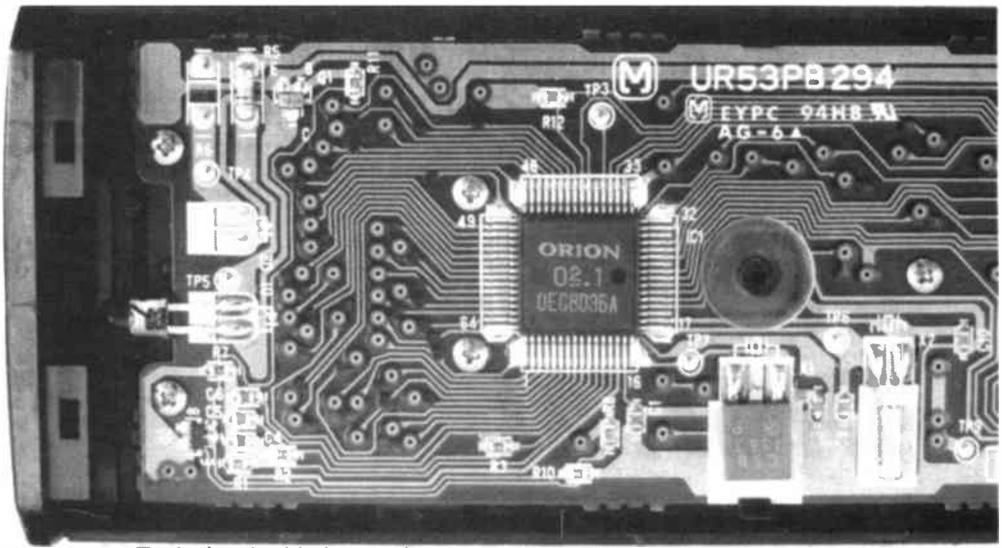
A final problem which may not at first seem to be a problem is that of dealing with errors which occur while an embedded controller is running. If something goes astray with an expensive PC spreadsheet, for example, then the user can expect a reasonably friendly message explaining what has gone wrong and what the computer is going to do about it. With cheaper software the computer usually sulks and the only remedy is the reset button or the on/off switch. This is mildly annoying but not normally a problem unless a large amount of data has just been lost.

With an embedded controller system, though, a message such as "Cannot find file.." or "MSDOS Error 2" is not very useful if the washing machine is busy emptying its contents over the floor or worse if you are landing your fly-by-wire fighter aircraft on an aircraft carrier in the dark.

A common error which can lead to such problems is to declare an array of "n" elements and then to try and access the "n + 1th" element of that array. At best you get an incorrect result, at worst you overwrite some other vital data. Some languages, e.g. ADA which is used for military applications, will detect errors and allow the programmer to write software which will handle the errors if they occur. Most languages, though, don't have this feature and unless great care is taken over the software an error will cause the embedded controller to fail, usually disastrously.

A technique used to increase the reliability of embedded controller systems in life critical situations is to use more than one system for each function. Three systems are commonly used with three independent microcontrollers using a "majority vote" system to define any output. This means that an error in one controller will be overruled by the other two controllers if operating correctly.

One problem which will not be solved with this method is that any bugs in the software will be replicated in each controller so that although hardware failures will be handled, software bugs will not. A method of overcoming this last difficulty is to have three systems as before but to have each system programmed by a different team so that hopefully software bugs are not replicated across the three systems. This method is used on projects such as the *Airbus* fly-by-wire systems.



Typical embedded controller application – TV remote controller.

FUTURE DEVELOPMENTS

Over the past decade the trend for microcontrollers has been to make them smaller and consume less power whilst packing in more features. There has also been a tendency over the past few years to provide microcontrollers with dedicated specialised functions. An example of this is a microcontroller which is able to drive an l.c.d. and to scan a keyboard for use in remote control handsets. Others provide specialist communication path interfaces, e.g. for telephones.

The interconnection of chips is also being changed from the traditional parallel address and data busses to using a simple serial link. The I²C bus pioneered by Philips is an example. Fig. 2 shows a possible future application for an integrated home control system using all the features described above.

Finally, what will undoubtedly change is the range of skills needed by the engineers who design and build these embedded controller systems. No longer will there be a clear cut distinction between hardware and software design and engineers will need both types of skills. The final system design for any embedded controller application will always be a compromise between hardware and software design and the most successful design will be the one which combines the best from each discipline. □

UNIVERSAL DIGITAL CODE LOCK

BART TREPAK

PIC and choose the code that keeps crooks from your pad.

EVER since the earliest civilisations, when men found that they were not all equal and some had more possessions than others, there has been a need for locks. Even the ancient Egyptians had one which, interestingly, worked on the same basic principle as the modern pin-tumbler lock mostly in use today for domestic applications, although theirs was much bigger and made mostly of wood. This simple affair, backed up no doubt by draconian punishments for offenders (such as chopping the hands off anyone caught stealing etc.) was presumably sufficient to keep one's valuables safe.

With the progress of civilisation and technology, the sophistication of the locksmith and the criminal has advanced to the stage where complicated mechanical locks with three, five or more levers are required to satisfy insurance companies while the more liberal approach to punishment ensures that even these are not always sufficient to deter the burglar.

KEY PROBLEMS

The "trick" with any lock design is to make it easy to open for the legitimate owner, but extremely difficult for everyone else. With mechanical locks this is done by providing the owner with a key which (hopefully) only he possesses.

The problem here is that while it is possible to buy a duplicate key or at least have one cut, it is not possible to buy a duplicate lock with the result that instead of having one key to open all your doors, a whole bunch is required. This may be better from the security point of view but it can be very annoying to have to carry around all this metal and then to fumble in the dark to find the correct key. (Ancient keys were very large, some up to a metre long so they must have had an even bigger problem and no electronics to offer a solution!)

Worse still, keys can be easily lost or left inside the premises and then the lock becomes more of an obstacle to the legitimate owner than to the burglar who feels less inhibited about, say, smashing a window to get in.

Those who have had the misfortune to lock themselves out of their car will know the feeling of frustration, especially when told stories of "professionals" who can break into any car in 30 seconds. When keys are stolen the position is even worse since all the locks may have to be changed to ensure that a thief does not gain access.

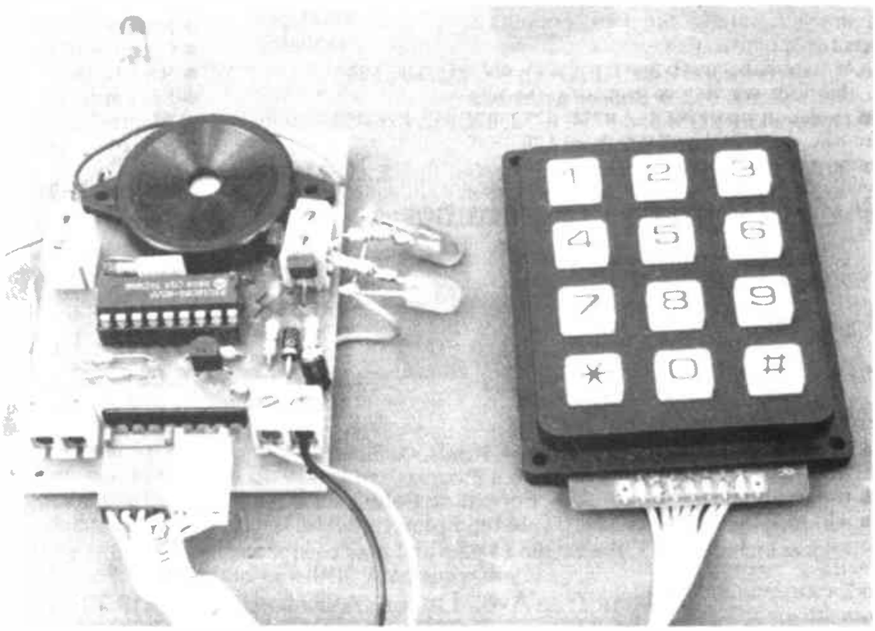
Combination locks overcome most of these difficulties at a stroke because they eliminate the need for a key, but there remains the problem of changing the combination if the code is discovered. This can be difficult or even impossible with mechanical combination locks but is relatively simple with electronic ones. Over the years, some lock chips have appeared on the market which required the changing of a few links to alter the code, while later developments have a memory which can be re-programmed from the key pad.

These perform admirably but still have limitations which preclude their use in many applications. It was therefore decided to design a lock which would be virtually impossible to pick (unless one had the patience of a saint) and which would be useful in as wide a range of applications as possible, from replacing your front door lock, to preventing the unauthorised use of your computer. It is worth mentioning at this point that there is no such thing as a totally secure lock as given sufficient time and a computer, any code can be cracked. Also, it should be remembered that a lock is only as good as the door to which it is fitted.

LOCK REQUIREMENTS

Combination locks are used in many different kinds of premises all of which can have different requirements, but common to all, is that they must be simple to use, difficult to open if the code is not known and easy to re-program. Not much more is required from a domestic lock but for one used in a hotel or guest house for example, two open codes would be an advantage. One could be given to the *customer* or guest which he or she could change at will, while the *management* would have another code which would allow the staff to enter rooms to clean or when the guest had left and omitted to leave the number that he had programmed.

The *customer* should be able to change only his own code while the *management* should be able to change either should



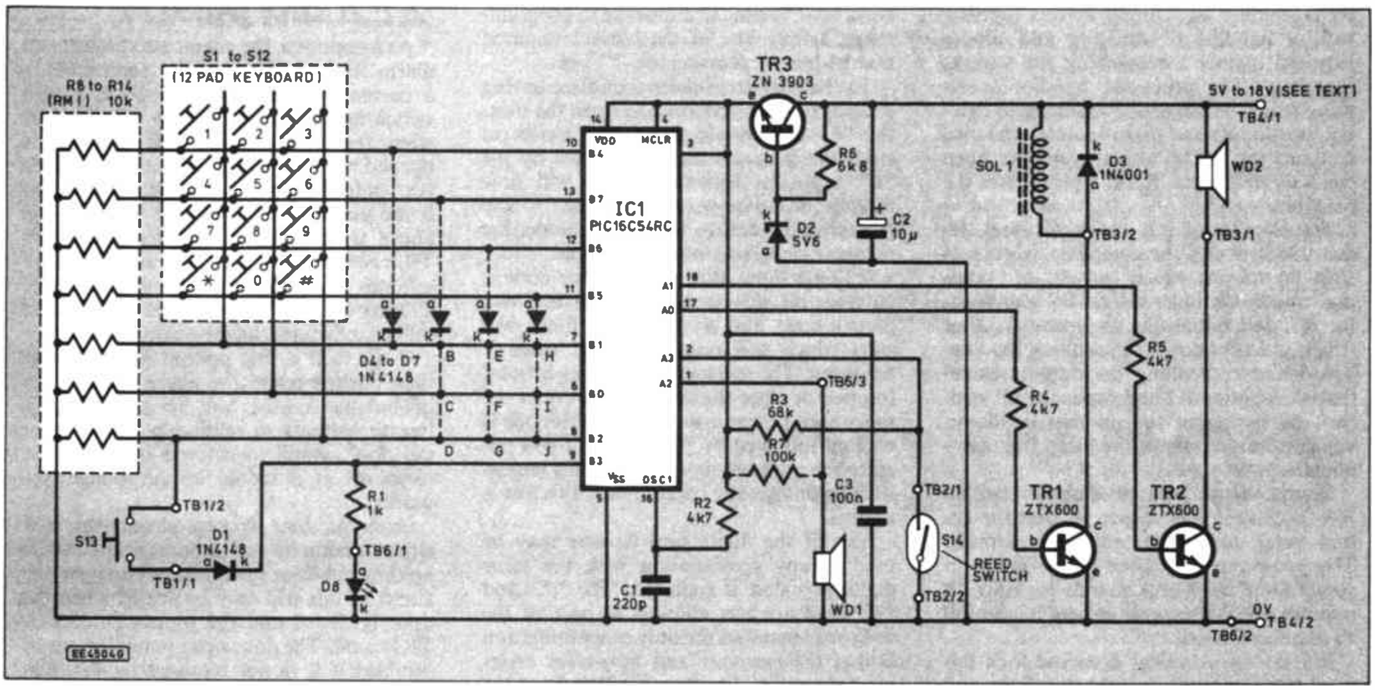


Fig. 1. Principal circuit diagram for the Universal Digital Code Lock.

this be required. In an office or research laboratory, the requirement could be similar but it may be useful to give cleaners or other people who need to have access for a limited period a special *temporary* code without the need to go around and re-program all the locks once they had gone. The lock to be described has a special temporary code which can be easily programmed and automatically cancels itself 15 minutes after it is last used.

Another requirement concerns the use to which the circuit is put. Most electric door release mechanisms require to be energised for a short period only to enable the door to be pushed open, but in some situations, such as arming or disarming a burglar alarm or car ignition, the output must remain latched in the open or closed state. The lock is designed to provide either type of output and this can be selected by means of a diode link.

In some applications, it could be useful to be able to connect a door contact enabling the unit to sense if the door was open or closed. A warning could then be given if the door were inadvertently left open, a desirable feature for fire doors or doors in security sensitive areas.

An external alarm could also be sounded if the door was forced, enabling the unit to function as a self contained alarm for the door or be connected to a more comprehensive alarm system covering the whole building. This feature has also been added to the circuit and may be used with a reed switch/magnet combination, the contacts being normally closed when the door is closed. If this feature is not required, the input may be permanently shorted with a wire link.

Programming should also be easy (for the legitimate owner) without the need to take the unit to bits or refer to a manual so this should be possible from the keypad using as few entries as possible. Some digital locks feature EEPROM memories to store the programmed open code if there should be a power failure. This is difficult to justify in terms of cost or even convenience especially if, as in this case, the lock control unit takes only a few seconds to re-program.

Since a battery would be required to power the solenoid to enable the user to enter during a power failure anyway, this battery could also retain the memory contents. The unit consumes so little current that a small battery would easily retain the memory contents for the duration of a power cut.

In this design, programming is carried out by simply entering the current code followed by two depressions of the star ("*") key while the output is open, keying in the new sequence and pressing the star key again. An l.e.d. is included which lights to show when the unit is in the "program mode".

Finally, to make the circuit compatible with any key pad, it should be possible to connect a piezo sounder to bleep each time a key is pressed. This is particularly useful with membrane keypads or those which have little or no tactile feedback. The sounder could then also form the local alarm in case of tampering and alert the user to any errors when programing.

HARD TO PIC

If the lock is to be easy to use, then the open combination should be limited to as few numbers as possible so that the owner does not have to remember long strings of digits or spend a long time entering them. Obviously, the longer the code, the more possible combinations there will be and the harder it will be for the intruder to chance on the correct one, so a compromise must be made.

Given a 12-way keypad, the number of possible three-digit codes is 1728 ($12 \times 12 \times 12$). The corresponding possibilities for four and five-digit codes are 20,736 and 248,832 respectively. If the prospect of trying nearly two thousand combinations sounds daunting, twenty thousand does not bear thinking about, so a four-digit combination was chosen.

To make things more difficult for the determined code breaker or the one who feels he has the time to spend trying every combination, the circuit is designed to sound a warning alarm for a short time and disable the keyboard for a slightly longer time following a preset number of incorrect entries. This means that assuming that the keyboard lock out time has been set to 15 seconds and the alarm sounds after two incorrect entries, the intruder would only be able to enter at most six digits per minute (in fact, after the first two incorrect digits, every incorrect entry generates a 15 second delay so only four digits can be entered every minute) so that it would take him over three and a half days, working day and night to try them all.

Even ignoring the sheer boredom of this task and the inevitable breaks which would be required, this estimate is wildly optimistic. As there is no indication that the open sequence is a four-digit one and not a three, five, eight or some other number, or that the keyboard is being disabled for most of the time, the chances of someone discovering the combination by trial and error are virtually non-existent.

With so many requirements, the only realistic way of performing all these functions without resorting to twenty or thirty standard logic chips, or developing a custom chip, is to use a microcomputer. This circuit is based somewhat appropriately on a PIC microcontroller and all the above features have been incorporated.

The additional cost of adding any of these features to a basic lock circuit is only a few more lines of program code and many of them can be easily disabled should they not be required in a particular situation. This makes the circuit suitable for the majority of applications from controlling access to buildings or parts of buildings, including flats, hotels or offices, to preventing the unauthorised use of equipment such as computers, domestic alarm systems or car ignition immobiliser/alarm systems. The only modifications required will be the type of output device selected, such as a relay or solenoid, and which diode links are fitted.

CIRCUIT DETAILS

The circuit diagram for the digital code lock controller is shown in Fig. 1. The use of a pre-programmed microcontroller, IC1, reduces the circuit to almost trivial proportions consisting of little more than the chip, keyboard, programming indicator l.e.d., piezo sounder and output drivers together with a handful of resistors and diodes required mainly for selecting the various functions. The processor handles everything from the keyboard scanning to driving the outputs and piezo sounder and also contains the RAM which stores the open codes as well as the ROM which stores the program.

The chip includes a power on reset circuit which makes the computer execute its start up routine which consists of "reading" the diode links D4 to D7 and resistor R7, and initialising the memory, after which it settles down to scanning the keyboard and controlling the outputs as required. Resistor R2 and capacitor C1 control the timing of the on-chip oscillator, which in turn controls the bleep frequency and alarm time, etc.

Since none of these times are critical, an R/C oscillator was chosen so that the actual times quoted are only approximate. The prospective intruder is not going to complain if the alarm sounds for only 14 minutes and 35 seconds instead of the full 15 minutes quoted!

For use in a typical domestic lock application, the output would switch on and energise the lock solenoid SOL1 via transistor TR1 for approximatly five seconds following the entry of the pre-progammed four digit combination. Each time a digit is entered, the sounder WD1 is bleeped and an internal timer restarted so that if no digit is entered within the next five seconds, the digit counter is reset and the next digit is assumed to be the first in the sequence.

Incorrect entries are counted and when the count exceeds the preset number, the internal alarm is sounded and the keyboard is locked out for the preset time. Any further incorrect entries will also do this and will activate the external alarm WD2 via transistor TR2. This may be a loud siren or bell depending on the application and it will sound for approximately 15 minutes, or until the correct security code is entered.

Since the chip requires a 5V d.c. supply whilst most solenoids run at 9V or 12V, Zener diode D2 and transistor TR3 are included to supply the 5V from the higher voltage.

PROGRAMMING

Once the lock is open (i.e. the output is on), the unit may be re-programmed by entering "**" ("*" key twice). This will cause the program l.e.d. (D8) to light and the output to remain on (unlocked) indefinately, or until the programming sequence is finished even if the unit is being used in the momentary mode. Care should therefore be taken not to leave the lock in this state as some solenoids may not be rated for continuous operation.

Depending on whether the *manager* or *customer* code was entered when opening the lock, (the *manager* code must always start with the "#" key followed by four digits while the *customer* code consists of only four digits) the next four numbers keyed will reprogram that code. The program mode is terminated by pressing the "*" key once, when the l.e.d. will switch off and the output will follow (if the unit is in the momentary mode).

If the "*" key is pressed after fewer than four keys had been entered, the sounder will bleep three times and the unit will remain in the program mode until at least four digits have been entered. If more than four digits are entered before the "*" key is pressed, only the last four will form the new code, so if you make a mistake in programming, simply key in the correct required number before pressing the "*" key.

To change the *customer* code after having entered the *manager* code to open the lock, the "*" key should be pressed twice (to enter the program mode) followed by the "#" key. The following digits will now modify the *customer* code with the "*" key returning the unit to its normal mode, the *manager* code remaining unchanged.

If this is done after the *customer* code is entered, the new code will form the *temporary* code and a 15 minute timer will start which will reset this code when it times out. The *temporary* code may be used to open or close the lock and will reset the timer each time it is used, but if this code is entered followed by "**" the unit will not enter the program mode so that it is impossible to change any codes if only this one is known.

Any of the digits zero to nine may be used in any combination with the same digits repeated if required. The "*" and "#" keys are not allowed as part of the code sequence and the only other limitation is that the *customer* and *temporary* codes must not start with the same digit, i.e. 5451 and 4451 is acceptable but 5451 and 5936 is not.

