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JUNE 1994

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

VIEWDATA RETURNS £6 made by Tandata, includes 1200.75 modem, k/bd, RGB and comp o/p, printer port. No PSU.£6 MAG6P7

IBM PC CASE AND PSU Ideal base for building your own PC. Ex equipment but OK. £14.00 each REF: MAG14P2

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, TTL/ECL inputs, 15" landscape, 1200x1664 pixel complete with circuit diag to help you interface with your projects. JUST £24.99. REF MAG25P1

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. £99 each REF MAG99P1

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

ANSWER PHONES Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1, BT Response 400's £25 ea REF MAG25P3 Suitable power supply £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. £29 REF MAG29P1

SINCLAIR C5 13" wheels complete with tube, tyre and cycle style bearing £6 ea REF MAG6P10

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 IBMcompatible 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. These are 12v DC 3,300 rpm 6"x4", 1/4" OP shaft. £25 REF: MAG25

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

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

JUG KETTLE ELEMENT good general purpose heating element (about 2kw) ideal for heating projects. 2 for £3 REF: MAG3

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

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

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

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

TALKING COINBOX STRIPPER originally made to retail at £79 each, these units are designed to convert 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

VELCRO 1 metre length of each side 20mm wide (quick way of fixing for temporary jobs etc) £2 REF: MAG2P3

MAGNETIC AGITATORS Consisting of a cased mains motor with lead. The motor has two magnets fixed to a rotor that spin round inside. There are also 2 plastic covered magnets supplied. Made for remotely stirring liquids! you may have a use? £3 each REF: MAG3P3

BULL'S BULLETIN BOARD

100MHZ DUAL TRACE OSCILLOSCOPES JUST £259 RING FOR DETAILS

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WAREHOUSE CLEARANCE

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AMSTRAD 1512SD

1512 BASE UNIT, 5.25" FLOPPY DRIVE AND KEYBOARD. ALL YOU NEED IS A MONITOR AND POWER SUPPLY. WAS £49.00

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REF: MAG29

AMSTRAD 1512DD

1512 BASE UNIT AND KEYBOARD AND TWO 5.25" 360K DRIVES. ALL YOU NEED IS A MONITOR AND POWER SUPPLY WAS £59.00

NOW ONLY **£39.00**

REF: MAG39

SOLAR POWER PANELS

3FT X 1FT 10WATT GLASS PANELS 14.5v/700mA NOW AVAILABLE BY MAIL ORDER £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

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Brand new, UNUSED top quality *Famous brand* licensed software discs. Available in 5.25" DSDD or 5.25" HD only. You buy the disk and it comes with free BRAND NEW UNUSED SOFTWARE. We are actually selling you the floppy disc for your own "MEGA CHEAP" storage facilities, if you happen to get software that you want/need/like as well........ you get a "MEGA BARGAIN" too!

DSDD PKT10 £2.99 REF: MAG3P7 PKT100 £16.00 REF: MAG16

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TOP QUALITY SPEAKERS Made for Hi Fi televisions these are 10 watt 4R Jap made 4" round with large shielded magnets. Good quality general purpose speaker. £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 modification 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

XT KEYBOARDS Mixed types, some returns, some good, some foreign etc but all good for spares! Price is £2 each REF:MAG2P8 or 4 for £6 REF: MAG6P4

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

COMMODORE MICRODRIVE SYSTEM mini storage device for C64's 4 times faster than disc drives, 10 times faster than tapes. Complete unit just £12 REF:MAG12P1

SCHOOL STRIPPERS We have quite a few of the above units which are 'returns' as they are quite comprehensive units they could be used for other projects etc. Let us know how many you need at just 50p a unit (minimum 10).

HEADPHONES 16P These are ex Virgin Atlantic. You can have 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

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.