The same programming procedure is used when the unit is in the latched mode, the only difference being that the output will not switch off when the programming mode is finished by pressing "*" until the new valid code is entered.

The following examples should make the process clear:

Current *manager* code: 1066
Current *customer* code: 1234
Current *temporary* code: 5678

Key sequence entered:
1234 ** 0000 * *customer* code will now be 0000. Other codes remain unchanged.

Key sequence entered:
#1066 ** #0123456789 *

Customer code will change to 6789 (only the last four digits are stored).

Key sequence entered:
5678 ** #98765 . . .

No change in any codes because program mode is disabled if temporary code is entered. Program indicator l.e.d. remains off.

Key sequence entered:
6789 ** #4321 *
Temporary code will change to 4321.

Key sequence entered:
#1066 ** 1111 *

Manager code will now be 1111 (enter #1111 to open or close the lock).

ALARM INPUT

As mentioned, the circuit also features an alarm input which may be connected to a normally closed contact such as a reed switch/magnet assembly S14 which opens when the door is opened. If the door is opened while the lock is in the closed mode (i.e. output is off) as would be the case if the door were forced, for example, the alarm is immediatly activated (transistor TR2 switches on) and will sound for 15 minutes or until the correct code is entered. Closing the door once the alarm has gone off will, of course, have no effect.

If the lock is first opened and the door then pushed open, the alarm will not go off but the sounder will bleep twice every twenty seconds to remind personnel that the door is still open even if the output turns off as it would in the momentary mode.

Once the door is open, closing the lock either manually or automatically while holding the door open will not activate the alarm as this will only be armed when the door is closed and the output (transistor TR1) is off. The door open reminder can be disabled if it is not required by omitting resistor R7. The alarm can be disabled by simply connecting a link in place of the reed switch. In this case resistor R3 may also be omitted.

There is, of course, one problem which occurs when a person already inside the room or building wants to leave, as opening the door (even from the inside) without first entering the open code would set off the alarm.

Another keypad could be provided on the inside but it would be tedious to have to keep entering numbers to leave as well as to enter, so a separate input for switch S13 (which would be mounted within the protected area) has been provided. Pressing this will disable the alarm while the door is opened and remove the need for an exit timer, which would also need to be user programmable to cater for different situations. The alarm is again enabled only after the door has been closed.

SELECTING OPTIONS

Functions such as momentary or latched output, keyboard lockout time (following incorrect entries), number of incorrect entries allowed without setting off the alarm, and initial open codes are selectable by means of diodes D4 to D7 as shown in Table 1. Note that only the pre-programmed *management* code selected is valid after power on so that the first entry must begin with the "#" key. These codes have been chosen to make them easy to remember and some readers may recognise them as important historical dates. 1805

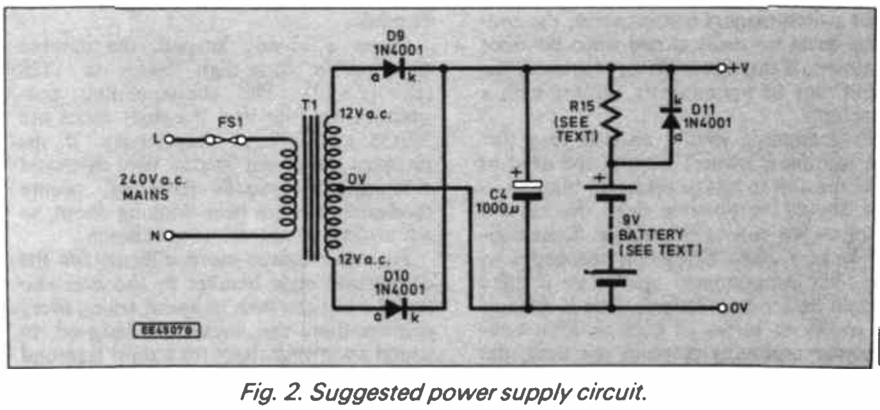


Fig. 2. Suggested power supply circuit.

was the Battle of Trafalgar, 1914 and 1939 the beginning of the First and Second World Wars and 1066 which should need no explanation.

Following initial power-up, *customer* or *temporary* codes can be entered and changed, as can the *management* code, only after the initial preset code has been entered. Note also that irrespective of the preset number of incorrect entries which have been selected, the circuit will give a warning after the first incorrect entry and an alarm following the second after the unit is powered up. This will change to the selected number once the correct sequence has been keyed in.

POWER SUPPLIES

The circuit will operate from any supply in the range 5V to 18V so the choice of supply will be determined largely by the supply requirements of the load and the use to which the unit is to be put.

For door locks and area access applications where a solenoid or electric latch are to be operated, a mains supply, such as that shown in Fig. 2, capable of supplying sufficient current to operate the solenoid will be required, plus perhaps a rechargeable battery with sufficient capacity to operate the solenoid in the event of power failure. This circuit could be treated as a small plug in d.c. power supply with a rechargeable PP3 battery in the case of some low power electric latch mechanisms. Alternatively, it could be a higher power d.c. supply and a stack of rechargeable C or D cells in the case of some heavy duty solenoids.

If the rectified d.c. supply has a slightly higher output voltage than the battery, then this may also be used to trickle charge it via resistor R15. The latter should have a value to limit the charging current to that recommended by the battery manufacturer (usually 0·1 times the amp-hour rating in the case of Ni-Cads). Non-rechargeable batteries should not be used with this circuit.

If the circuit is to be used to switch on a car alarm or disable the ignition, the 12V car battery would be the obvious power supply choice with the lock driving suitable 12V relays. It is not advisable to use the car horn as the external alarm as these are not normally rated for continuous use.

For restricting the use of other equipment such as computer systems, photocopiers etc., similar power supply and output requirement considerations will apply.

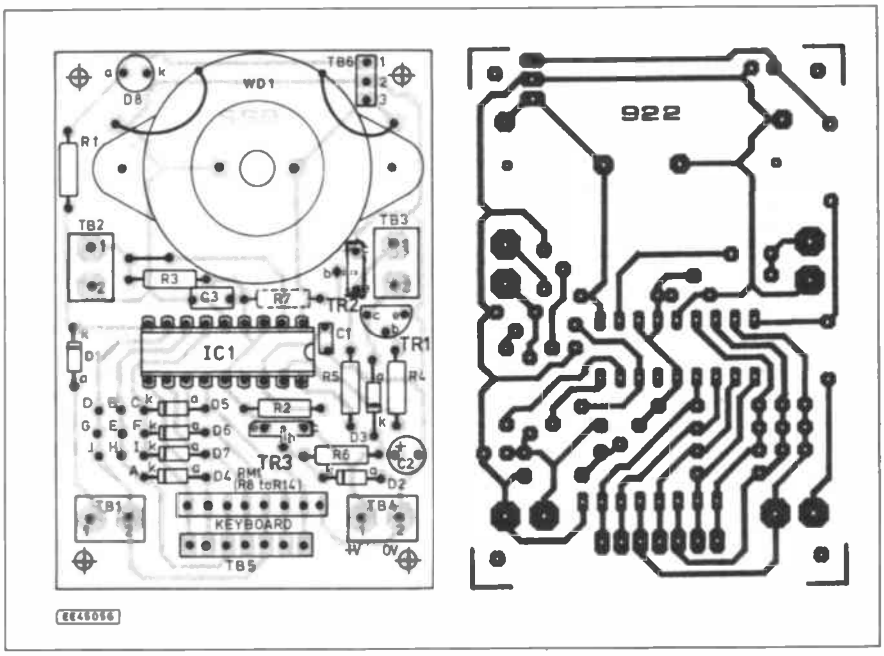


Fig. 3. Printed circuit board component layout and full size copper foil master track pattern.

COMPONENTS

Resistors
R1 1k
R2, R4, R5 4k7 (3 off)
R3 68k
R6 6k8
R7 100k
R8 to R14 (RM1) 7 × 10k s.i.l. resistor module
R15 see text

See SHOP TALK Page

Capacitors
C1 220p ceramic
C2 10µ radial elect. 16V
C3 100n polyester
C4 1000µ radial elect. 25V

Semiconductors
IC1 PIC16C54RC pre-programmed microcomputer (see text)
TR1, TR2 ZTX600 *npn* Darlington transistor (2 off)
TR3 2N3903 *npn* transistor
D1, D4 to D7 1N4148 signal diode (5 off)
D2 BZY88C5V6 Zener diode
D3, D9 to D11 1N4001 rectifier diode (4 off)
D8 5mm red l.e.d.

Miscellaneous
Miniature piezo transducer, printed circuit board available from the *EPE PCB Service*, code 922; 2-way p.c.b. terminal block (4 off); 3-way terminal block; 18-pin i.c. socket; 7-way keyboard connector (see text); 4 × 3 matrix keyboard.

Optional
S1 push-to-make switch; S2 door contact (reed switch/magnet assembly); siren; solenoid/lock mechanism; power supply/battery (see text).

Approx cost guidance only **£37**

CONSTRUCTION

It is recommended that the circuit is built on a printed circuit board (p.c.b.) as this will make construction quicker and much less error prone. Details of the component layout and full size copper foil master track pattern for the suggested p.c.b. are shown in Fig. 3. This board is available from the *EPE PCB Service*, code 922.

Care should be taken to ensure that all diodes, transistors, electrolytic capacitors and the integrated circuit are fitted to the board the correct way around. Note also that the resistor network module RM1 must be fitted the correct way around, the common connection usually being indicated by a dot on the component. The microprocessor IC1 is a CMOS type and although the input circuitry at the pins has been designed to protect the device from electrostatic damage it is best to fit a suitable i.c. socket to the board and insert the chip into this.

The order of assembly is of course immaterial but it is usually best to begin with the low profile components such as resistors and diodes and then progress to the taller ones (capacitors, transistors, l.e.d. and terminal blocks). Resistor R7 should be omitted if the "door open" signal is not required and diode D7 fitted if a latched output is required. Diodes D4 to D6 should be fitted or omitted as required in accordance with Table 1.

The circuit is designed to operate with virtualy any keyboard as long as it has matrix connections (i.e. rows

Table 1.

DIODE	POSITION	FUNCTION
D4	A Not fitted	Latched Output Momentary Output
D5	B C D Not fitted	# 1805 Code # 1914 Code # 1939 Code # 1066 Code
D6	E F G Not fitted	1 Incorrect Entry Allowed 2 Incorrect Entries Allowed 5 Incorrect Entries Allowed 255 Incorrect Entries Allowed
D7	H I J Not fitted	10 secs Lockout Time 15 secs Lockout Time 25 secs Lockout Time 5 secs Lockout Time
R7	Fitted Not fitted	DOOR OPEN Warning No Warning

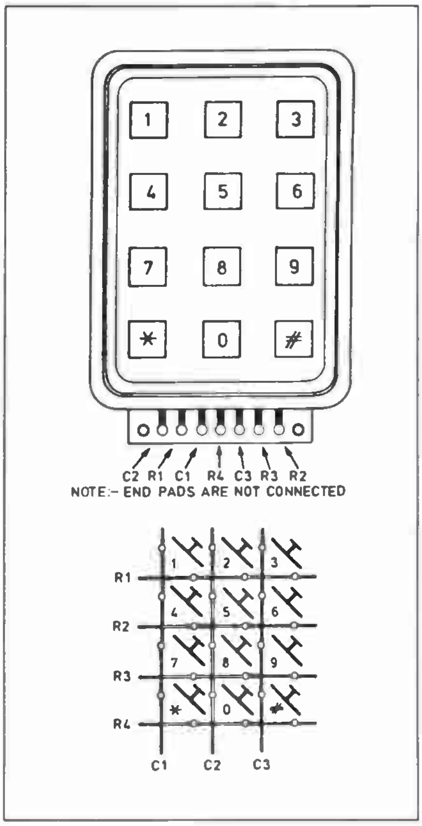
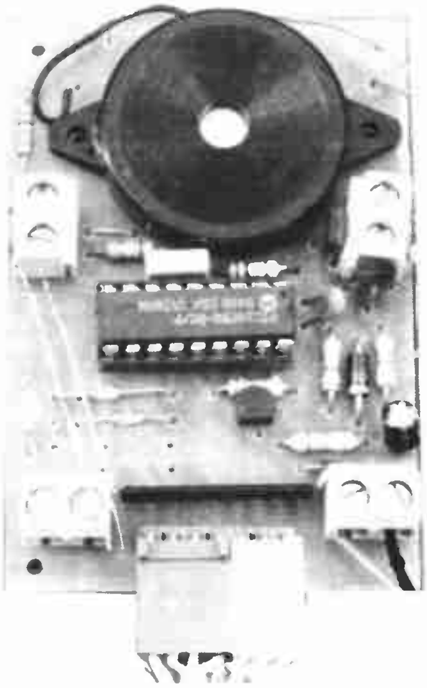


Fig. 4. Keyboard connection details.

and columns) and is not one with a common connection. These are easily distinguished as a 12-way keyboard with a common connection will have 13 terminals while a matrix connected keyboard will have only seven. The choice of keyboard will depend largely on the application, personal preference and of course cost. If the unit is to be mounted outside then a weather proof type should be used, but as long as it is not subjected to driving rain then a membrane type or the low cost conductive rubber type specified may suffice.

The connections for the keyboard used are shown in Fig. 4 but if your keyboard does not have the same connections this is not too important as long as the column connections of the keyboard are connected to the column connections on the printed circuit board and likewise with the rows. In this case the circuit will work, although the numbers will be different and in particular the functions of the "*" and "#" keys may be performed by two of the numbered keys. The wiring details used by the author are shown in Fig. 5.



Although the keyboard could be wired directly to the board using short lengths of stiff copper wire, it is best from a security point of view to mount the keyboard remotely from the unit on a length of ribbon cable. This enables the circuit board to be mounted within the protected area with only the keyboard outside and prevents anyone from simply shorting out the output transistor on the printed circuit board to gain access, which could be easy to do if the whole unit were mounted outside.

KEY PLUGGED

Installation is also made much easier if a plug and socket are fitted to enable the keyboard to be "plugged" into the circuit. Any suitable miniature 7-way plug and socket such as a DIN or D-type connector may be used although a 7-way p.c.b. pin header and mating crimp socket are probably the simplest. These are available in 0·1in spacing in 2, 3 and 4-way versions so a 7-way version can be easily made up.

If other keyboards are used, such as membrane types or even ones made up from individual switches (as long as the switches are connected in a 4 × 3 matrix), the method of connection will need to be modified to suit. In some applications, it may be desirable to fit the l.e.d. and sounder near the keyboard so that a similar ribbon cable/plug and socket arrangement would be required. To prevent noise pick-up on the keyboard inputs, leads should be kept as short as possible.

Note that this circuit uses a piezo sounder or piezo element which should not be confused with piezo buzzers which, as well as the element, also contain an oscillator circuit to produce a sound when connected to a d.c. voltage. The p.c.b. has been designed to accommodate either a p.c.b. mounted sounder or one with flying leads.

TESTING

When assembly is complete the circuit may be tested using a 9V d.c. supply (or a 9V PP3 battery) with the correct polarity connected to terminal block TB4. Light emitting diodes with one kilohm series resistors may be connected from the terminals of TB3 to the positive line to simulate the solenoid and siren. A toggle or slide switch maybe used to replace the reed

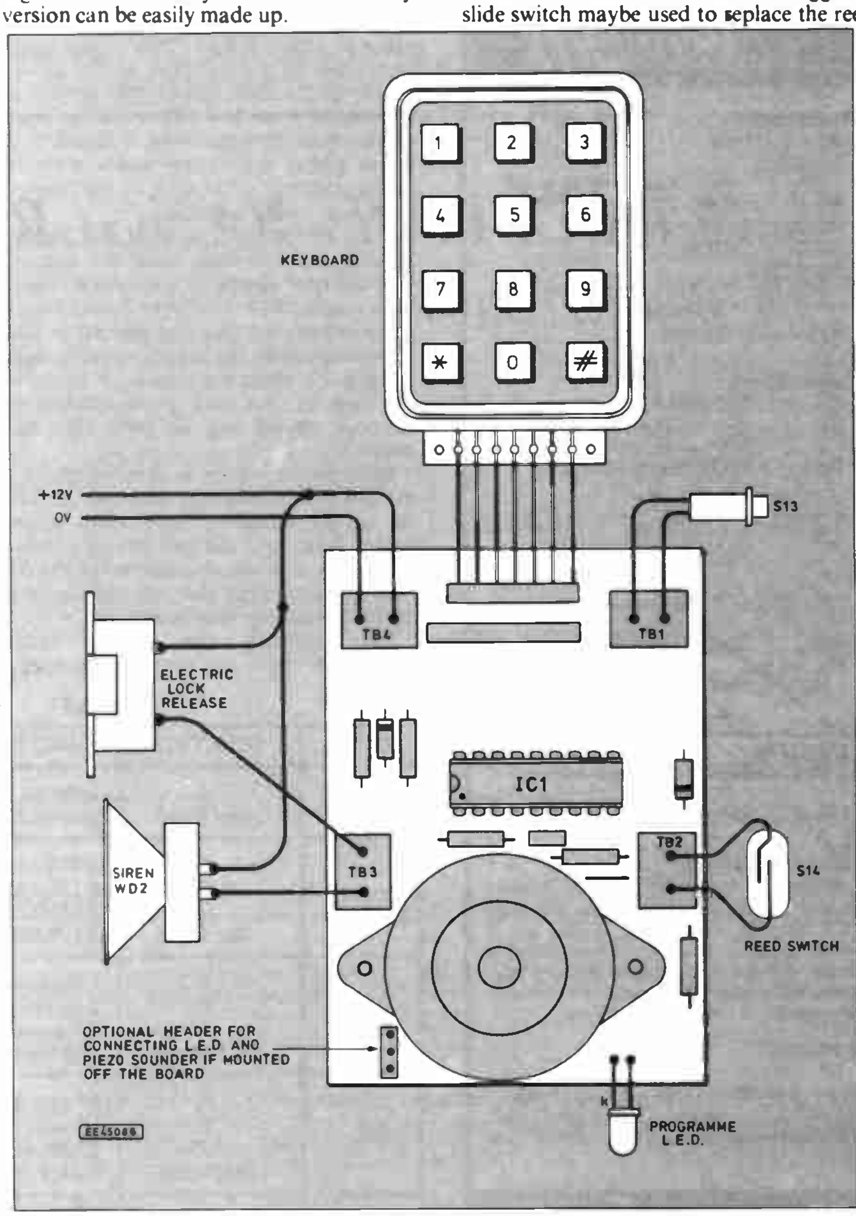
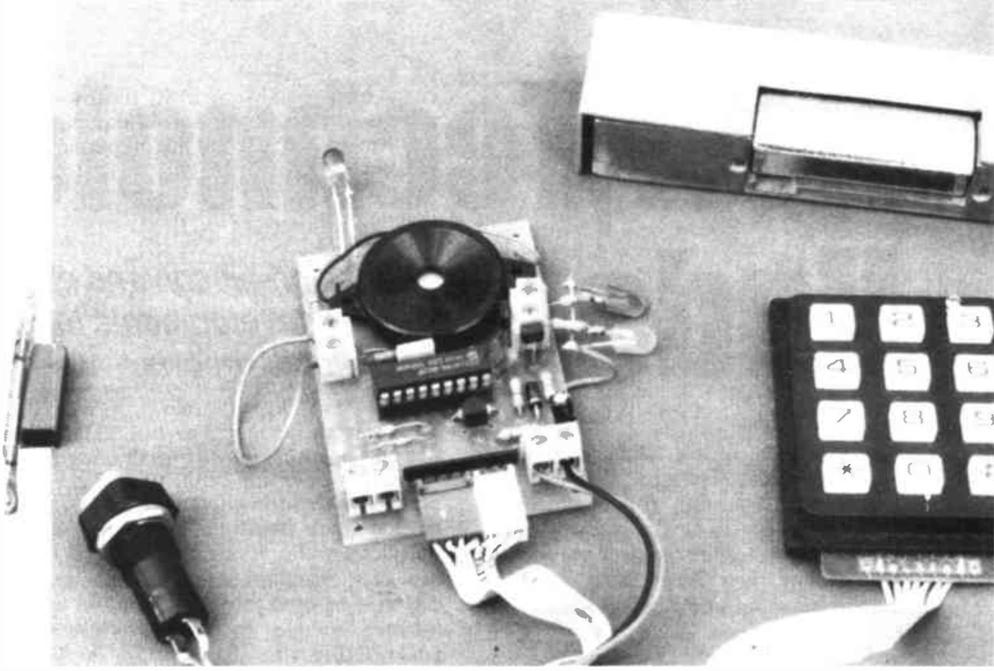


Fig. 5. Details of the interconnections between the printed circuit board and the other components.

switch and connected between the terminals of TB2. A push-to-make switch, S13, should also be connected to the terminals of TB1.