FOREIGN DOS 3.3-German, French, italian etc £2 a pack with manual. 5.25" only. REF:MAG2P9

CTM644 COLOUR MONITOR Made to work with the CPC464 home computer. Standard RGB input so will work with other machines. Refurbished £59.00 REF:MAG59

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

COMMODORE 64 TAPE DRIVES Customer returns at £4 REF: MAG4P9 Fully tested and working units are £12 REF: MAG12P5

COMPUTER TERMINALS complete with screen, keyboard and RS232 input/output. Ex equipment Price is £27 REF: MAG27

MAINS CABLES These are 2 core standard black 2 metre mains cables fitted with a 13A plug on one end cable the other. Ideal for projects, low cost manufacturing etc Pack of 10 for £3 REF: MAG3P8 Pack of 100 £20 REF: MAG20P5

SURFACE MOUNT STRIPPER Originally made as some form of high frequency amplifier (main chip is a TSA5511T 1.3GHz synthasiser) but good stripper value, an excellent way to play with surface mount components £1.00 REF: MAG1P1.

MICROWAVE TIMER Electronic timer with relay output suitable to make enlarger timer etc £4 REF: MAG4P4

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

SUPER SIZE HEATSINK Superb quality aluminium heatsink. 365 x 183 x 61mm, 15 fins enable high heat dissipation. No holes! sale price £5.99 REF: MAG6P11

REMOTE CONTROL PCB These are receiver boards for garage door opening systems. You may have 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 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.

SHOP OPEN 9-5.30 SIX DAYS A WEEK

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

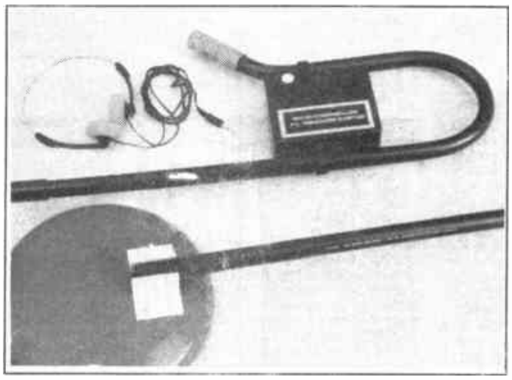
ISSN 0262 3617
PROJECTS ... THEORY ... NEWS ...
COMMENT ... POPULAR FEATURES ...

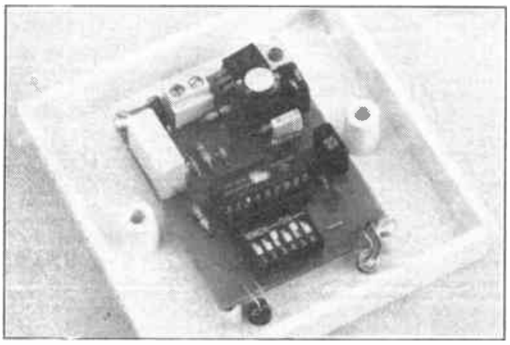
VOL. 23 No. 6 JUNE 1994

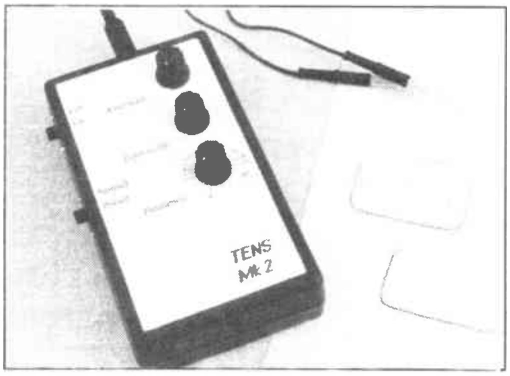
EVERYDAY WITH PRACTICAL
ELECTRONICS

INCORPORATING ELECTRONICS MONTHLY

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







Our July '94 issue will be published on Friday, 3 June 1994. See page 407 for details.

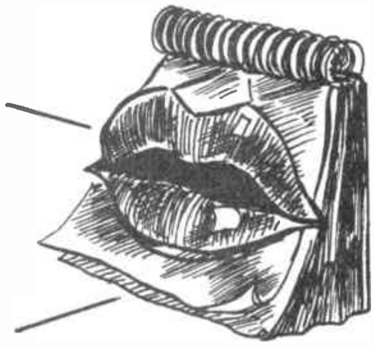
Projects

Series

Features

NEXT MONTH

VOXBOX



GPT, the major European Telecoms Company, is the kind of gentle giant that likes to do all it can to encourage youngsters into a career in electronics. When GPT, who's name comes from GEC-Plessey Telecomms, was invited to participate in the local "Technology in Action Day", the annual feature of a campaign to promote engineering in schools, two design engineers tore themselves away for a short break from designing the successor to the world-standard System X telephone exchange, and created the Voxbox.