Before plugging in the chip, switch on and check with a voltmeter that you have +5V between pins 5(−) and 14(+) of the i.c. socket. If this is not the case, check the polarity of the Zener diode D2 and transistor TR3. If all is well, *switch off* and insert the chip into its socket.

Note the diode settings and switch on. All the l.e.d.s should be off and the operation of the circuit should be checked. If the circuit appears to go into alarm mode immediately on switch on, check that the switch substituting for the reed switch is closed. If the circuit appears to ignore any keyboard entry, check that diodes D4 to D7 (where fitted) are soldered the correct way around.



INSTALLATION

No details are given for enclosing the unit as so much will depend on how and where the circuit is to be used. For a door lock application, the circuit could be housed in a suitably sized plastic box which could also house the power supply and battery if used. This could be mounted conveniently near to the door to avoid long cable runs to the keyboard, electric lock mechanism, reed switch and siren. Switch S13 could be mounted on the box. Whether or not the piezo sounder is mounted in the box will depend on if it can be heard from the location of the keyboard.

The keyboard could be mounted on some kind of decorative panel, on which the l.e.d. (and sounder) could also be mounted. The panel need not be particularly robust (such as the thick steel panels normally used in such applications) unless you are afraid of someone wilfully vandalising the keyboard out of sheer desperation at being unable to break the code. If the unit is constructed with the electronics separate as suggested above, removing or smashing the keyboard will only make entering numbers more difficult, making it even harder to get in. □

New Technology Update

Glass-on-silicon and etched aerials are two of the latest developments in communications technology – Ian Poole reports.

THIS month we are taking a look at some of the developments which are taking place in radio communications. This technology is now a major growth area of the electronics industry. As people are finding they need more versatile mobile communications, developments in radio are taking place at an ever increasing rate.

New breeds of cellular phones and cheaper prices as well as developments in data transmission, and of course the rise in satellite television, have all fuelled a tremendous amount of development. Many of the new developments have already hit the market place and we are beginning to see the rewards. There are, though, still a very large number in the pipe line which promise some exciting improvements for the future.

Microwave I.C.s

The enormous growth in radio telecommunications has brought about a need for cheap high performance microwave i.c.s. In the past, microwave components have been notoriously expensive, but the increased markets have now given many manufacturers the incentives to start developing low cost components for these frequencies.

For some years now low cost MMICs (monolithic microwave i.c.s) have been available for operation at up to frequencies of 1GHz (1000MHz) and more. Now there is an increased demand for greater levels of integration at frequencies of up to 10GHz.

At these frequencies circuit losses become a significant problem. Even conventional glass fibre boards cannot be used because of their poor performance. This results in the use of expensive teflon or p.t.f.e. based boards. If further components could be integrated onto a single chip, then many of the losses could be reduced and costs cut.

Seeing the need for the development of lower cost and more integrated microwave circuits, the Microelectronics Division of M A Com Inc. have developed a new glass microwave i.c. technology. This allows microwave i.c.s and discrete components to be placed onto the same substrate to give high performance for a relatively low cost.

When developing circuits for microwave applications there are a number of features which must be included which are not normally present for digital circuits. Low r.f. losses are obviously of paramount importance. In addition to this, tracks between many of the stages and components must form accurately matched transmission lines.

Glass-on-Silicon

To fulfil these requirements M/A Com devised a new structure. Their new glass-on-silicon wafer forms the basis of the new i.c.s. Standard thin film techniques can then be used to place the tracks and transmission lines and lay down the components, (Fig. 1.).

The ground plane is created by using a layer of silver or gold between the glass and silicon. It is then possible to connect to this layer by bringing the ground connection up through the glass using "via" holes similar to those seen in ordinary multi-layered printed circuit boards.

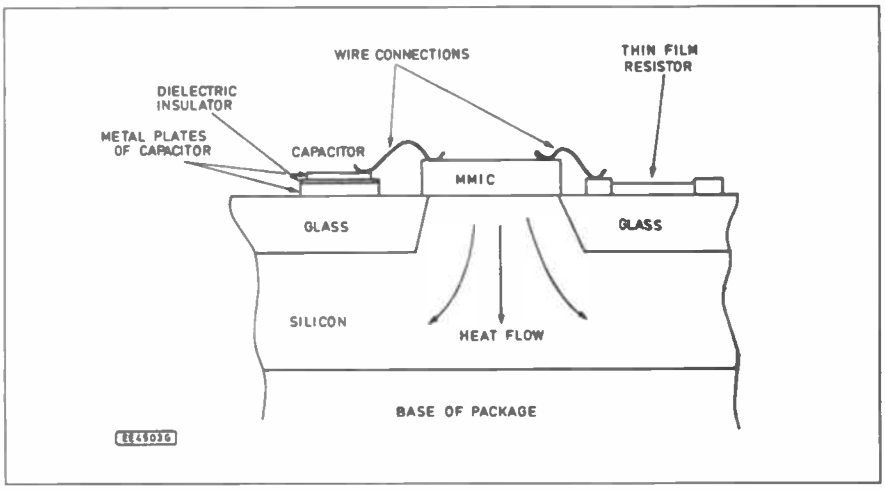


Fig. 1. Part of a typical glass-on-silicon i.c.

The silicon layer itself consists of heavily doped silicon, and this provides a highly conductive path to the outside package.

In the development of this technique, great attention was paid to the thermal aspects of the design. Many microwave i.c.s consume high levels of current, and this results in high levels of heat being generated in localised areas. The silicon itself has high thermal conductivity and it provides an efficient path for the heat to flow away from the i.c.s.

In addition to this, the thermal coefficients of expansion of the glass and silicon are closely matched. This significantly increases the reliability of the final circuit. If this were not so then the resultant stresses built up in the circuits could lead to early failure of some of the components.

These circuits, along with many other new ideas, should help to open up higher frequencies to mass produced products. New generations of cellular phones together with a host of other uses could all benefit as the lower frequencies become fully used and higher ones have to be used to cope with the demand.

New Dishes

Television aerials are a feature of our modern society. Most houses will have one attached to a chimney stack, and there are a growing number of satellite dishes appearing on building walls. In view of this, a number of companies have been working on developing methods of manufacturing less unsightly aerials for a variety of uses, commercial and domestic.

In one development being undertaken at the Georgia Institute of Technology a flat aerial which can be hung in a window, or incorporated into a roof has been developed. Although its current operating range is between 500MHz and 4GHz it is expected to find widespread usage in a variety of applications including TV reception, cellular telephones and even satellite communications. Possible further developments may be able to extend its coverage up to satellite TV frequencies in the region of 12GHz.

The aerials are constructed out of a teflon or p.t.f.e. sheet and the conductors for the aerial are etched out of copper on the sheet using ordinary p.c.b. techniques. These conductors make up an array of dipoles, and by careful choice and calculation of the lengths and positions it is possible to alter the frequency bandwidth and directivity performance.

Once the basic aerial has been manufactured it is mounted in a layer of foam over a metal sheet. This construction ensures that the assembly does not distort and alter its properties.

To aid with the design of the individual aerials the development team use a computer program which enables the basic specifications for the aerial to be turned directly into the artwork needed to manufacture the aerial.

INTERFACE

Robert Penfold

IN LAST month's *Interface* article the basics of fibre-optic data links were discussed. This month we will look at a practical fibre-optic RS232C interface capable of operation at up to 19200 baud.

This system is a simple direct coupled type, and is not of the tone encoded/decoded variety. Consequently its range is not particularly large. However, I found that it was possible to obtain good results using a 10 metre length of fibre-optic cable, and this should be more than adequate for most purposes.

Bright Lights

The transmitter end of the system is really just an electronic switch driving a l.e.d. The transmitter circuit diagram is shown in Fig. 1. Transistor TR1 is a simple common emitter switching stage. It is driven by the serial input signal via the potential divider formed by resistors R1 and R2.

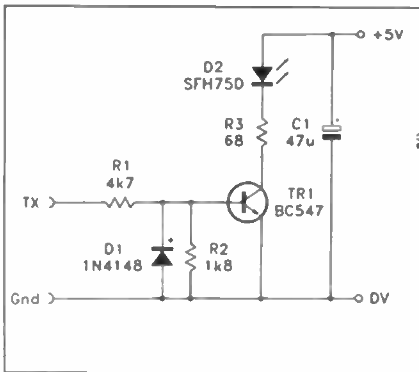


Fig. 1. Circuit diagram for the transmitter section of the fibre-optic data link.

When the input signal is high (at about +3V to +12V) TR1 is biased hard into conduction, and it drives the l.e.d. (D2) by way of current limiting resistor R3. The "on" l.e.d. current is a little over 40mA, but the average current consumption of the circuit will normally be no more than about 20mA.

When the input signal is low (at about −3V to −12V) TR1 is cut off, and it is protected against an excessive reverse base voltage by resistor R1 and diode D1. These limit the base voltage to about −0·7V. Incidentally, the input should be low under standby conditions, which results in the circuit having a negligible current consumption when it is not handling any data.

The circuit will work on a 9V or 12V supply, but the value of resistor R3 must be altered to suit the higher supply voltage, and maintain an "on" current of about 40mA or so. Use a 180 ohm resistor for a 9V supply, or a 270 ohm resistor for a 12V supply.

A direct coupled optical link is heavily dependent on a reasonable amount of light from the transmitter reaching the photocell at the receiver. In order to achieve this, it is necessary to use a proper fibre-optic device at both ends of the system. Improvising with an ordinary l.e.d. and some Blu-Tack is unlikely to give usable results even over a range of a few millimetres!

The specified l.e.d. is a visible red type having a moulded-in orifice to accept a standard 2·2mm diameter cable. The system should work using any similar fibre-optic l.e.d., but I have only tested it using the specified device.

Seeing The Light

The circuit for the receiver is shown in Fig. 2. The photocell is phototransistor TR1, and this a special fibre-optic type which has a moulded-in receptacle for the cable. It is used as what is effectively an emitter follower stage driving a common emitter switch, transistor TR2.

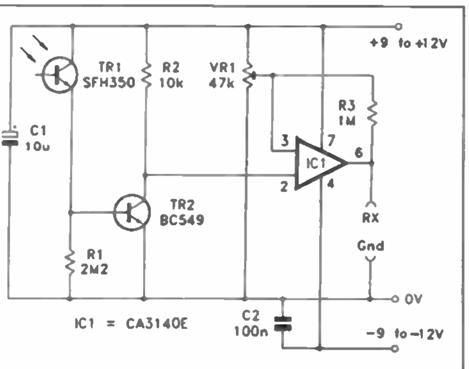


Fig. 2. Circuit diagram for the fibre-optic data link receiver.

Under standby conditions TR1 passes only minute leakage currents. The emitter load resistor (R1) ensures that these currents are insufficient to even partially bias TR2 into conduction. The pulses of light from the transmitter result in much greater leakage currents through TR1, causing TR2 to conduct strongly. Op.amp IC1 acts as a trigger circuit and level shifter. This gives an output signal that switches rapidly and cleanly at normal RS232C levels.

For IC1 to provide proper RS232C signal voltages it must have a negative supply of around −9V to −12V. In practice it may well be found that satisfactory results are obtained even if IC1 pin 4 is simply connected to the 0 volt supply rail, especially if only a short cable is used to connect the receiver to the peripheral device.

If dual supply operation proves to be necessary, the negative supply can be generated from the positive supply using the circuit of Fig. 3. Note that this circuit should not be used on a supply voltage of more than 10V. The receiver circuit only consumes about 3mA from each supply rail.

Clear-Cut

The correct cable to use with the SFH350 phototransistor and SFH750 l.e.d. is a single core type having an outer diameter of 2·2mm and an inner core 1mm in diameter. A fibre-optic cable will only operate efficiently if both ends are properly prepared.

Cables are not usually supplied with either end of the filament prepared and ready for use, and they are often very inefficient as supplied. The ends of the polymer filament can be polished, but there seems to be no real need to do this. Provided the ends of the cable are cut neatly and cleanly at right angles the cable should provide high transmission efficiency.

I find that the best way of doing this is to trim off the ends of the cable using a modelling knife fitted with a *new* blade. Place the end to be trimmed on a cutting board, and then cut through the cable in one go using plenty of pressure (but taking due care to cut nothing other than the cable). Make sure that the cut is at right angles to the cable. When both ends have been prepared, aim one end of the cable at a light source and check that plenty of light can be seen coming from the other end of the cable.

The SFH350 and SFH750 have holes into which the cable must be pushed fully home. They do not require any of the cable's outer sleeving to be removed. The cable is a simple push-fit, and it pulls out again just as easily as there is no form of built-in grip.

It should not be too difficult to devise a simple method of clamping the cable in place so that it is not continually being pulled out of the photocells, but be careful not to clamp it too tightly. Any damage to the polymer filament could seriously reduce the efficiency of the cable. Note that the clear casing of the SFH350 makes it sensitive to any ambient light. It must therefore be shielded from any bright light sources.

Adjustment

Preset potentiometer VR1 must be given a setting that will accurately retain the input waveform at high baud rates. At these baud rates, particularly 19200 baud, the collector

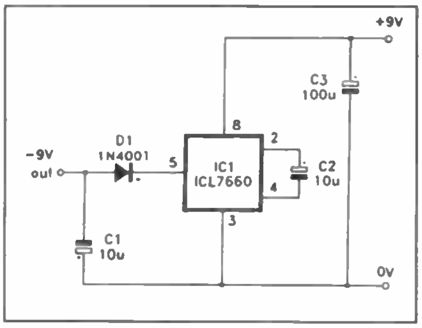


Fig. 3. Simple negative supply generator.

of transistor TR2 at the receiver switches relatively slowly from one level to the other.

Probably the easiest method of setting VR1 is to first measure the positive supply voltage of the receiver circuit. Then at the transmitter circuit, temporarily connect the "TX" input to the +5V supply rail so that l.e.d. D2 switches on.

Next measure the voltage at the collector of phototransistors TR1. This should be about 5V or more below the positive supply voltage. If the voltage drop is much less than this it is unlikely that the unit will work properly, especially at high baud rates.

Preset VR1 should be adjusted for a wiper potential that is half way between this voltage and the actual supply voltage. For example, if the voltage at the collector of TR2 is 5·6V, and the measured supply potential was 11·8V, VR1 should be adjusted for a wiper voltage of 8·7V (5·6V + 11·8V = 17·4V, 17·4V divided by 2 = 8·7V). Alternatively, if a logic pulse generator and an oscilloscope are available, feed a 10kHz squarewave signal to the input of the transmitter, and then adjust VR1 for a 1-to-1 squarewave output from the receiver.

Handshaking

A single fibre-optic data link is only suitable for one-way (simplex) operation, and it does not support any form of handshaking. If two-way operation is needed it is necessary to build two complete systems, one for communication in each direction. The two links must use separate optical cables.

If handshaking is needed it is possible to accommodate it using additional links. This is not a particularly neat or cheap way of handling the problem though. Where possible it is best to avoid handshaking altogether by using a low enough baud rate to ensure that the receiving device does not become overloaded with data. If some form of handshaking is essential, a two-way link and software handshaking may well be the simplest and most versatile solution.

Projects that connect to the serial port of a computer can usually be relied upon to bring in a few letters from readers who are experiencing difficulty in getting the computer to output any data. The problem does not usually arise when the serial port hardware is being controlled directly, and it is mainly when data is sent to the port via the computer's operating system that difficulties occur.

The important point to bear in mind here is that although your hardware add-on may not be using any form of hardware handshaking, it is quite likely that the computer's operating system will be monitoring and responding to the handshake lines. This means that it is often necessary to activate a handshake input (i.e. take it high) before the computer will output any data. If the handshake output or outputs are not being used, these usually represent the most simple way of activating one or more handshake inputs.

With the BBC computers, simply linking the two handshake lines enables data to be output from the RS423 port. With PCs the method of connection shown in Fig.4 should enable a flow of data from the port. In this case two sets of handshake lines must be linked (RTS to CTS, and DTR to DSR). Presumably the same general technique will work equally well with other computers.

Beating Time

A number of PC shareware companies are now distributing shareware and commercial demo disks that have a sort of built-in timeout function. The software works fine until a certain date is reached, and thereafter it refuses to run. Instead you simply get an on-screen message explaining that the disk is past its use-by date. This is fair enough, but many of these disks originate in the USA, and are near or past their expiry dates by the time they reach British users.

Fortunately, with most of these disks there is no difficulty in getting them to run so that you can try out the software. Simply using the computer's built-in setup program to set the clock/calendar back to a suitable date seems to do the trick. The programs are probably reading the MS/DOS clock/calendar rather than directly accessing the hardware clock, so it would probably be possible to fool these programs into action simply by using the usual MS/DOS DATE command.

Fibre-optic cable 2·2/1·0mm is available from Maplin (order code (XR56L). The SFH350 phototransistor and SFH750 l.e.d. are available from ElectroValue.

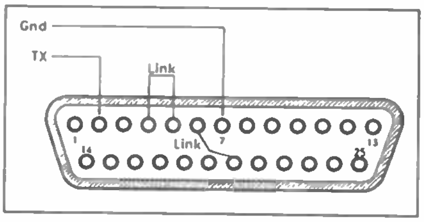
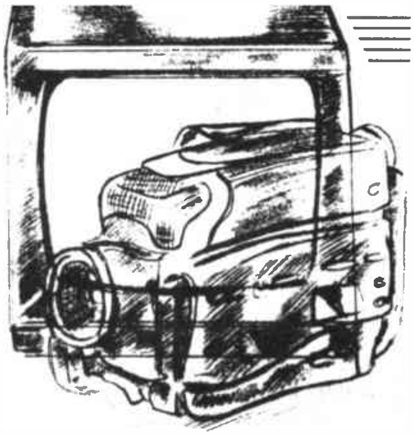


Fig. 4. A method of connection that permits an easy flow of data from a PC serial port.

Constructional Project

VIDEO MODULES
HORIZONTAL WIPER



ROBERT PENFOLD Part Two

Your home videos will take on a whole new meaning if you build these low cost modules. Professional presentations couldn't be easier! You can tailor the controller to meet your own special needs and budget.

- *Simple and Improved Faders* • *Horizontal and Vertical Wipers*
- *Video Enhancer* • *4-Channel Audio Mixer*
- *Audio Dynamic Noise Limiter* • *System PSU*

LAST month we dealt with simple video faders and also gave details for a Video Enhancer to boost picture definition. This month we introduce the subject of video wipers plus we describe the construction of a simple 4-Channel Audio Mixer.

Video wipers offer an interesting alternative to faders. The two basic types of wiper are the horizontal and vertical types.

A wiper operates on the basis of having part of the screen showing a normal picture, and the other section completely blanked. The blanked part of the screen is normally black, but a wiper circuit could be designed to have the blanked area of screen white, or any shade of grey. The wipers featured here produce the usual black area of blanked screen.

With a vertical wiper the screen is progressively blanked from the top downwards until all the visible part of the screen has been blanked. At the beginning of the next scene the picture is restored from the bottom upwards.

Most vertical wipers offer the alternative of blanking from the bottom upwards, and restoring the picture from the top downwards. A horizontal wiper provides a side-to-side blanking and restoring action.

HOW IT WORKS

The block diagram of Fig. 9 helps to explain the way in which the Horizontal Wiper functions. This is similar in many respects to the Improved Fader circuit described last month, and the Horizontal Wiper has been developed from the Improved Fader circuit.

The input signal is split two ways, with part of the signal being fed to a synchronisation separator. This provides output pulses which trigger a monostable at the beginning of each line synchronisation pulse.

The monostable has a variable output pulse duration, and it is the pulse length potentiometer that acts as the wiper control. With the minimum pulse duration set, the pulse ends just as the luminance signal begins. With the maximum pulse duration set, the pulse finishes at the end of the current line scan.

In the other signal path there is a d.c. restoration circuit, an electronic switch, and an output amplifier. The electronic switch is controlled by the monostable, and it permits the input signal to pass through to the output of the unit only during a pulse from the monostable.

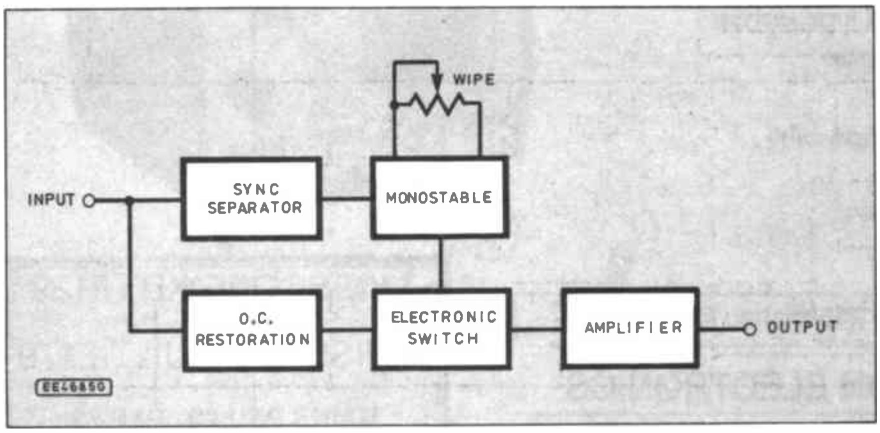


Fig. 9. Block diagram for a horizontal wiper.

The waveform of Fig.10a is a section of the input signal, and Fig. 10b is the processed output signal. Although there is a small gap between one pulse and the next, and a section of the signal is blanked, the missing section is very small. It does not carry any important picture information.

By shortening the pulse length slightly, the electronic switch is turned off just before the end of each line scan. This results in the extreme right hand section of the screen being blanked. If the monostable's pulse duration is set at about half its maximum length, the electronic switch will be turned off about half way through each line scan, and the right half of the screen will be blanked.

Reducing the pulse length to its minimum duration results in the switch being turned off just before the luminance signal commences, and the entire screen is then blanked. Waveforms Fig. 11 and Fig. 12 show the way in which this process operates.

CIRCUIT DETAILS

The full circuit diagram for the Horizontal Video Wiper is shown in Fig. 13. This has obvious similarities with the Improved Wiper circuit, including the same synchronisation separator circuit based on transistors TR1 and TR2.

This again drives a negative edge triggered monostable based on a 4047BE (IC1), but the *C/R* timing network is different. Resistor R8 sets the minimum pulse duration at a suitable figure, and VR1 is the Wiper control. Resistor R9 and preset VR2 are connected in parallel with VR1, and VR2 is used to trim the maximum pulse duration to precisely the correct figure.

The d.c. restoration, electronic switch, and output amplifier sections are also much the same as their equivalents in the Improved Fader circuit. The obvious difference is that the input of IC2b is simply wired to "earth", (0V) rather than being fed an the input signal via a "fader" potentiometer. The current consumption of the circuit is typically about 25mA.

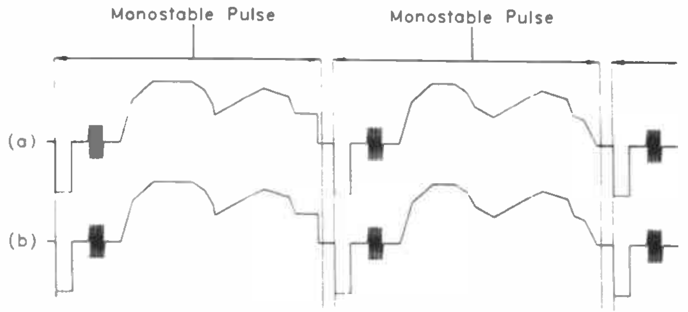


Fig. 10. With the maximum pulse length each line signal passes unprocessed.

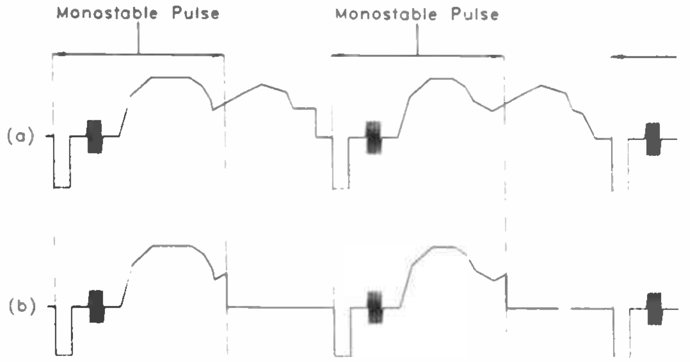


Fig. 11. The effect of the circuit with about half the maximum pulse duration.

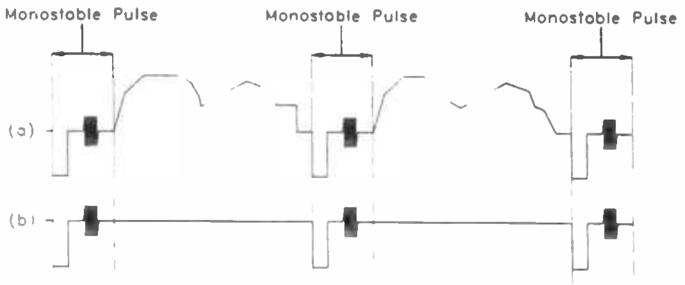


Fig. 12. The effect of the circuit with the minimum pulse length.

COMPONENTS

HORIZONTAL WIPER

Resistor

R1, R19	470 (2 off)
R2, R3, R10	47k (3 off)
R4	18k
R5, R7, R13, R15, R18	4k7 (5 off)
R6, R9	33k (2 off)
R8	5k6
R11, R12	22k (2 off)
R14	1k
R16	220k
R17	12k
R20	68

All 0·25% carbon film

See SHOP TALK Page

Potentiometers

VR1	47k rotary carbon, linear
VR2	100k min. preset, horizontal

Capacitors

C1	220n polyester
C2	10µ radial elect. 25V
C3	10n polyester
C4	1n polyester
C5	100µ radial elect.
C6	100n ceramic
C7, C8, C9	100µ radial elect. 10V (3 off)

Semiconductors

IC1	4047BE CMOS timer
IC2	4016BE or 4066BE CMOS analogue siwtch
TR1	BC557 *pnp* silicon transistor
TR2, TR3, TR4, TR5	BC547 *npn* silicon transistor (4 off)
D1, D2	1N4148 signal diode (2 off)

Miscellaneous

SK1, SK2	phono socket (2 off)

Printed circuit board available from the *EPE PCB Service*, code 916; 14-pin i.c. holder (2 off); control knob; connecting wire; single-sided solder pins; solder etc.

Approx cost guidance only **£14**

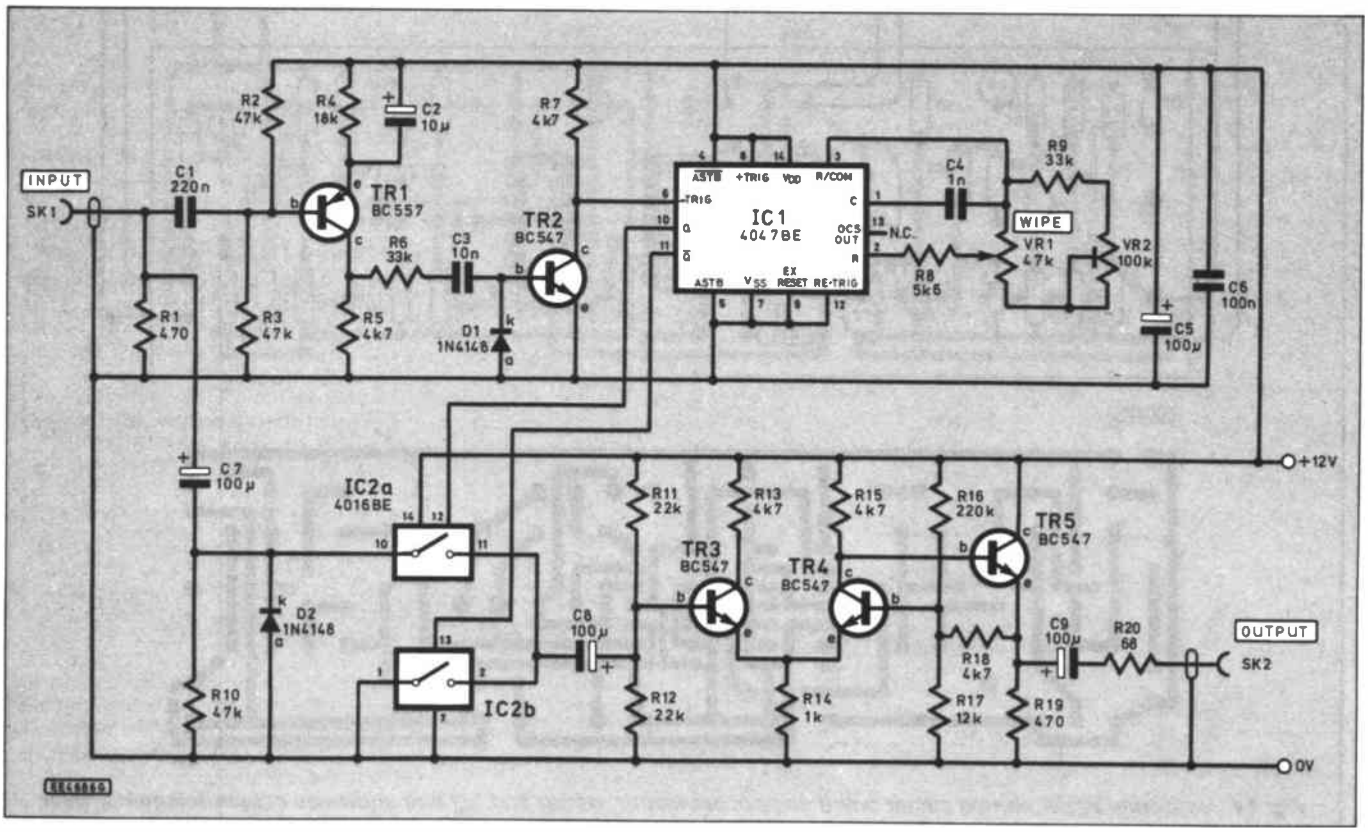


Fig. 13. Complete circuit diagram for the Horizontal Video Wiper.

CONSTRUCTION

The printed circuit board (p.c.b.) component layout and full size underside copper foil design for the Horizontal Wiper is shown in Fig. 14. This board is available from the *EPE PCB Service*, code 916.

As IC1 and IC2 are CMOS integrated circuits the normal anti-static handling precautions should be taken. Use holders for these two components, and do not plug them into the p.c.b. until the unit is complete.

Do not overlook the two link-wires (below IC2). Construction of the board is perfectly straightforward in all other respects. The small amount of hard wiring is also clearly illustrated in Fig. 14.

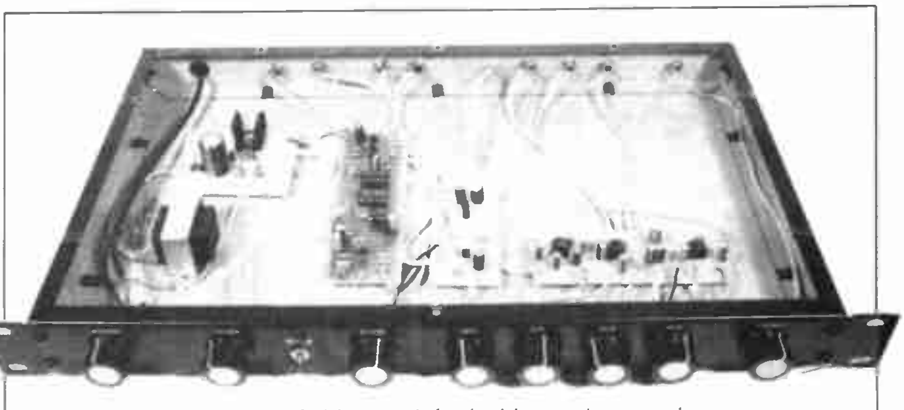
TESTING

To test the unit connect it between the video output of a camcorder and the composite video input of a suitable television or monitor. Start with preset VR2 at a roughly middle setting. The unit should function more or less correctly, but VR2 must be set so that none of the screen is blanked with Wipe control VR1 at maximum resistance. This is just a matter of setting VR1 at maximum resistance and adjusting VR2 for the correct picture.

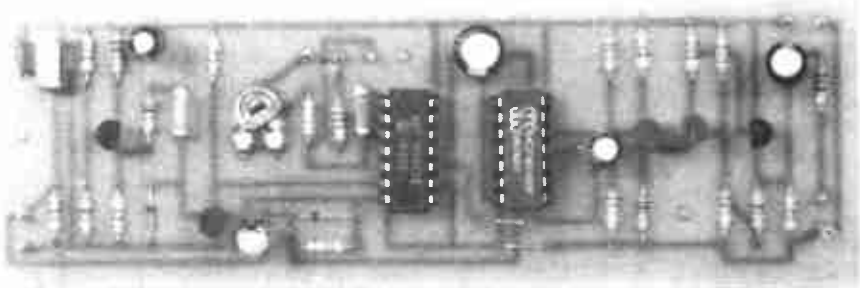
If VR2 is set too low in value (too far in a clockwise direction) the right hand section of the screen will be blanked. If it is set too high in value the beginnings of every other line scan will be blanked, probably resulting in a severe loss of picture stability. There should be a narrow range of in-between settings that give the desired result.

It is just possible that with VR1 at minimum resistance there will be a very narrow band down the left hand side of the screen which is not blanked. Reducing the value of resistor R8 to 4k7 should cure this problem.

If the monostable is set for the maximum pulse duration, the electronic switch is in the "on" state for what is virtually the whole of each line scan, and the input signal is effectively passed though to the output without any processing. The television or monitor therefore shows an unblanked screen. Fig. 10 helps to explain this process.



General layout of video modules inside a rack-mounting case.



The completed Hozizontal Wiper circuit board.

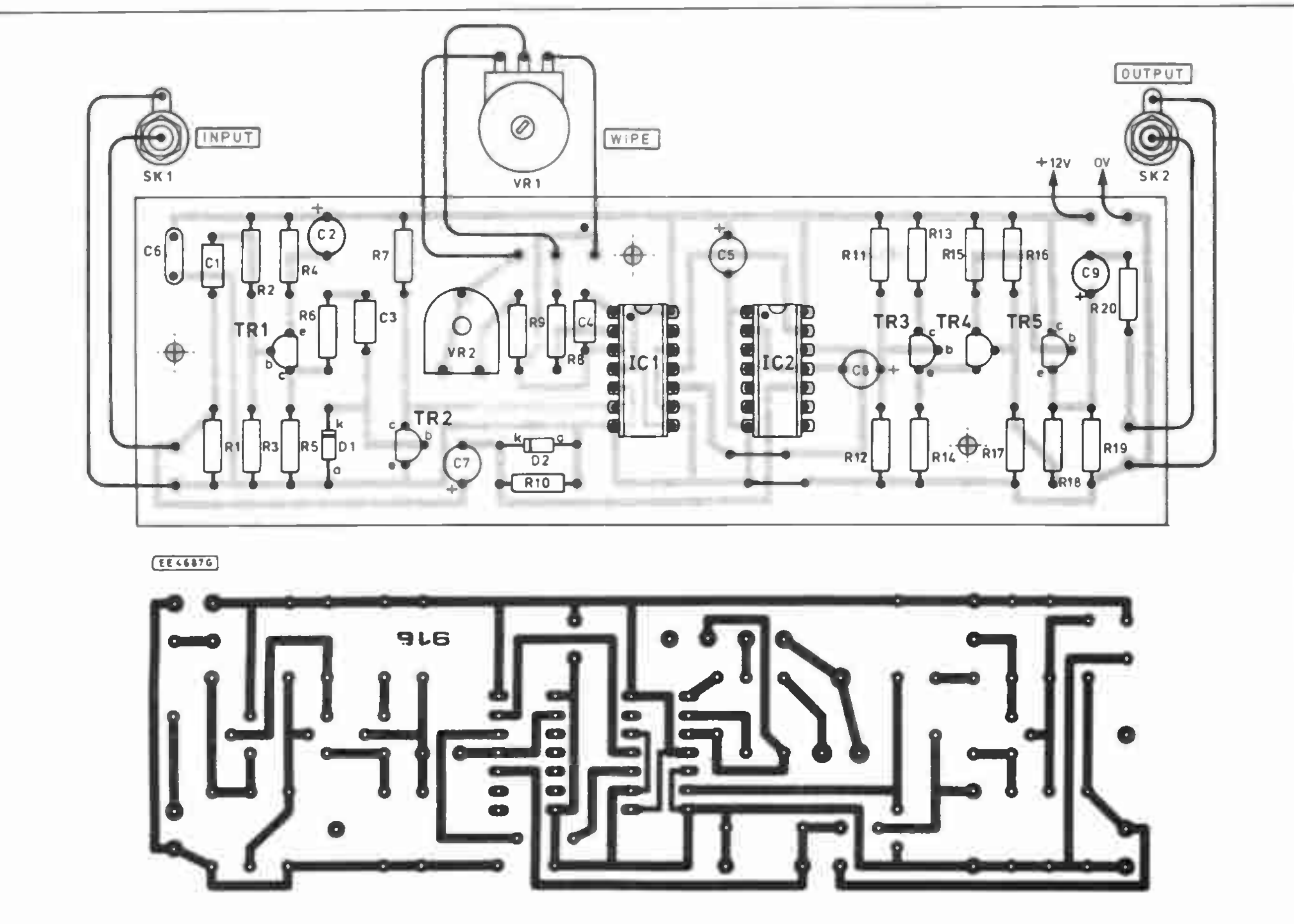
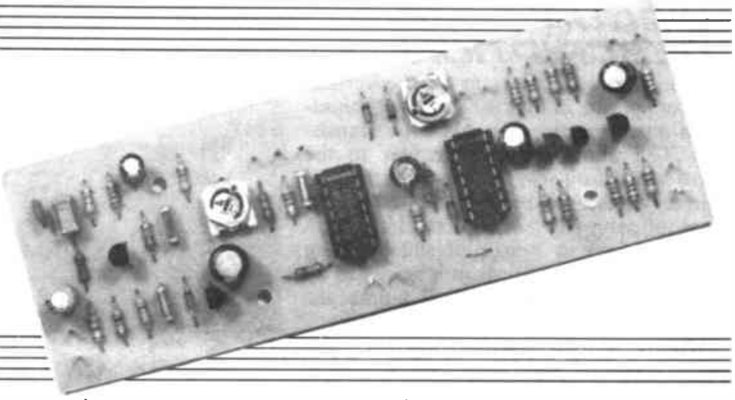


Fig. 14. Horizontal Wiper printed circuit board component layout, wiring and full size underside copper foil master track pattern.

VERTICAL WIPER



Blanking the television or monitor screen using the "frame-by-frame" technique.

A VERTICAL wiper operates in a manner which is not dissimilar to a horizontal type, but there are some important differences between the two types of circuit. Fig. 15 shows the block diagram for the Vertical Wiper module.

Like the Horizontal Wiper, this arrangement has part of the signal fed to a synchronisation separator, with the resultant output pulses driving a monostable multivibrator. This in turn controls an electronic switch.

The synchronisation separator used in this application is different to the one used in the Horizontal Wiper. This circuit must operate on a "frame-by-frame" basis, rather than using a line-by-line approach. Accordingly, the synchronisation separator produces a trigger pulse for the monostable at the beginning of each frame synchronisation pulse.