Developed to be a straightforward and involving project, suitable for novices by being easy to make and use, the Voxbox was a great success and appears for the first time in any magazine next month.

Voxbox is a solid state non-volatile voice recording board, it can record and replay a message up to twenty seconds long, (or two messages, each up to ten seconds long), features simple push-button operation, and is non-volatile when the battery is disconnected.

Its sensitive microphone allows it to be used as an electronic note pad or with a telephone, for instance to record spoken addresses or travel directions, and we found it could capture and replay tone dial signalling sequences to permit one-button dialling using any telephone connected to a System X telephone exchange.

With the addition of a simple timer circuit the Voxbox could be used as part of a versatile system for making repeated PA announcements. For helping the disabled, the Voxbox is small, cheap and verstaile enough to be used as an audible beacon, perhaps continuously calling out warnings of some unexpected obstruction in a thoroughfare, for example, used by blind people. Disabled users might also find the Voxbox useful when dealing with a doorphone. It also has an obvious application in reproducing sound effects say for a stage production.

STEREO HI-FI CONTROLLER

This project was designed to provide background music once a CD, disc, or tape, etc had finished. The design is intended to accept inputs from typical audio sources using the existing preamplifiers' phono pre-preamp and RIAA equalisation for the phono input. The unit defaults to a background input (e.g. tuner) in the absence of a signal on any of the four priority inputs. The unit fades the signals in, giving a smooth "professional" changeover.

WATERING WIZARD

Keeping the garden watered can be a problem expecially when you are away on holiday. This automatic watering system will turn on a hosepipe or lawn sprinkler at regular preset times – daily, every three days or weekly as required. Water will then be delivered for any pre-selected time from 15 seconds to 2½ hours approximately. The time of day when watering takes place may be chosen anywhere in the 24 hour cycle, according to the user's preference.

This unit differs from simple systems in working on demand. That is, water being deliviered only when the soil is dry enough to need it.

EVERYDAY WITH PRACTICAL ELECTRONICS

OUR JULY '94 ISSUE WILL BE PUBLISHED ON FRIDAY JUNE 3

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 preterminated, 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 TC1DD.

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 TC1DD.............. Our price only £10.99

DISK-COUNT Classical CD's.

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.

CD Roms

Like music CDs these have been overpriced for some time but with the low prices of CD Rom drives the multimedia revolution is with us now. Send for our list of titles. Most popular up to now have been "Too Many Typefonts" with 514 TrueType fonts along with 393 ATM and lots of others. "Shareware Overload" with over 6100 programs extending to 550MB and "Kodak Photo CD Access". The first two are only £12.95, the Kodak only £24.

TECHNICAL BOOKSHELF

Modern Books. Selected to represent the state of the art today.

"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.

"THE ART OF SOLDERING", R. Brewster.
Absolutely essential reading for anyone who ever picks up a soldering iron. Written from knowledge gained in a lifetime in the field, this is the first book ever solely devoted to this essential and neglected skill for all electronic enthusiasts. Covers everything from the correct choice of soldering iron and solder to the correct procedures to follow with many illustrations and practical exercises.
0-85935-324-3 ..... £3.95

"AUDIO", F.A. Wilson, 320 pages. 178 x 111. Publ. 1985.
BP111 "AUDIO" by F.A. Wilson £3.95

"AN INTRODUCTION TO LOUDSPEAKERS & ENCLOSURE DESIGN", V. Capel, 160 pages. 178 x 111. Publ. 1988.
BP256 ..... £2.95

"LOUDSPEAKERS FOR MUSICIANS", V. Capel, 176 pages. 178 x 111. Publ 1991.
BP297 ..... £3.95

"HOW TO USE OSCILLOSCOPES & OTHER TEST EQUIPMENT", R.A. Penfold, 112 pages. 178 x 111. Publ. 1989.
BP267 ..... £3.50

Classics from the "Golden Age"