The pulse duration of the monostable can be varied via a potentiometer, and this acts as the Wipe control. As the blanking process is being applied to frames rather than to lines, the maximum pulse duration is much longer in this application. It is approximately equal to the duration of one frame, or about 20ms in other words.

ELECTRONIC SWITCH

The electronic switch is a changeover type, and one input is fed with the full composite input via a d.c. restoration circuit. The other input is fed via a luminance stripper circuit which removes the brightness modulation signal, but leaves the negative synchronisation pulses (both the frame and the line types).

With the monostable set for its minimum pulse duration the full composite signal is only switched through to the output for the first few lines. As these are not displayed on a correctly adjusted television or monitor, this has no effect on the displayed picture. For the rest of each frame the luminance stripped signal is fed through to the output. This gives a blanked screen, but it contains the line synchronisation signals that are necessary to maintain a stable picture.

As the monostable pulse duration is increased, more lines at the top of the screen have the luminance signal, and the picture is "wiped" onto the screen from the top downwards. With the maximum pulse duration only a few lines at the bottom of the screen are wiped. As these are not normally displayed, a normal picture appears on the screen of the television or monitor. Gradually shortening the pulse duration of the monostable has the opposite effect, and "wipes" the picture from the screen.

Although this setup "wipes" away the signal from the bottom upwards, and reintroduces it from the top downwards, it is easy to obtain the opposite effect. Simply inverting the control signals to the electronic switch results in the picture being wiped from the top downwards, and reintroduced from the bottom upwards.

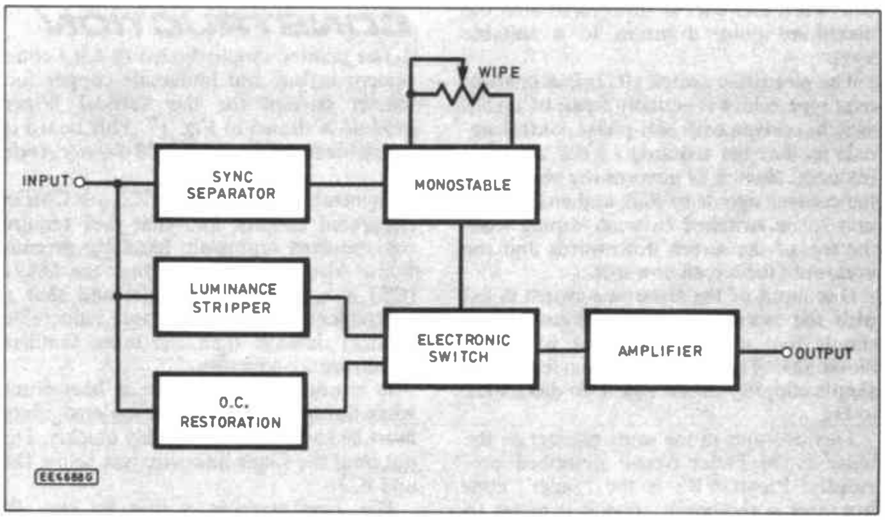


Fig. 15. The Vertical Wiper module block diagram.

COMPONENTS

Approx cost guidance only **£15**

VERTICAL WIPER

Resistors

R1	120
R2	390
R3, R4	47k (2 off)
R5	18k
R6, R8, R11, R12, R15, R17	4k7 (6 off)
R7	10k
R9	2k7
R10	560k
R13, R14	22k (2 off)
R16	1k
R18	220k
R19	12k
R20	5k6
R21	470
R22	68

All 0·25 5% carbon film

See SHOP TALK Page

Potentiometers

VR1	470k rotary carbon, linear
VR2, VR3	1M min. preset, horizontal (2 off)

Capacitors

C1	220n polyester
C2	10µ radial elect. 25V
C3	15n polyester
C4	1n polyester
C5	22n polyester
C6	100µ radial elect. 16V
C7	100n ceramic
C8, C9, C10, C11	100µ radial elect. 10V (4 off)

Semiconductors

IC1	4047BE CMOS timer
IC2	4016BE or 4066BE CMOS analogue switch
TR1	BC557 *pnp* silicon transistor
TR2, TR3, TR4, TR5	BC547 *npn* silicon transistor (4 off)
D1, D2, D3, D4	1N4148 signal diode (4 off)
D5	OA91 germanium signal diode

Miscellaneous

S1	d.p.d.t. min. toggle switch
SK1, SK2	phono socket (2 off)

Printed circuit board avaiable from the *EPE PCB Service*, code 917; 14-pin i.c. holder (2 off); control knob; connecting wire; 1mm single-sided solder pins; solder etc.

CIRCUIT DESCRIPTION

The full circuit diagram for the Vertical Wiper appears in Fig. 16. The synchronisation separator circuit is based on transistor TR1 and TR2. It is similar to the synchronisation separator used in the previous two circuits, but it incorporates low-pass filtering (R7 and C3) so that it will only respond to signals of suitably long duration. In other words, it is activated by the frame pulses, but it will ignore the much shorter line synchronisation pulses.

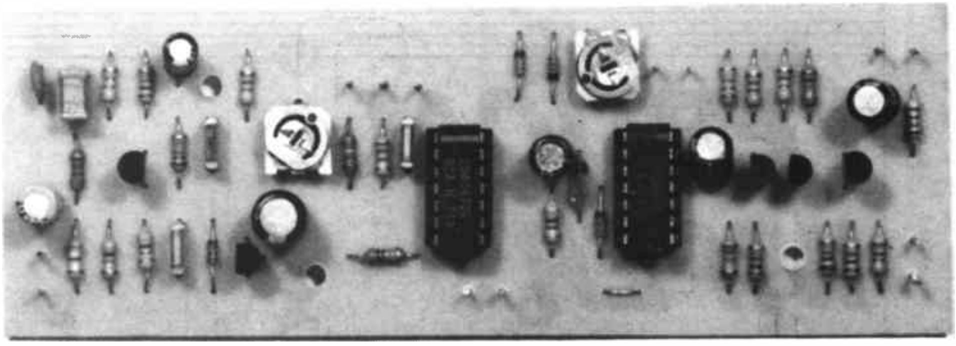
Once again, the monostable is a negative edge triggered type based on a CMOS 4047BE. In this case the values in the *C/R* timing network have been chosen to give much longer pulse durations. Resistor R9 sets the minimum pulse duration at a suitable figure of about 150µs. Potentiometer VR1 is the Wiper control, and this permits the pulse duration to be varied up to about 20ms. The series resistance of R10 and preset VR2 is connected in parallel with VR1, and VR2 is adjusted to limit the maximum pulse duration to a suitable level.

The electronic switch (IC2) is a changeover type, which is actually a pair of s.p.s.t. switches driven with anti-phase control signals so that the required s.p.d.t. action is obtained. Switch S1 governs the phasing of the control signals to IC2, and enables the unit to be switched between wiping from the top of the screen downwards and the bottom of the screen upwards.

One input of the electronic switch is fed with the normal composite signal via a simple d.c. restoration circuit based on diode D5. The other input is fed via a simple clipping circuit based on diodes D2 to D4.

This operates in the same manner as the basic Video Fader circuit described previously. Preset VR3 is the "fader" control, and in this application it is preset to give a fully faded signal, so that only the synchronisation pulses are passed through to IC2.

Transistors TR3 to TR5 are used in a buffer amplifier, at the output of the circuit. The current consumption of the circuit is typically a little under 25mA.



Component layout on the completed Vertical Wiper p.c.b.

CONSTRUCTION

The printed circuit board (p.c.b.) component layout and underside copper foil master pattern for the Vertical Wiper module is shown in Fig. 17. This board is available from the *EPE PCB Service*, code 917.

Remember that IC1 and IC2 are CMOS integrated circuits, and that they require the standard anti-static handling precautions. Also bear in mind that the OA91 (D5) is a germanium diode, and that a component of this type is more vulnerable to heat damage than the more familiar silicon semiconductors.

It is not essential to use a heat-shunt when fitting D5, but the two soldered joints must be completed reasonably quickly. Do not omit the single link-wire just below D4 and IC2.

The point-to-point wiring is also illustrated in Fig. 15. This is very straightforward, and should give no problems.

ADJUSTMENT

Like the units described previously, testing and setting up this device is easiest if it is connected between a camcorder and a suitable television set or monitor. With presets VR2 and VR3 set at roughly middle settings the unit should work to some degree. Preset VR3 should be adjusted for the lowest resistance that gives a properly "wiped" screen. In other words, it should be given the most clockwise setting that gives good results.

Preset VR2 must be set for the lowest resistance that enables the full screen to be "wiped". This should be carried out with switch S1 set for a "top downwards" wipe of the screen. If VR2 is set for too low a resistance it will not be possible to fully "wipe" the screen.

If VR2 is set for an excessive resistance, with VR1 at around maximum resistance the screen blanking will only occur on every other frame, giving a very flickery picture. Finding the right setting for VR2 is a matter of first setting VR1 at maximum resistance, and then using a bit of trial and error.

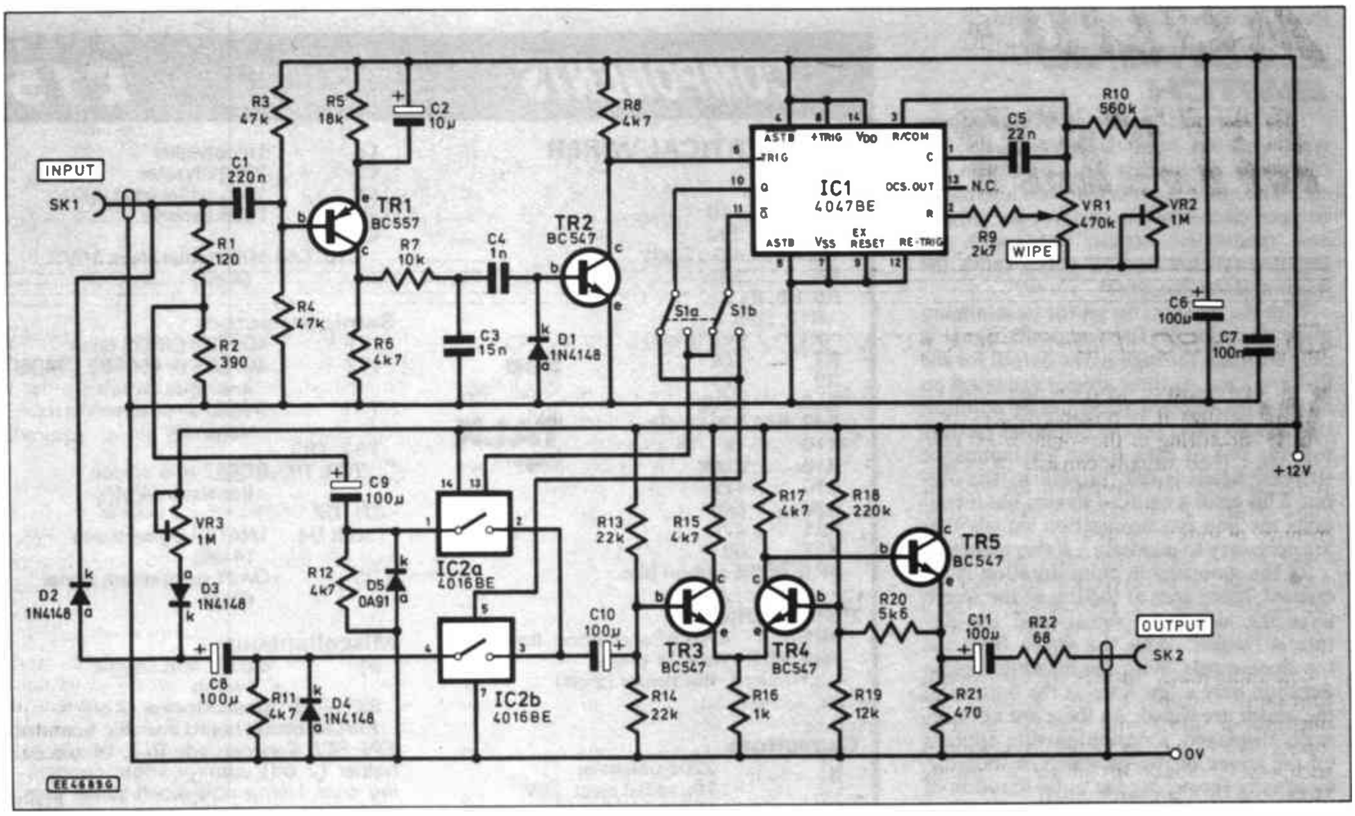


Fig. 16. Full circuit diagram for the Vertical Wiper module.

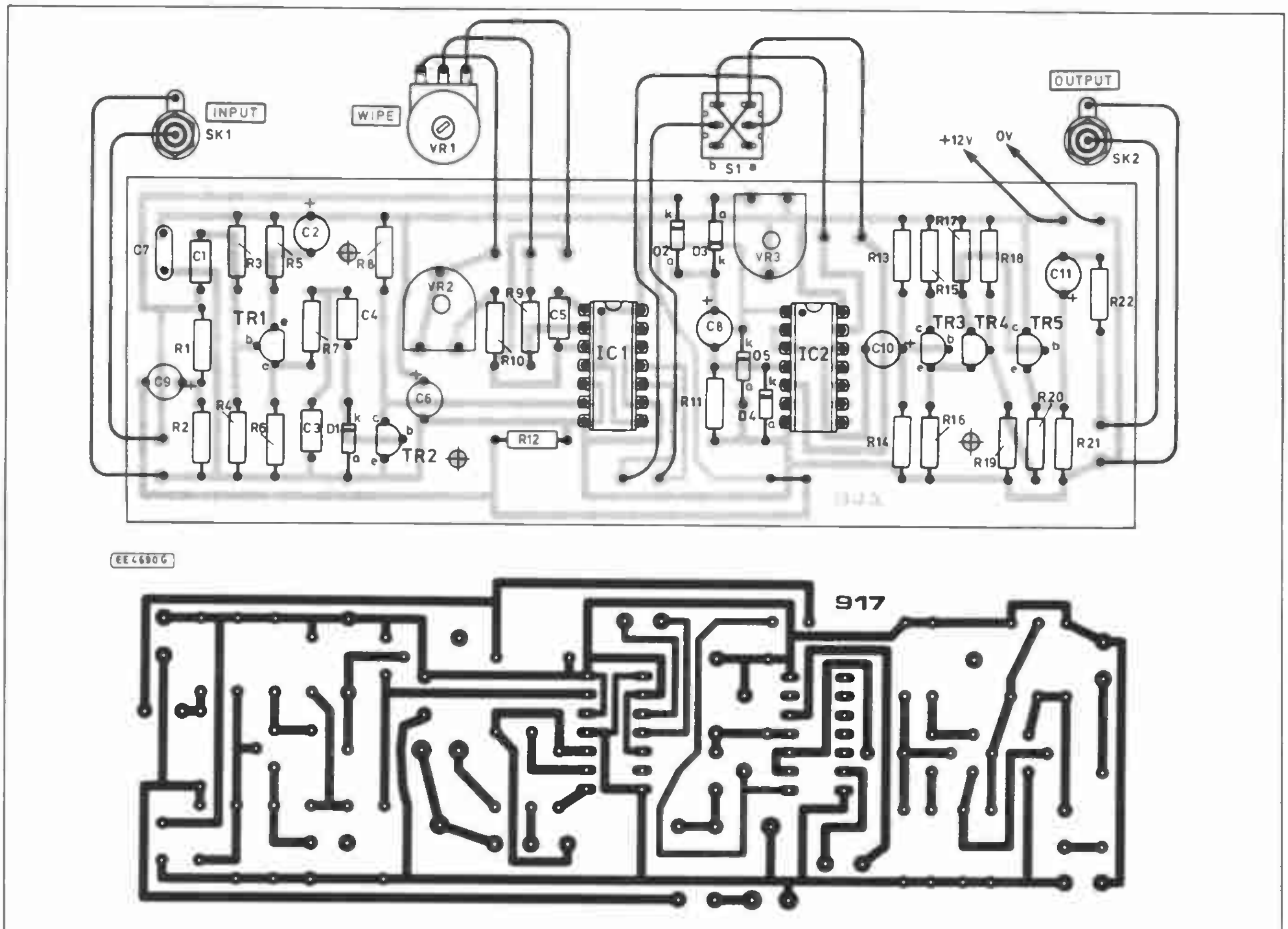
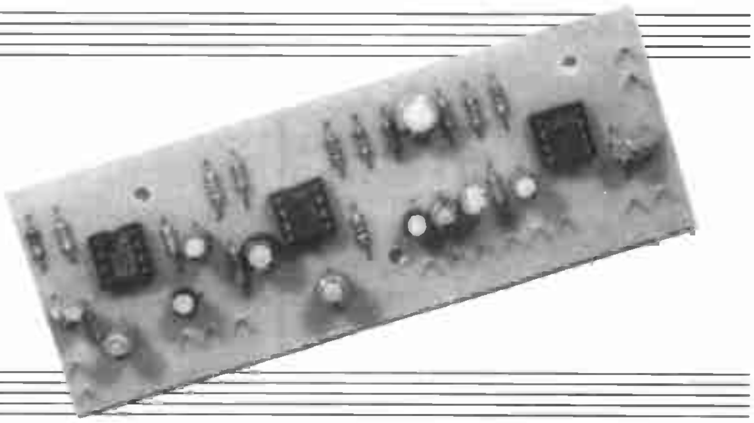


Fig. 17. Component layout, wiring and full size copper foil master for the Vertical Wiper p.c.b.

AUDIO MIXER



Dub a sound-track on your home videos.

WITH most camcorders and video recorders it is possible to do some doctoring of the sound when editing tapes. This usually consists of mixing some background music with the original sound track, and possibly adding a commentary of some kind as well.

An Audio Mixer is needed in order to accomplish this audio editing, but a sophisticated mixing desk is not needed. In fact a fairly basic mixer will handle the job very well.

The audio mixer featured here is a simple four-input (channel) type having one microphone input and three high level inputs. The latter can be fed from sources such as a Compact Disc player, a Cassette Deck, and the Camcorder itself.

The microphone input can be used with a low impedance (about 200ohms to one kilohm) dynamic microphone, or any microphone which has comparable output characteristics. This includes most electret type microphones. The microphone input is easily modified for operation with high impedance (about 20k to 50k) dynamic microphones, or microphones which provide a similar output level.

STEREO

Although the mixer was designed as a mono unit, it can be built as a stereo mixer. It is basically just a matter of building *two* mixer boards, one for use in each stereo channel.

The "fader" potentiometers could then be dual-gang types so that the two channels can be adjusted simultaneously. An arrangement preferred by many is to have individual slider controls for the two channels, with each pair mounted side-by-side. It is then easy to adjust the two channels simultaneously, but it is also possible to adjust them individually if some correction of the channel balance should be required.

CIRCUIT DESCRIPTION

The circuit is basically just a standard summing mode circuit. The complete circuit diagram for the Four-Channel Audio Mixer is shown in Fig. 18.

The low-noise j.f.e.t. input op.amp IC3 is used as the basis of the mixer stage, and this is really a form of inverting mode amplifier. However, in this case there are four input resistors (R10 to R13), and the output of the circuit adjusts to balance the sum of the input voltages.