"THE WILLIAMSON AMPLIFIER", D.T.N. Williamson.
In April 1947, Williamson's power amplifier, using excellent-quality push/pull output valves, a special output transformer, and a highly filtered power supply, became an overnight success. The author takes the reader deep into his design considerations, offering practical advice on how to build the units plus concise instructions on setting up the new amp. A cult classic.
1947, Reprinted 1990. 40 Pages.
0-9624-1918-4 ..... £4.95

LOUDSPEAKERS; THE WHY AND HOW OF GOOD REPRODUCTION, G.A. Briggs.
This easy-to-read classic, last revised in 1949, introduces the reader to concepts such as impedance, phons and decibels, frequency response, response curves, volume and watts, resonance and vibration, cabinets and baffles, horns, room acoustics, transients, crossovers, negative feedback, Doppler and phase effects, and much more. A provocative survey of the right questions about sound reproduction.
1949, Reprinted 1990. 88 Pages. 215 x 140.
0-9624-1913-3 ..... £6.95

COMPUTER TITLES

"A CONCISE ADVANCED USERS GUIDE TO MS DOS", N. Kantaris, 144 pages. 198 x 130. Publ. 1992.
BP264 ..... £3.95

"A CONCISE USERS GUIDE TO MS DOS 5", N. Kantaris, 144 pages. 198 x 130. Publ. 1992.
BP318 ..... £4.95

"MAKING MS DOS WORK FOR YOU", N. Kantaris & P.R.M. Oliver, 160 pages. 198 x 130. Publ. 1993.
BP319 ..... £4.95

"A CONCISE USERS GUIDE TO WINDOWS 3.1", N. Kantaris, 160 pages. 198 x 130. Publ. 1992.
BP325 ..... £4.95

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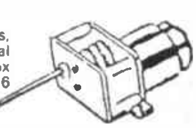

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FAR AWAY

At the time of writing, a summer sun and sea scene like that shown on the front cover seems a long way away. I have spent the last three week-ends watching the wind blow at up to Force 8, preventing me from pushing my dingy out in Poole Harbour. But, perhaps better weather will be with us by the time you read this and our new Treasure Hunter design should provide hours of beachcombing fun.

The *Microcontroller P.I. Treasure Hunter* is particularly easy to use and will work with the search head under water if necessary. I suppose that if the electronics were housed in a waterproof enclosure it could also be used completely underwater by sub-aqua enthusiasts.

µC

As regular readers will be aware the microcontroller is starting to feature in various projects and, as Bart Trepak mentions in the *Smartswitch* article, it may not be very long before some homes have a "computer" in every room. A few years ago that would have sounded ridiculous but now with simple and cheap, easy to use, microcontrollers available it is well worth replacing a few conventional logic chips with one.

The Treasure Hunter has improved performance plus simplified construction and setting up because of the µC (microcontroller) while the *Smartswitch* simply would not be a viable project without such a device. It is often now easier to program a µC than to design conventional logic to do the same job and both our µC projects in this issue illustrate just how easy it is to use one in practical terms. These devices are likely to continue to feature in a number of our projects.

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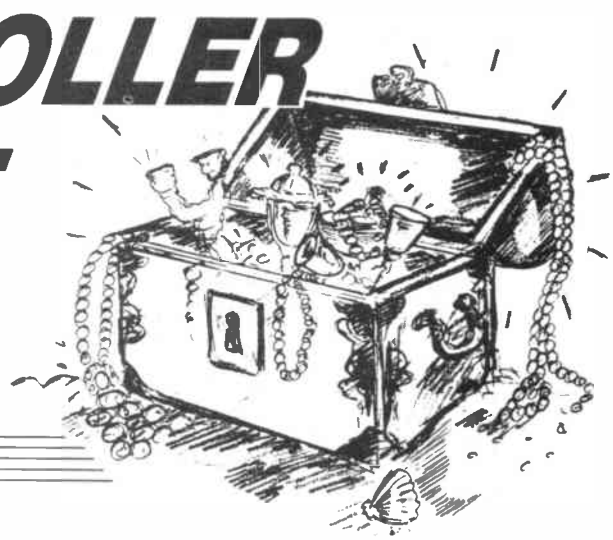
MICROCONTROLLER P.I. TREASURE HUNTER



MARK STUART

A powerful and stable design that is reliable, easy to assemble set up and operate.