This gives the required mixing action, and it also gives almost complete isolation between the inputs due to the "virtual

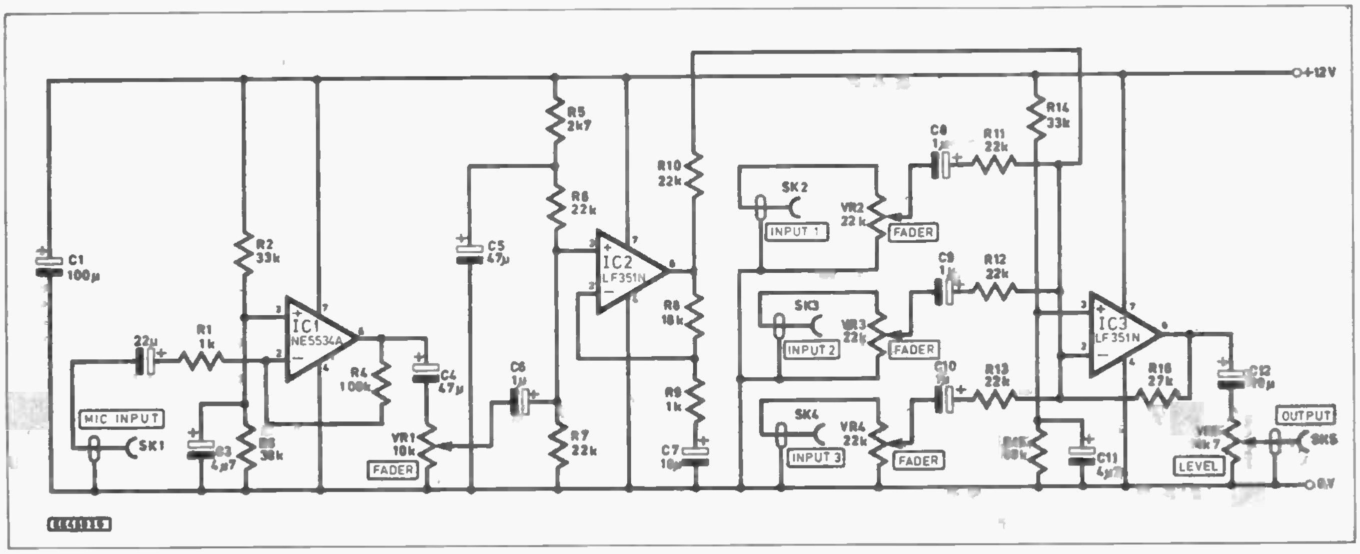


Fig. 18. Complete circuit diagram for the 4-Channel Audio Mixer. The input/output sockets can be mono or jack types.

earth" produced at the inverting input of IC3. This ensures that adjustments to the Fader control for one channel have no significant affect on the other three channels.

Sockets SK2 to SK4 are the high level inputs, and these feed three inputs of the mixer via "fader" potentiometers (VR2 to VR4). The maximum gain from each high level input to the output is a little over unity.

If necessary, slightly higher gain can be obtained by making resistor R16 slightly higher in value. The maximum voltage gain is actually equal to the value of R16 divided by 22k (the value of the input resistors). The input impedance at the high level inputs is around 15k.

MICROPHONE PREAMPLIFIER

The output level from a low impedance microphone is very low. In fact it is normally well under one millivolt r.m.s., which is about one to two thousand times less than the signal from a high level source such as a compact disc player. A high gain preamplifier is therefore used to boost the microphone signal to a level which is comparable to the signal level at the other inputs.

A very low noise bipolar operational amplifier, IC1, is used in the input stage of the preamplifier. This provides a much better signal to noise ratio than the standard 741C, or even a low noise bifet device such as the LF351N. In fact it gives a noise level which is only about one tenth of that provided by a 741C.

Good noise performance is important in an application such as this where very low input levels are involved. IC1 operates in the inverting mode, and has a closed loop voltage gain of about 100 (40dB). Resistor R1 sets the input impedance at approximately one kilohm (1k), which will give satisfactory results with any normal low impedance microphone.

For operation with a high impedance microphone R1 should be increased in value to 10k, and capacitor C2 should be reduced to 2µ2. This will give a closed loop voltage gain of 10 (20dB) and an input impedance of about 10k. This should give good results with virtually any high impedance dynamic microphone, or an electret type which has a built-in step-up transformer.

Further amplification is provided by IC2, and this is a non-inverting mode circuit. It has a closed loop voltage gain of just under 20 (26dB), giving a total voltage gain of just under 2000 (66dB). This gives an output level of several hundred millivolts r.m.s. Potentiometer VR1 is the Fader control for the microphone input.

The output Level control VR5 would normally be set for maximum output. It provides an easy means of simultaneously fading *all* the input signals. The current consumption of the circuit is approximately 9mA.

CONSTRUCTION

The printed circuit board (p.c.b.) component layout and full size underside copper foil maser pattern are shown in Fig. 19. This board is available from the *EPE PCB Service*, code 918.

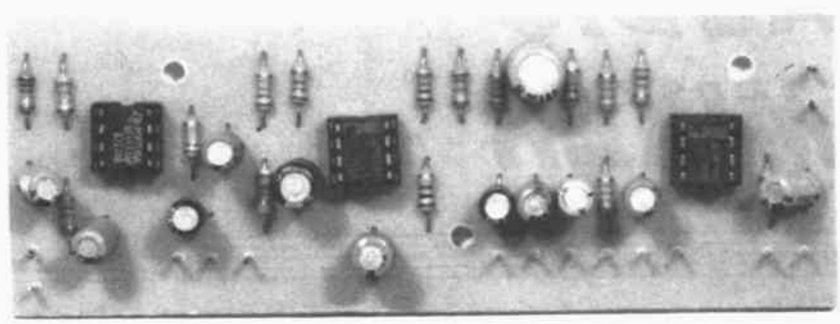
None of the integrated circuits are static-sensitive, but the NE5534A used for IC1 is not a particularly cheap device. It is strongly recommended that an i.c. holder is used for this component, and it would be advisable to use holders for the other two integrated circuits as well. Fit single-sided pins to the board at the numerous points where connections to off-board components will be made.

There is a substantial amount of hard wiring, and this is also illustrated in Fig. 19. The wiring to socket SK1 is very sensitive to stray pick up of mains "hum" and other electrical noise. Therefore, it is essential to use a *screened* cable to connect SK1 to the printed circuit board.

The wiring from the other input sockets to their respective Fader potentiometers is

COMPONENTS

Approx cost guidance only **£15**



AUDIO MIXER

Resistors

R1, R9	1k (2 off)	
R2, R3, R14, R15	33k (4 off)	
R4	100k	
R5	2k7	
R6, R7, R10 to R13	22k (6 off)	
R8	18k	
R16	27k	

All 0·25W 5% carbon film

See SHOP TALK Page

Potentiometers

VR1	10k rotary carbon, log
VR2, VR3, VR4	22k rotary carbon, log. (3 off)
VR5	4k7 rotary carbon, log

Capacitors

C1	100µ radial elect. 16V
C2	22µ radial elect. 16V
C3, C4, C11	4µ7 radial elect. 63v (3 off)
C5	47µ radial elect. 16V
C6, C8, C9, C10	1µradial elect. 63V (4 off)
C7, C12	10µ10µradial elect. 25V (2 off)

Integrated Circuits

IC1	NE5534A low noise op.amp
IC2, IC3	LF351N bifet op.amp (2 off)

Miscellaneous

Printed circuit board available from the *EPE PCB Service*, code 918; 8-pin i.c. holder (3 off); control knob (5 off); connecting wire; single-sided solder pins; solder etc.

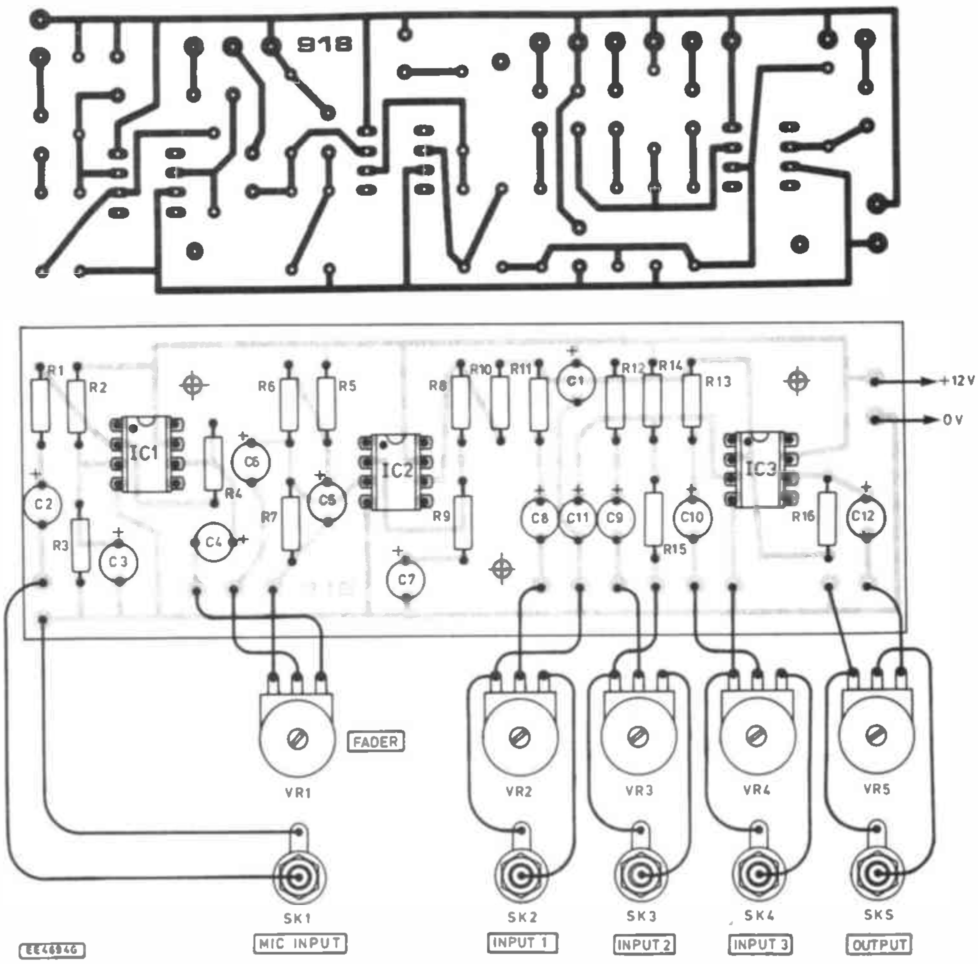
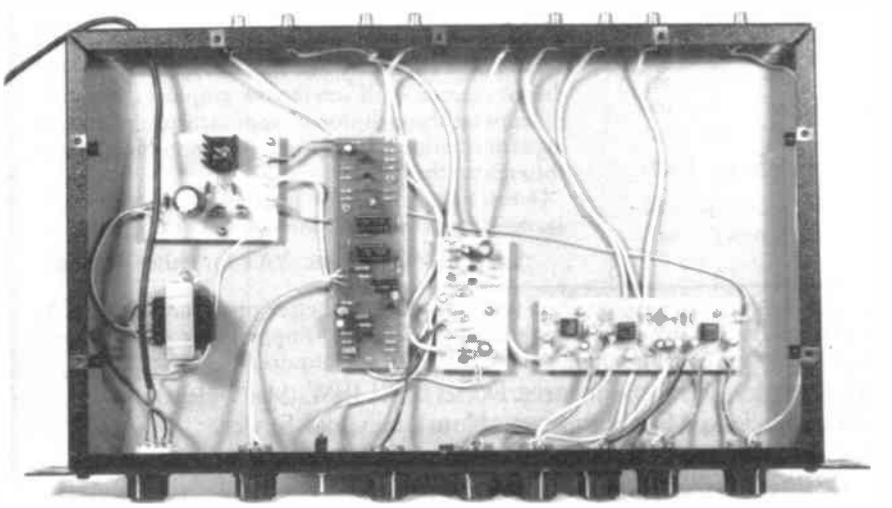


Fig. 19. Audio Mixer printed circuit board component layout, wiring and full size copper foil master.

The Audio Mixer input and output sockets are mounted on the rear panel of the case.



Wiring to the Mixer module printed circuit board, using screened leads, can be seen in the right-hand corner of the metal case.

less prone to stray pick up, but it would still be advisable to use screened cables for these connections unless this wiring is very short. Similarly, screened cables should also be used to connect controls VR2, VR3, and VR4 to the p.c.b. unless this wiring is very short.

Phono sockets are shown for SK1 to SK5 in the wiring diagram Fig. 19, and this is the type of socket normally used for both the audio and video signals on amateur video equipment. However, it is obviously in order to use any type of audio connector which fits in well with your other equipment. For example, a 3·5mm jack socket might be a better choice for SK1.

TESTING

When initially testing the mixer it is probably best to feed its output to the *audio* input of a television set or monitor. You can then feed signals to the inputs, and check that the various controls have the correct effect.

When trying the microphone input remember that "howl-around" will almost certainly result if the microphone level control (VR1) is advanced too far. For this reason, when using the microphone input in earnest the audio output signal *should not* be monitored using a loudspeaker. It might be all right to monitor the signal using headphones, but even this can cause feedback problems.

Next Month: We conclude with a Dynamic Noise Limiter and the System Power Supply module.

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A range of videos designed to provide instruction on electronics theory. Each video gives a sound introduction and grounding in a specialised area of the subject. The tapes make learning both easier and more enjoyable than pure textbook or magazine study. They are proving particularly useful in schools, colleges, training departments and electronics clubs as well as to general hobbyists and those following distance learning courses etc.

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Constructional Project

RODENT REPELLER

TERRY de VAUX-BALBIRNIE

A flashy but soundly conservationist way to rid your rooms of rodents – goodbye Mr. Mouse!

THIS project was born out of the need to produce a simple but effective means of repelling some unwelcome visitors to the attic – the Mouse Family.

Some people lay down poison and others set traps. Some are not so brave and wish the rotten rodents would go away without having to kill them. The idea of a poisoned animal wandering off and dying somewhere is repugnant to many people.

Also, a trap sometimes leaves the terrified creature caught by the tail and releasing it can be a gruelling experience. Humane traps are available which catch the mouse alive but these would need to be checked regularly if the occupant is not going to starve to death – also, not everyone can pluck up the courage to carry the trap containing the terrified creature within to release it.

PACK YOUR BAGS

The Rodent Repeller will be found best at keeping mice away. However, it should also be successful at making the established "Mouse Family" pack their bags and seek hospitality elsewhere. It works by using a brilliant intermittent flashing light and a high-pitched whistle – a combination which frightens Ronald Rodent and family and deprives them of a good night's sleep.

Although not very suitable for the general living area of the house, it could be used there to keep mice at bay while away on holiday. It works well in cupboards, roof spaces and other dark places since then the light appears particularly bright. The flashing lamp and sounder operate together at varying intervals to keep Mr. Mouse on his toes – the effect is not truly random because the timing cycle repeats after three but these animals are not thought to be good at their arithmetic.

The Rodent Repeller is mains-operated so may be left connected continuously for very little cost. Although in the prototype, the flashing light and audible warning device are part of the main unit, it would be a simple matter to mount them remotely on a subsidiary plastic box.

It would then be possible to site the main section in a convenient location – possibly more accessible to the mains supply – so that it could be switched on and off as required. The inter-connecting wire could be of any light-duty twin type of any reasonable length.

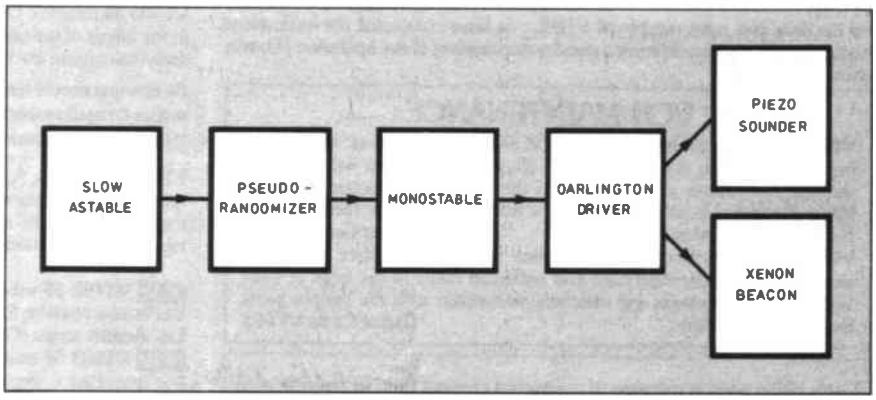


Fig. 1. Block diagram of the Rodent Repeller.

XENON TUBE

The light source is a xenon flash tube (of the type used in small photographic flash guns). This is part of a ready-made unit – a xenon beacon – which is often to be seen mounted on the external housings of burglar alarm sirens. A clear (uncoloured) beacon is best for this project. When activated, these devices flash between once and three times per second which makes them effective for the present purpose.

The sounder is a piezo-electric buzzer. A high-pitched sounder is most effective and it should be chosen to be as loud as possible. It is also important to use the correct type and more will be said about this later. The sounder specified in the components list will be found very suitable although other types could be tried.

It is recommended that a frequency no lower than 2·4kHz is used – the higher the better. High-pitched sounds appear to be particularly annoying to mice. Also, high frequency sound does not "carry" very well to the human living area since it is easily absorbed by intervening objects.

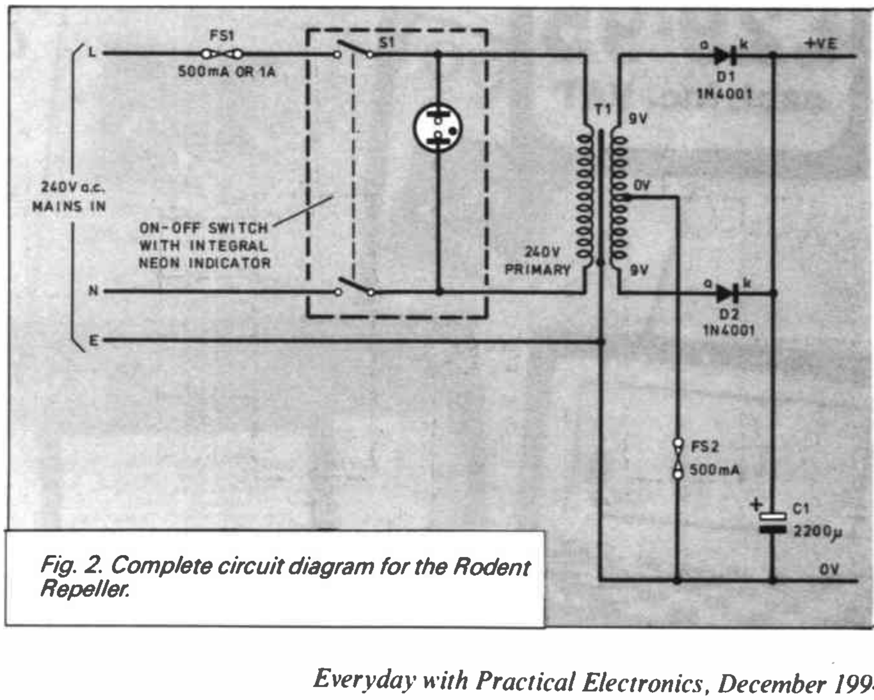


Fig. 2. Complete circuit diagram for the Rodent Repeller.

This means that it will be very loud where the mice live, but less likely to disturb paying occupants some distance away.

Although useful as a rodent repeller, this is a versatile circuit and some readers will, no doubt, find alternative uses for it. Other 12V output devices could be connected, up to a total maximum loading of 250mA.

BLOCK DIAGRAM

The Rodent Repeller is illustrated in block diagram form in Fig. 1. The first section consists of a slow astable. This produces a regular chain of pulses at a rate of between one every 13 seconds and one every 22 minutes approximately, depending on adjustment and component tolerances.

These pulses are applied to the second section which *pseudo-randomizes* them. New pulses are then delivered after a certain number of input pulses have been counted. These will be provided at twice, three times and five times the frequency of the astable. The cycle then repeats indefinitely.

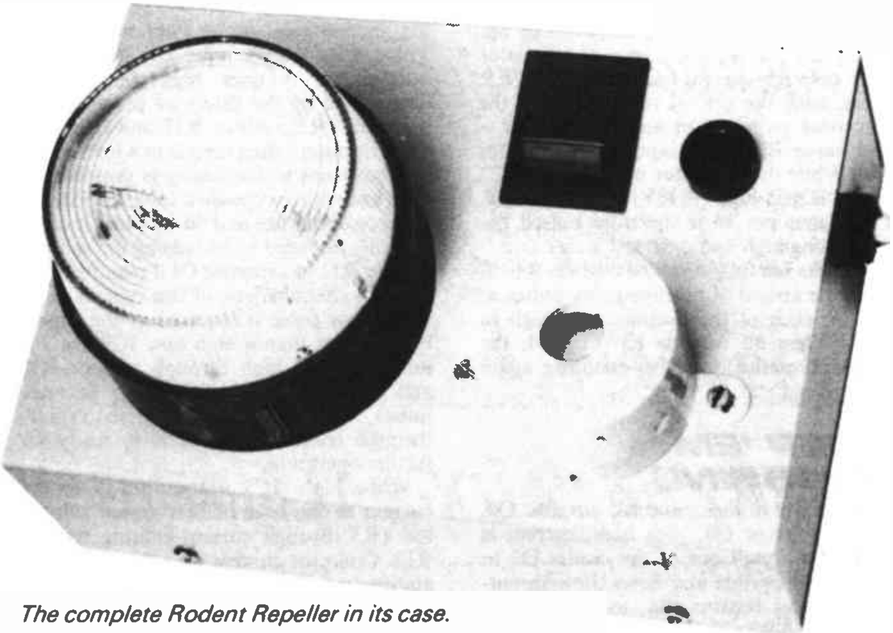
At minimum adjustment, therefore, there will be output pulses at intervals of 26, 39 and 65 seconds approximately. At maximum, the nominal timings will be 44, 66 and 110 minutes.