THIS project is the natural successor to the highly acclaimed and original design featured in the August 1989 issue. This new version retains all of the good features of the original and brings up to date ideas and technology into the design to produce a more powerful stable circuit. It is reliable and easy to assemble, and can be set up without any special tools or equipment.

As well as the electronic circuit design, the hardware has been improved, and is available separately or as part of the full kit.

PULSE INDUCTION - GENERAL

The pulse induction (P.I.) method of metal detection relies on the electrical conductivity of buried objects. Thin sectioned material such as foil is not very conductive and so is largely ignored. Solid objects such as coins, rings, nails, are much more conductive and are readily detected, as of course are larger objects.

The biggest advantage of pulse induction is that it is virtually free of "Ground Effect" – so much so that it works perfectly with the search head immersed in fresh or sea water, provided the coil is adequately protected.

The only real disadvantage of this type of detector is that it detects ferrous and non-ferrous metals alike – and cannot discriminate between different types of metal. This is more than compensated by the sensitivity, simplicity, and ease of use that the P.I. system offers, and it is a firm choice with detector enthusiasts, especially for beach combing.

The sensitivity of a P.I. detector is determined mainly by the current in the search coil, which also determines the battery life. This design has been optimised to operate for a sensible length of time from six AA cells, whilst giving a good practical level of sensitivity – it will detect a new 10p coin at 20cm.

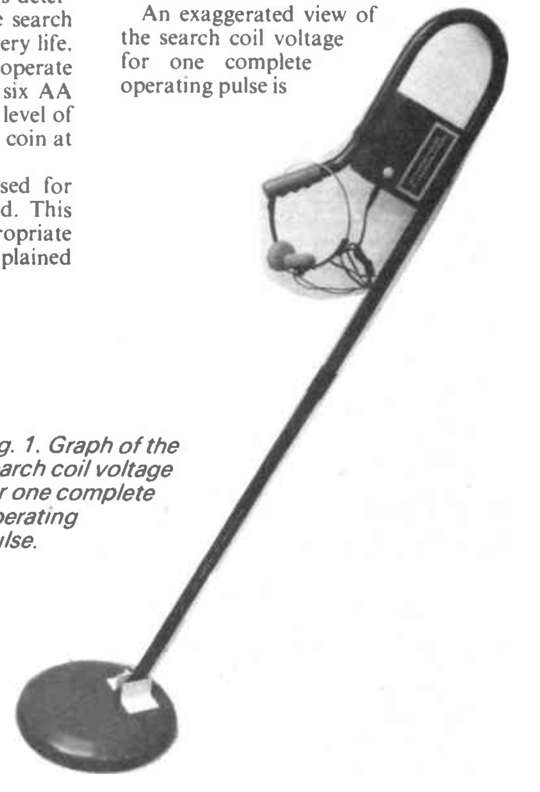
The sensitivity has been optimised for less conductive metals such as gold. This has been done by setting the appropriate pulse sampling time – and will be explained in detail later.

PULSE INDUCTION - PRINCIPLES

The pulse induction method of detection works by subjecting objects to a rapidly changing electromagnetic field. The field is produced by building up a current in a simple multi-turn search coil, and then forcing the current to fall very rapidly by switching off the supply. As the electromagnetic field decays it induces a voltage back into the coil, and also into objects near the coil.

Poor or non-conductive objects are unaffected, but in conductive items a current is induced, producing a small magnetic field which opposes the decay of the original field. This opposing field means that when near metal, the magnetic field around the search coil decays in a different way, and so the voltage induced in the search coil also differs.

An exaggerated view of the search coil voltage for one complete operating pulse is



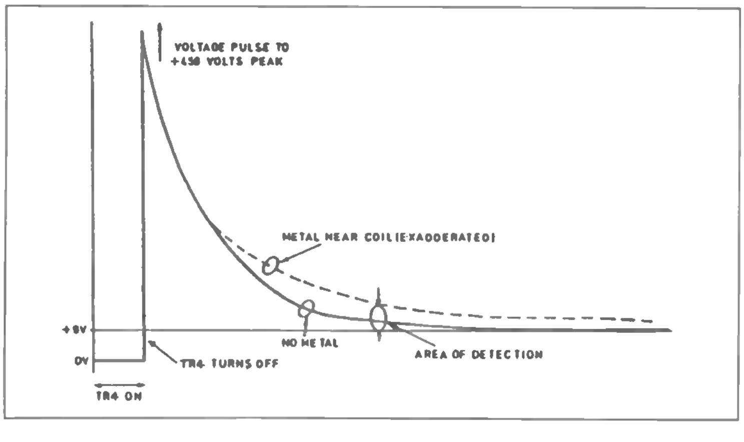


Fig. 1. Graph of the search coil voltage for one complete operating pulse.

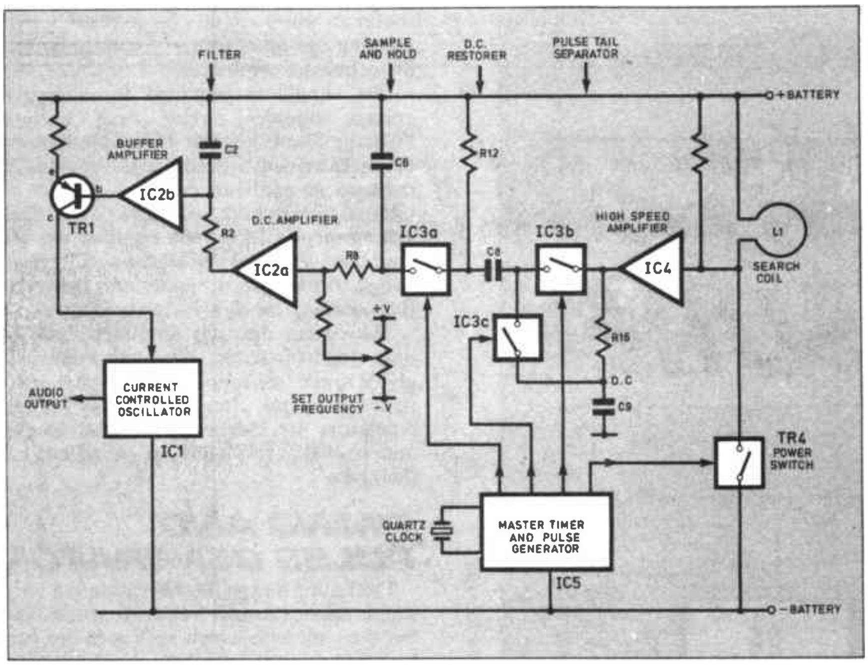


Fig. 2. Simplified diagram of the Microcontroller P.I. Treasure Hunter.

shown in Fig. 1. Initially TR4 is turned on and the coil voltage is close to 9 volts as the current builds up. When TR4 is turned off, the voltage across the coil rises rapidly as the magnetic field through the coil falls. After a time, the field falls more slowly and the induced voltage falls accordingly, dropping gradually to zero. The solid line shows the observed waveform when the coil is clear of metal, whilst the dotted line shows the waveform when metal is near.

The difference between the two curves is very small – much less than one millivolt – and so a large amount of amplification is needed to produce a useful signal. The demands on the amplifier are harsh. It must be very fast, be able to respond to a very small signal after being overloaded by a huge one, and have a high voltage gain.

The main (earlier) part of the pulse is of no value as it shows no difference between metal and no metal conditions. As the pulse decays, although the actual voltages fall, there is an increase in the difference between the two conditions. To get the required signal it is necessary to "sample" the waveform at a fixed time after the initial pulse and from this to derive a voltage which can be used to give an audible or visual output.

The timing of when the sample is taken allows a limited degree of discrimination between different types of metal. A later sample shows a larger signal for very conductive metals such as copper and silver, whilst an earlier sample (as set in this design) shows a larger signal for gold (and, unfortunately, aluminium). It is a sad fact that the best setting for jewellery is also that for ring pulls!

DESIGN FEATURES

The main objective of the design was to produce a circuit that could be divided easily into sections. This was considered important because it simplifies fault finding, makes the circuit easier to understand, and most importantly, allows each section to be optimised for its particular function. Fig. 2 shows the circuit in a simplified functional form.