The next section is a monostable. The "randomized" pulses trigger this so that, with the arrival of each one, an output is provided of between five and 50 seconds duration, depending on the adjustment. This output operates the final part of the circuit which is a Darlington driver having sufficient current-handling capacity to power the piezo-sounder and xenon beacon.

POWER SUPPLY

The complete circuit diagram for the Rodent Repeller project is shown in Fig. 2. Power is derived from the 240V a.c. mains supply by a conventional arrangement of step-down transformer, T1, twin full-wave rectifier diodes, D1 and D2 and smoothing capacitor, C1. There is a double-pole ON-OFF switch with integral neon indicator, S1, in the mains feed and fuses are included in both the mains circuit (FS1) and low-voltage section (FS2).

Note that a 9V transformer is sufficient to provide a nominal 12V supply since capacitor C1 charges up to the *peak* voltage



The complete Rodent Repeller in its case.

of the rectified waveform. This is approximately 1·4 times the nominal output provided by the transformer secondary winding – giving 13V approximately.

However, there is the forward voltage drop (0·7V approximately) across the rectifier diodes to take into account and an additional voltage drop caused when the load of the flashing beacon and sounder is applied. The specified audible warning device will operate over a wide voltage range and tests show that the xenon beacon will work on less than 10V so the operating voltage is not particularly critical.

COUNTING PULSES

The astable section is centred on IC1 – a ZN1034E precision timer integrated circuit. IC1 differs from the common "555 timer" type device by using digital techniques to allow a very slow pulse repetition frequency to be obtained without the need for high-value timing components which would be bulky and costly.

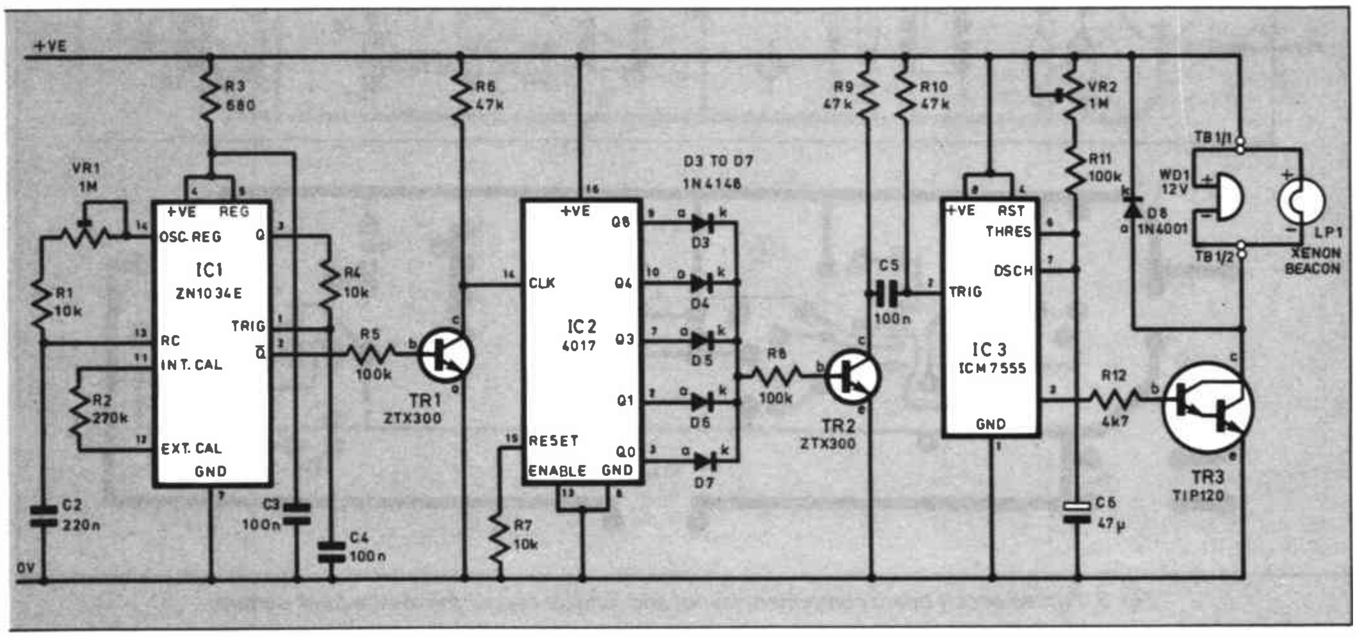
With a supply connected to IC1 pins 4 and 5 through resistor R3, a precision 2·6V output is produced by an on-chip regulator. This is available at pin 14.

Capacitor C2 charges up from this precision supply through preset potentiometer VR1 and resistor R1. The time taken to do this is set by the values of VR1, R1, R2 and C2. Thus, with R1, R2 and C2 fixed in value, the rate at which C2 charges can be varied by adjustment to VR1.

As capacitor C2 charges, the voltage across it rises and, at a pre-determined threshold level, a count of one is clocked-up by an on-chip binary register. It then discharges to begin a further cycle. When 4095 ($2^{12} - 1$) counts have been registered, output pin 2 goes from *low* (0V) to *high* (+5V) and output pin 1 goes from *high* to *low*. This marks the end of the timing cycle.

When this happens, the low state of pin 1 resets the i.c. by taking pin 3 low via resistor R4. Timing begins once again and the cycle repeats as long as a supply exists. Since precise timings are not required in this circuit, an inexpensive ceramic capacitor may be used in the C2 position. Capacitor C3 is required for stable operation of the i.c.

The randomizing section centres on decade counter IC2. This accepts pulses applied to its clock input, pin 14, these being derived from IC1 output pin 2. However, these pulses are not of a sufficient voltage level to be used directly. This is because they arrive from IC1 at +5V rather than at +12V as required by IC2.



The voltage is therefore amplified by applying the pulses to the base of transistor TR1 through current-limiting resistor R5. Thus, with the arrival of each pulse, the transistor switches on and its collector – and hence IC2 clock input pin 14 – goes low. While the transistor is turned off, IC2 pin 14 is held high (+12V) via resistor R6. Clock inut pin 14 is therefore pulsed between long high and short low states.

IC2 has ten fully decoded outputs 0 to 9. With the arrival of positive-going pulses at pin 14, each of the outputs goes high in turn. When all outputs have cycled, the chip automatically begins counting again form zero.

KEEP 'EM GUESSING

When any of the connected outputs, Q0, Q1, Q3, Q4 or Q8, goes high, current is directed through one of the diodes D3 to D7 as appropriate and flows through current-limiting resistor, R8, to the base of transistor TR2. The transistor will therefore turn on at varying time intervals. Note, however, that there is no further effect if TR2 base remains high, only if it goes low before becoming high again. The outcome is that the collector of transistor TR2 goes low successively at twice, three times and five times the basic clock frequency.

If, for example, VR1 is adjusted so that IC1 produces 10-minute pulses, then TR2 will turn on at 20, 30 and 50 minutes then repeat – good enough to keep Mr. Mouse guessing. This particular arrangement of used IC2 outputs gives good results with the prototype but other combinations could be tried if desired.

The low transitions occurring at TR2 collector are applied, via capacitor C5, to the monostable circuit centred on IC3. Thus, when trigger input pin 2 goes low, output pin 3 goes high for a time determined by the values of preset potentiometer VR2, resistor R11 and capacitor C6. The output then reverts to a low level.

Adjustment to the timing is provided by VR2 and with the specified values this will lie between about five and 50 seconds. It could be easily extended by increasing the value of resistor R11 or capacitor C6 if required.

It is a characteristic of this type of timer that a low pulse is required at the trigger input rather than a high one. IC3 Pin 2 is normally held high through resistor R10 and this prevents false triggering. Between pulses, capacitor C5 discharges rapidly through resistors R9 and R10, ready for further operation.

While high, IC3 output pin 3 directs current to the base of Darlington transistor TR3 through current-limiting resistor R12. Collector current then flows through audible warning device WD1 and xenon beacon LP1 connected in parallel.

A Darlington device consists of two interconnected transistors in the same package. It is equivalent to a single transistor with a high input impedance and an exceptionally high current gain. Thus, a very small base current is sufficient to provide a large collector output.

Note that TR3 is amply-rated to drive the specified AWD and xenon lamp and does not require a heat sink. Diode D8 is included as a precaution in case an inductive load, such as a relay, is ever connected to the output. If this were done, the collapse of the magnetic field on switching off could generate a high-voltage pulse which could damage semiconductor components in the circuit. Certain types of audible warning device could have a similar effect.

MAINS POWER

Important Safety Warning: Construction of this project involves making mains connections. It is therefore essential for any reader who is not certain of being able to make a safe job to seek professional advice. Before removing the lid of the case to make adjustments to the timings or for any other reason, the unit must first be unplugged from the mains.

The Rodent Repeller is designed to be plugged into a standard mains wall socket. It should not be permanently wired-in. Note also that the completed project must be housed in an **earthed** metal box and correctly fused in both transformer primary and secondary circuits as indicated.

It is important to use a good quality transformer of adequate current rating (see components list). This will remain cool in operation and be suitable for continuous use.

Some cheap transformers have an excessive off-load voltage. The theory is that the voltage drops to the nominal value when a full load is applied. These transformers should be avoided in this application since, between operations of the beacon and sounder, very little current is drawn from the transformer – that is, it is almost off-load. The output voltage could then be sufficiently high to cause damage to the circuit.

CONSTRUCTION

One further practical point is that the chosen sounder must be of the type with *internal drive circuitry*. Other types will not work. The correct type will be described as being suitable for 12V d.c. operation (or a range of d.c. voltages spanning 12V).

Most of the components for the Rodent Repeller are mounted on a single-sided

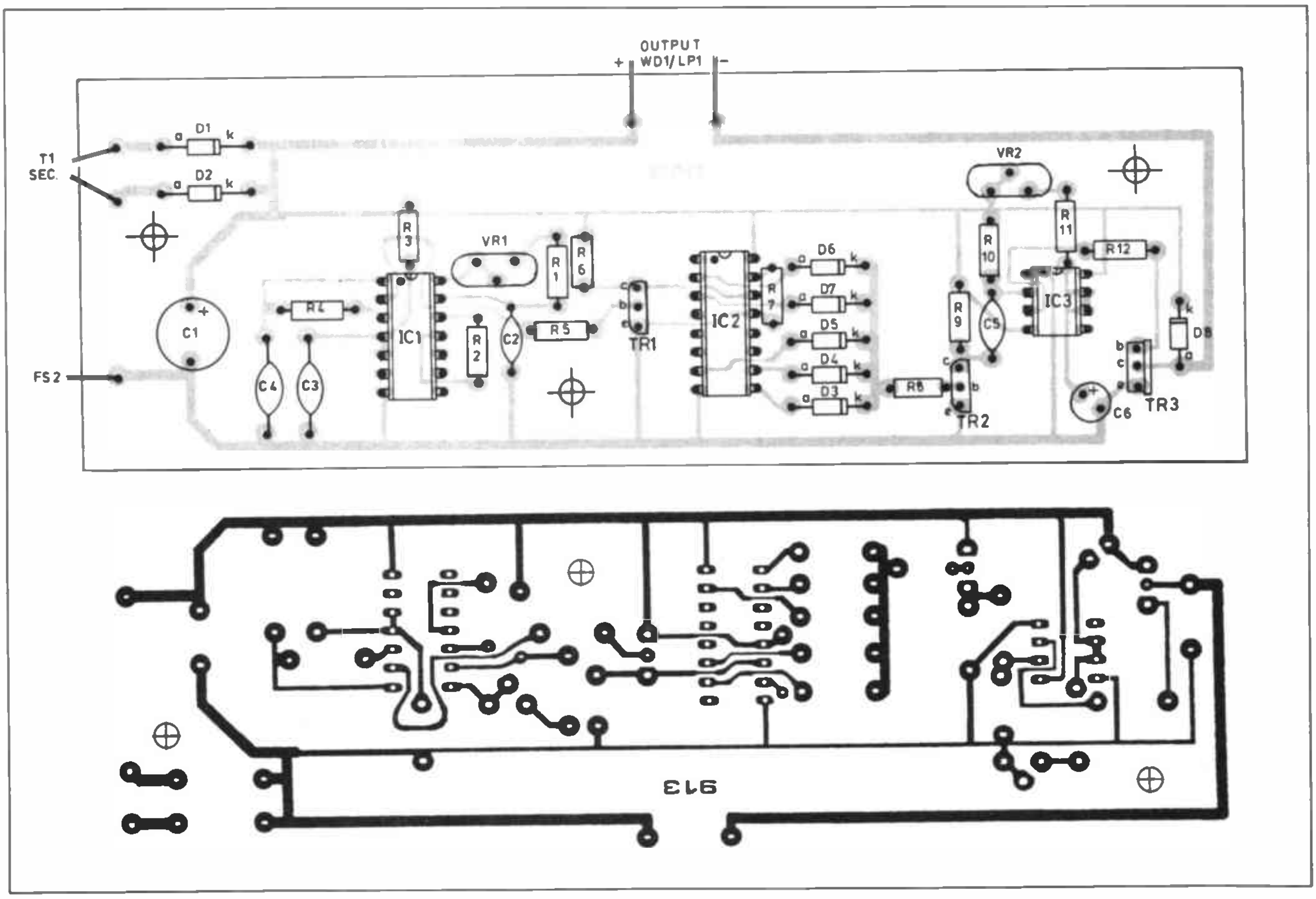


Fig. 3. Printed circuit board component layout and full size copper foil master track pattern.

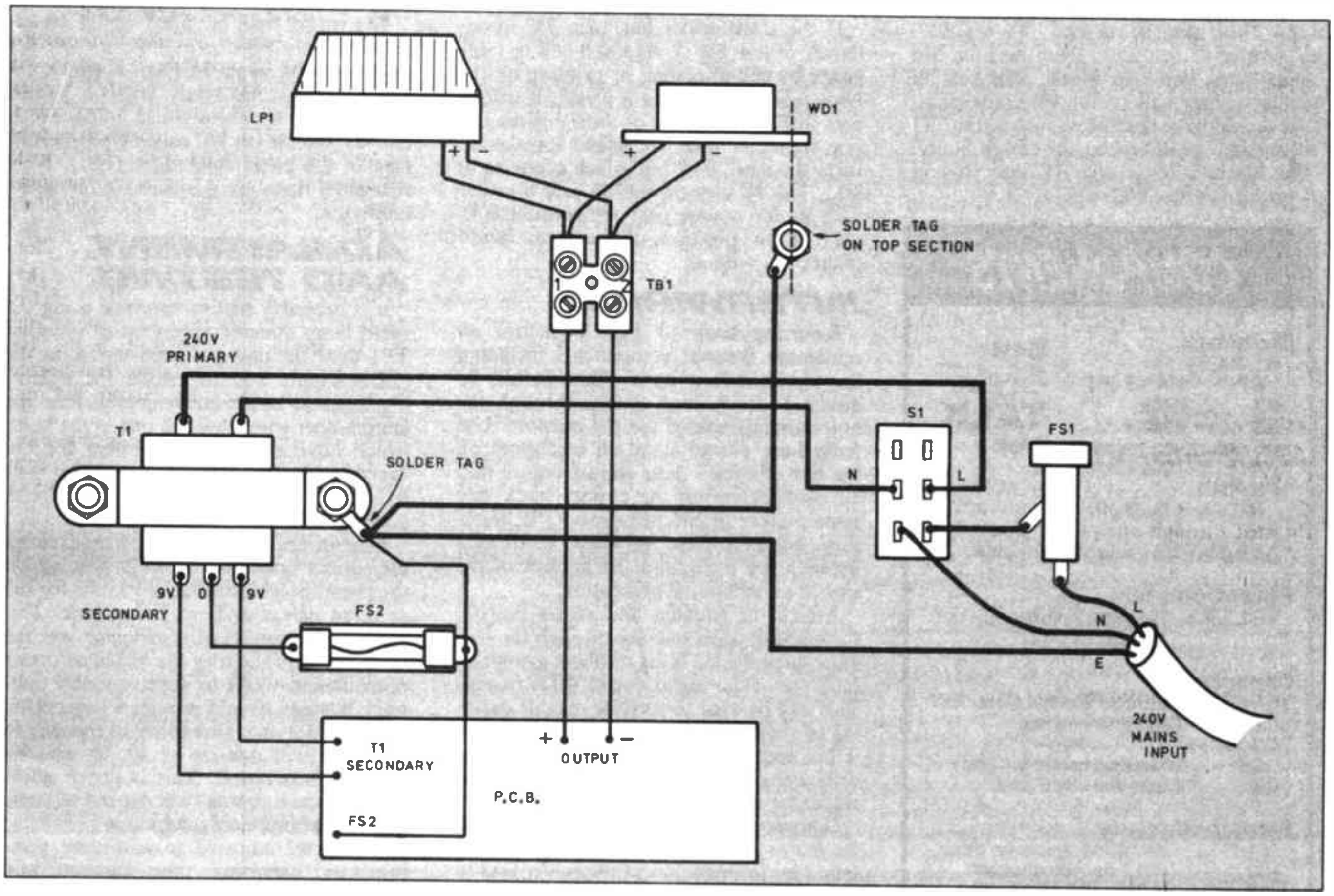


Fig. 4. Wiring details for the Rodent Repeller.

printed circuit board (p.c.b.). A full-size copper foil master track pattern and component layout details are shown in Fig. 3. This board is available from the *EPE PCB Service*, code 913.

Begin construction by drilling the three mounting holes in the circuit board, 2mm in diameter, at the positions indicated. The recommended assembly order is as follows. Firstly, solder in the three i.c. sockets followed by resistors, non-electrolytic capacitors (C2 to C5) and diodes – all mounted flat to the board. Next, mount the transistors and the two preset potentiometers. Finally, solder in electrolytic capacitors C1 and C6. Take particular care over the polarity of the diodes, transistors and electrolytic capacitors.

Adjust the presets fully anti-clockwise (as viewed from the top edge of the circuit board) – this will provide the shortest timings which will be convenient for testing purposes. Solder a temporary wire 10cm long to either position labelled "T1 sec" on the circuit board and a similar piece of wire to the position marked "FS2". Solder two further pieces of wire to the output pads and secure the two-section piece of screw terminal block to the free ends of these.

The terminal block will eventually be used for the sounder and beacon connections. However, it is better if a small 12V bulb (an MES type of 2·2W rating in a suitable lamp holder for example) is used for the moment. It is then possible to test the p.c.b. using a 9V or 12V battery without the encumbrance of having to observe mains safety precautions. Any small problems may then be solved before attending to the mains-operated section.

A PP3 battery is not really up to this job. It would be better to use a PP9 type or, perhaps, six "AA" size cells in a suitable battery holder.

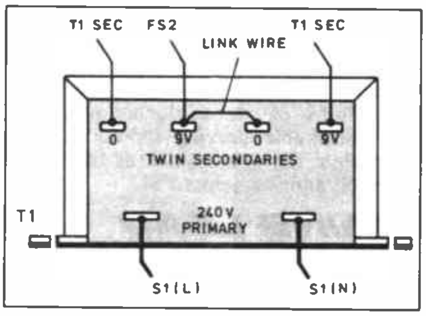


Fig. 5. Alternative transformer wiring.

Insert the i.c.s into their sockets taking care over the orientation. Since these are all CMOS devices, they could possibly be damaged by excessive static charge which might exist on the body. It would therefore be wise to touch something which is earthed, for example, a water tap, before removing them from their packaging and touching the pins.

Now, using crocodile clips or other reliable method, connect the battery negative terminal to the wire leading to the position marked "FS2" on the circuit board. Connect the positive terminal to the wire leading to diode D1 or D2. IC3 often triggers when power is first applied so the lamp will probably come on immediately and go off a few seconds later.

Leave the battery connected and check that the light operates at roughly the correct time intervals. As a guide these will be 26, 39 and 65 seconds, then repeat. Note that on powering-up, IC2 may begin with any one of its outputs high so the cycle may not begin as expected. If the circuit operates correctly in this basic test, attention may be given to preparing the case for the printed circuit board and other internal components.

JUST IN CASE

Prepare the box by drilling three holes in the base section to correspond with those already made in the circuit board. Drill holes also for transformer T1, chassis fuse holder FS2, and a further one of sufficient diameter to accommodate the strain relief bush to be used on the mains input lead. Drill holes in the top section of the case for on-off switch S1, panel fuse holder FS1 and terminal block TB1 mounting (see photograph).

Further holes will need to be drilled in the top of the case to mount the sounder and xenon beacon, depending on the type. Holes will also be needed for their connecting wires to pass through. If these components are to be mounted remotely, a hole will be needed for a small socket (for example, a 3·5mm mono jack-type socket) to enable them to be connected through a matching plug and length of twin wire.

TRANSFORMER MOUNTING

Mount the mains transformer (only loosely at the moment if the connections are difficult to reach with the soldering iron) noting the solder tag at one of its fixings. **This will be used for earthing the case and transformer core and is essential for safety reasons.** It will probably be necessary to de-solder the temporary wires which were previously connected to the circuit panel for testing purposes. However, those connected to the output pads will be used.

Make the three connections from the circuit board to the transformer secondary. If the transformer is of the type having a "9V-0V-9V" secondary (sometimes called a centre-tapped secondary), proceed by referring to Fig. 4. Here, the transformer is shown having three secondary wires, or tags. These may be marked "9V, 0V, 9V" or similar. If coloured, there may be two white ones and one black. The two of similar colour will be the 9V connections and should be connected as such to the "T1 secondary" positions on the circuit board. The black wire is the 0V one and is connected to fuse FS2.

COMPONENTS

Resistors

R1, R4, R7	10k (3 off)	
R2	270k	
R3	680	
R5, R8, R11	100k (3 off)	
R6, R9, R10	47k (3 off)	
R12	4k7	

All 0·25W 5% carbon film or better

See SHOP TALK Page

Potentiometers

VR1, VR2 — 1M vertical sub-min. preset (2 off)

Capacitors

C1	2200µ 25V radial elect. 25V
C2	220n disc ceramic
C3, C4, C5	100n disc ceramic (3 off)
C6	47µ radial elect. 25V

Semiconductors

IC1	ZN1034E precision timer
IC2	4017 decade counter
IC3	ICM7555 CMOS timer
D1, D2, D8	1N4001 50V 1A rectfier diode (3 off)
D3 to D7	1N4148 signal diode (5 off)
TR1, TR2	ZTX300 *npn* transistor (2 off)
TR3	TIP120 (or TIP121 or TIP122) *npn* Darlington transistor

Miscellaneous

T1	miniature transformer with 240V primary and 9V-0V-9V (or twin 9V secondaries) 250mA minimum
S1	d.p.s.t. rocker switch with 1A minimum *mains-rated* contacts and integral neon indicator
FS1	20mm panel fuse holder with 1A or 500mA *ceramic mains* fuse to fit
FS2	20mm chassis fuse holder with 500mA glass fuse to fit
TB1	2A screw terminal block – 2 sections required
WD1	12V piezo sounder suitable for 10V to 12V operation, 3kHz operation and 103dB output at 1 metre
LP1	clear xenon beacon (burglar alarm type) – 12V operation up to 200mA rating – see text.

Printed cricuit board avaiable from *EPE PCB Service*, code 913; aluminium box size 155mm × 105mm × 45mm; 8-pin d.i.l. socket; 14-pin d.i.l. socket; 16-pin d.i.l. socket; 3·5mm jack plug and socket (see text); 3-core 3A mains wire; strain relief bush, rubber grommets (2 off); heat shrinkable sleeving, cable ties, solder tags (2 off), nuts, bolts, connecting wire, solder, etc.

Approx cost guidance only **£39**

If the transformer has twin 9V secondaries, follow Fig. 5. Again, it will be clear either by colour-coding or printing on the body which wire or tag is which. It will be seen in Fig. 5 that one of the 0V wires and one of the 9V ones are linked together to form the new "0V" line which connects to FS2. The 9V wire or tag left over together with its 0V counterpart are connected to the "T1 sec" positions on the circuit board (either way round).

INTERWIRING

Referring back to Fig. 4, mount all remaining internal components including the circuit board itself. This should be attached using small fixings through the holes already drilled for the purpose. Use 5mm long plastic stand-off insulators on the bolt shanks – these should ensure that all connections on the copper track side remain clear of the metal-work. If necessary, place a piece of thick cardboard between the p.c.b. and the bottom of the case as an additional precaution.

Attach the sounder and xenon beacon. Connecting wires passing through the box must be protected using a rubber grommet. Note the solder tag at one of WD1 fixings. This will be used to provide reliable earthing of the case top section. If this position is not convenient, a small hole should be drilled elsewhere in the top section and the solder tag secured with a small fixing.

Complete the internal wiring apart from the mains input lead. Use a piece of **mains-type** wire to interconnect the solder tags in the base and top sections of the case. **Note that all wiring shown drawn in thicker lines in Fig. 4 must be mains type of 3A rating minimum.**

If the transformer has exposed primary tags, make a cardboard or plastic shield for these. Transformers having "flying lead" connections, of course, do not need this. Heat-shrinkable sleeving should be used to insulate the connections at the on-off switch S1 and fuseholder FS1.

MAINS LEAD

Make up the mains input lead using a sufficient length of 3-core mains-type wire of 3A rating minimum. Fit a standard mains plug on the end and insert a 2A fuse. Pass the other end through the strain relief grommet and secure it. Complete the mains wiring using more heat shrinkable sleeving to insulate otherwise exposed connections. **Make certain that all connections are secure and cannot pull free in service.**

The wiring may be tidied up by grouping wires into bundles and using cable ties or spiral wire wrap on them. Tighten the transformer fixings firmly. Insert a 500mA **glass** fuse in the chassis fuse holder (FS2) and a 500mA or 1A **mains-type ceramic** fuse in the panel fuseholder (FS1). Note that **glass** fuses are not suitable for direct mains use.

ADJUSTMENT AND TESTING

It is probably best to continue using the small lamp already connected to terminal TB1 until the unit has been tested on the mains supply and to enable the operating times to be set conveniently. Pass the lamp holder wires through one of the holes which have already been drilled for the beacon or buzzer wires so that testing may be undertaken with the lid of the case in position.

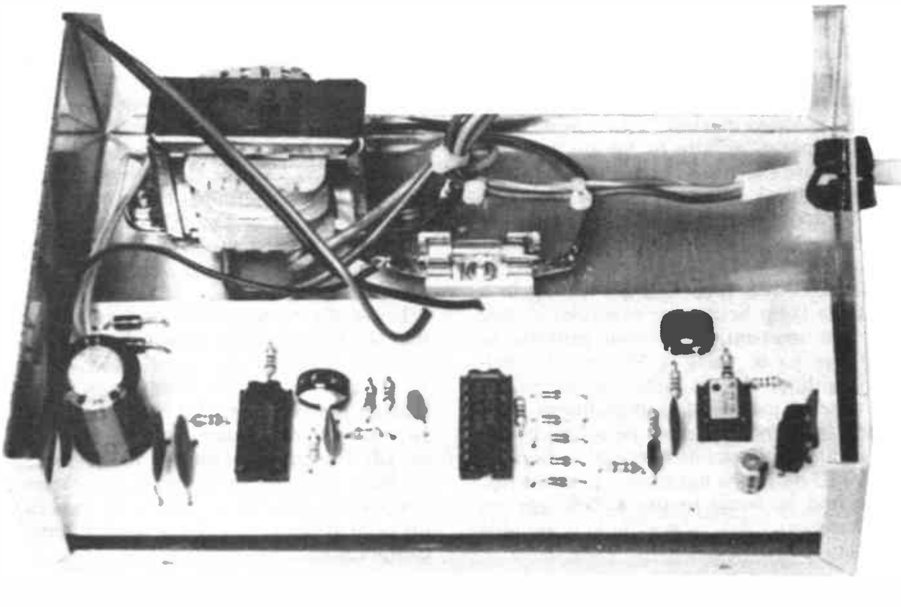
Plug in the unit, switch on and check for correct operation. If all is well, adjust the preset potentiometers clockwise for the required delays and operating time. This could be the subject of experiment over the next few days. Setting the wiper of preset potentiometer VR1 to approximately mid-track position should provide a basic clock rate of about one pulse every 10 minutes so the lamp will operate at 20, 30 and 50 minutes then repeat. This is just a guide and the actual timings will depend to some extent on component tolerances.

With VR2 adjusted to mid-track position, an operating time (beacon and sounder *on* time) of some 30 seconds would be expected. However, the actual value of capacitor C6 is often higher than its nominal value so the timing is likely to be rather longer than that calaculated. When the timings are set to satisfaction, the test lamp may be removed and the beacon and buzzer connected to terminal TB1 with the correct polarity.

FLASH LIFE

The rated life of the flash tube is approximately one million operations. Taking into account the fact that the unit operates only intermittently, the service life of the xenon beacon will be in excess of 12 months. Since it is unlikely that the unit will be used for more than a few weeks in the year, the potential life will be several years.

Experiment to find the best position for the unit – near where the Mouse Family nest and forage. Goodbye Mr. Mouse! □



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The subjects covered in each chapter of the book are: Introduction and Power Supplies; Small Signal Amplifiers; Power Amplifiers; Oscillators; Logic Circuits; Timers; Radio; Power Control; Optoelectronics.
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The guide covers versions 3.0, 3.1 and 3.2 of both PC-DOS and MS-DOS as implemented by IBM and other manufacturers of "compatible" microcomputers.
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N. Kantaris & P. R. M. Oliver
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The book explains: How to write customised batch files which allow you to display what you want on your screen, and in the form and order you want it, instead of being forced to use the DOS prompt on a blank screen. How to design and set up a fast interactive and professional looking menu system, so that you or anyone else can run utility applications or commercial software packages easily. How the ANSI.SYS display and keyboard commands can be used to position the cursor on any part of the screen, change the intensity of the displayed characters or change their colour. How the Edit screen editor or the Edlin line editor can be used to enter ESCape (ANSI.SYS) commands into simple ASCII files to allow control of both your screen display and your printer. How to control the operation of the two main types of printers in use today, Epson compatible dot matrix and HP compatible laser printers. How to use several useful routines, such as moving and finding files, protecting files from accidental erasure, a simplified backup process, a screen saver, and a disc cataloguing system.
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The Musical Instrument Digital Interface (MIDI) is surrounded by a great deal of misunderstanding, and many of the user manuals that accompany MIDI equipment are quite incomprehensible to the reader.

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This book is in effect more than just a dictionary of practical electronics terms, it goes a stage further in also getting down to fundamentals. Accordingly the number of terms may be limited but the explanations of the many which are included are designed to leave the reader more competent and satisfied – and this is without the use of complicated mathematics which often on first reading can even be confusing.

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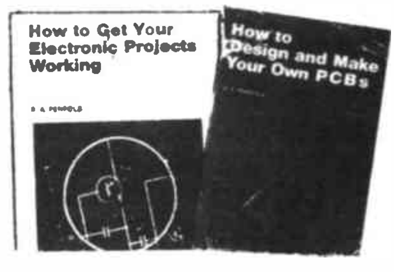

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The topics covered in this book include: 555 oscillators; sinewave oscillators, function generators; CMOS oscillators, voltage controlled oscillators; radio frequency oscillators, 555 monostables; CMOS monostables; TTL monostables, precision long timers, power supply and regulator circuits, negative supply generators and voltage boosters; digital dividers, decoders, etc. counters and display drivers; D/A and A/D converters, opto-isolators, flip/flops, noise generators, tone decoders, etc.

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I. D. Poole

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R. A. Penfold

Short wave radio is a fascinating hobby, but one that seems to be regarded by many as an expensive pastime these days. In fact it is possible to pursue this hobby for a minimal monetary outlay if you are prepared to undertake a bit of d.i.y., and the receivers described in this book can all be built at low cost. All the sets are easy to construct, full wiring diagrams etc. are provided, and they are suitable for complete beginners. The receivers only require simple aerials, and do not need any complex alignment or other difficult setting up procedures.

The topics covered in this book include: The broadcast bands and their characteristics, The amateur bands and their characteristics; The propagation of radio signals, Simple aerials, Making an earth connection, Short wave crystal set; Simple t.r.f. receivers, Single sideband reception; Direct conversion receiver.

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AN INTRODUCTION TO AMATEUR COMMUNICATIONS SATELLITES
A. Pickford

Communications and broadcast satellites are normally inaccessible to individuals unless they are actively involved in their technicalities by working for organisations such as British Telecom, the various space agencies or military bodies even those who possess a satellite television receiver system do not participate in the technical aspects of these highly technological systems.

There are a large number of amateur communications satellites in orbit around the world, traversing the globe continuously and they can be tracked and their signals received with relatively inexpensive equipment. This equipment can be connected to a home computer such as the BBC Micro or IBM compatible PCs, for the decoding of received signals.

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P. Shore

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REPORTING AMATEUR RADIO

Tony Smith G4FAI

CIS CALLSIGNS

There has been some confusion over the amateur callsigns of ex-USSR stations since the break-up of the Soviet Union. Some countries immediately reclaimed their pre-WW2 prefixes, for example Estonia, ES, Latvia, YL, and Lithuania, LY. There were official new allocations from 1st January 1994, but some stations have continued to use previously issued calls now allocated to other countries.

Callsigns are allocated in series by the International Telecommunications Union (ITU). Countries are allocated blocks of prefixes beginning with a single letter, a pair of letters, or a number and a letter. Sometimes a block covers all possible prefixes with the same beginning, sometimes a half-series is allocated so that two countries share the same prefix. Swaziland, for example, has 3DA-3DM and Fiji 3DN-3DZ. Other countries, with many radio amateurs, have several prefix blocks.

The following is a list of the new ITU allocations for the countries of the ex-Soviet Union, including their previous calls for ease of reference.

BLOCKS ALLOCATED	COUNTRY	PREFIXES NEW	OLD
EKA-EKZ	Armenia	EK	UG
EMA-EOZ	Ukraine	EO	UB/UT/UY
ERA-ERZ	Moldava	ER	UO
ESA-ESZ	Estonia	ES	UR
EUA-EWZ	Belarus	EV	UC
EXA-EXZ	Kyrgystan	EX	UM
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LYA-LYZ	Lithuania	LY	UQ
RAA-RZZ	Russia	RA	UA
UAA-UIZ	Russia	UA	UA
UJA-UMA	Uzbekistan	UM	UI
UNA-UQZ	Kazakhstan	UN	UL
URA-UZZ	Ukraine	US/UT/UX/UY	UB/UT
YLA-YLZ	Latvia	YL	UP
4JA-4KZ	Azerbaijan	4J/4K	UD
4LA-4LZ	Georgia	4L	UF
R1F	Franz Josef Land	R1F	4K2

YEAR IN REVIEW

I have been looking back over the last twelve months at some of the matters reported in this column to see if any conclusions can be drawn from them. I have chosen only one subject from each issue although there are of course several topics discussed each month.

In December 1993, an extract from the Radiocommunications Agency's Annual Report showed that there were fewer radio amateurs in 1992/93 than in the previous year. Numbers dropped from 61,442 in March 1992 to 59,242 a year later, a loss of 2,200. Publication of this year's Report has been delayed but I hope to have the 1994 figures next month.

January's column reported that the Radio Society of Great Britain's representatives at the IARU Region 1 Conference in the previous September had abstained from voting on the issue of the amateur Morse test. Apparently they had no mandate on this subject despite a recent RSGB survey in which a large majority of those voting had supported retention of the test.

February's column recorded that an Ariane launch vehicle had recently carried no less than seven amateur satellites into orbit.

March carried the finally released official Morse test survey results, showing that 67.5% of those taking part voted "No" to the concept of a code-free licence while 32.5% voted "Yes".

April highlighted the Young Operators' International Radio Club, a Russian based international organisation of young people under 30, which seeks to promote friendship and a better understanding of each other by sharing ideas and information about radio and other hobbies through radio communication and a newsletter.

COMMEMORATION

May saw news of "Operation Maquis", an amateur radio special event associated with the D-Day celebrations. Special French stations planned to be on the air to commemorate the WW2 clandestine radio links between France and Britain, and to honour the memory of those who died undertaking this dangerous work.

In June, there was a report on the work of Australian radio amateurs who provided communications support for the firefighters during the bush fires in New South Wales in January.

July carried the reassuring news that the Report of the Stage 3 Radio Spectrum Review Committee, covering 28MHz to 470MHz, "having noted the value of amateur radio to the community" proposed, for the foreseeable future, no change in the amateur radio frequency allocations.

In August this column reported, before any specialised amateur radio publication carried the news, that the International Amateur Radio Union had appointed a special sub-committee to examine the issues related to the amateur Morse test, and to propose the position the IARU should take on this controversial matter.

September saw a report on the first course run by STELAR (Science and Technology through Educational links with Amateur Radio) for teachers from schools with no current amateur radio programme.

In October, we delved into the fascinating world of "numbers stations", an intriguing aspect of short wave listening involving mysterious stations labelled with such names as the "Lincolnshire Poacher", Bulgarian Betty", "Bugle Station", and "Russian Counting Man".

In November there were details of changes in the terms and conditions of the amateur radio licence. These introduced some new privileges, including the use of higher power in the 1·8MHz and 50MHz bands; and some restrictions including a requirement that unattended packet operation should have the facility to close-down rapidly when other services were being interfered with.

CONCLUSIONS

So what conclusions can be drawn from this brief review of a year of "Reporting Amateur Radio"? It seems clear that the question of the amateur Morse test is the one issue that won't go away. A survey of amateurs resulted in a substantial "retain it" majority, yet the RSGB would not adopt that viewpoint as its policy. Now the IARU is trying to decide what its policy should be at international level.

The annual figures show that the numbers of licensees are decreasing, and there is a view that this trend could be reversed if only the Morse test were abolished. As the survey showed, there is also a substantial contrary view so this particular controversy is likely to continue for some time yet.

Frequent references to rules and regulations emphasise that amateur radio is very much a disciplined hobby governed by detailed terms and conditions. In a world where "breaking the rules" is a common occurrence, radio amateurs who do this can lose their licences and few choose to take the risk.

ABOVE ALL IT'S FUN

My limited selection of topics gives some indication of the scope of amateur radio. A look back at the actual pages, however, widens the perspective and shows very clearly that it is not just one but many hobbies rolled into one, offering enjoyment and satisfaction at many levels.

None of this is parochial either. Amateur radio is international, with many activities involving contact with amateurs in other countries, often resulting in lasting friendships with them.

This column seeks to emphasise how easy it is for beginners to make a start in amateur radio. Once they have studied for and acquired their licences, newcomers are welcomed by the "specialists" who are more than pleased to help them start and make progress in the various branches of the hobby.

If you have a radio with facilities for listening to amateurs, try listening to them on the international bands over the festive season when they catch up with old friends, and make new ones. You will begin to get some idea of what its all about. It's an absorbing activity, satisfying and rewarding. Above all it's fun. Happy Christmas!

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JANUARY 1994 TO DECEMBER 1994

Pages	Issue	Pages	Issue
1-88	January	489-560	July
89-176	February	561-644	August
177-248	March	645-716	September
249-332	April	717-808	October
333-404	May	809-892	November
405-488	June	893-984	December

VOLUME 23 INDEX

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