The use of a microcontroller i.c. (IC5) has allowed all of the vital pulse timing to be optimised, and set in software during development. All of the timing is set by division from the 4MHz microcontroller clock and so is extremely accurate and free from jitter and drift which would otherwise appear as noise and reduce the circuit sensitivity.

There are two other particularly important features in this design. The first is the method of drift cancellation which is applied around IC4. Despite its mundane sounding number, the LM318 is a very fast high gain amplifier which can recover immediately from large overdrive, and then amplify very small signals without overshoot or "ringing". To use it to its full benefit in this circuit it needs to be d.c. coupled and operated at the highest gain possible. With this level of gain, battery voltage and temperature changes produce significant output voltage shifts, which would mean regular re-adjustment of the frequency control.

To deal with this problem, a novel piece of circuitry has been added. The essential part of this is the combination of R16 and C9. These act as a low pass filter, removing any pulses and producing at their junction, a smooth d.c. voltage which is the average d.c. output of IC4.

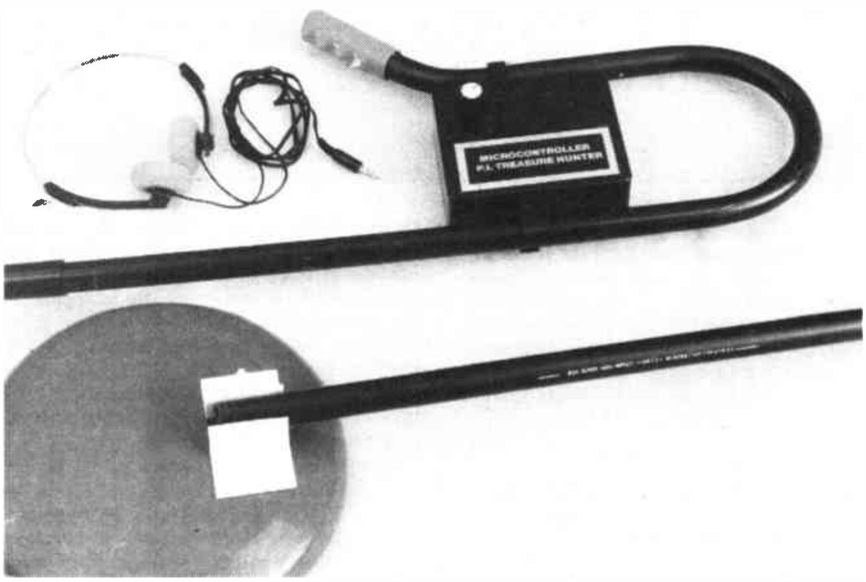
Two analogue gates IC3b and IC3c (which operate as electronic switches) are switched by the microcontroller in such a way that the average d.c. voltage from IC4 is subtracted from its direct output – which contains the same d.c. voltage but with the wanted pulse superimposed upon it. The net result is that the d.c. voltages cancel, leaving just the desired pulse to pass via capacitor C8 to the rest of the circuit. Since the output no longer contains any d.c., there cannot be any voltage drift.

SAMPLE AND HOLD

The second feature is the use of a "sample and hold" circuit to detect the wanted pulse height. Resistor R12 sets the d.c. level at the output from C8 so that the voltage at the junction of C8 and R12 is the positive supply voltage with the wanted negative going pulses superimposed upon it. These pulses need to be converted into a steady voltage proportional to their height which can be used to drive a voltage controlled oscillator to give a variable frequency signal in the headphones.

The conventional approach is to use an integrator circuit with a fast charge and slow discharge rate. This does the job, but as the discharge rate is slow, the circuit is limited in its speed of response. The output also contains a significant amount of the main operating pulse frequency as the integrator voltage rises and falls each pulse cycle, giving rise to a rough sounding tone in the headphones.

The sample and hold circuit uses analogue gate IC3a which is switched on only during the wanted pulse. In this time the pulse voltage is transferred to C6 where it is held during the time that the analogue gate is switched off until the next pulse is sampled. Any change (increase or decrease) in the height of the wanted pulse is immediately transferred to C6 during the sample period and held. Between sample pulses there is no path for C6 to discharge (except via the input resistance of IC2a which is practically infinite) and so the voltage is held perfectly steady.



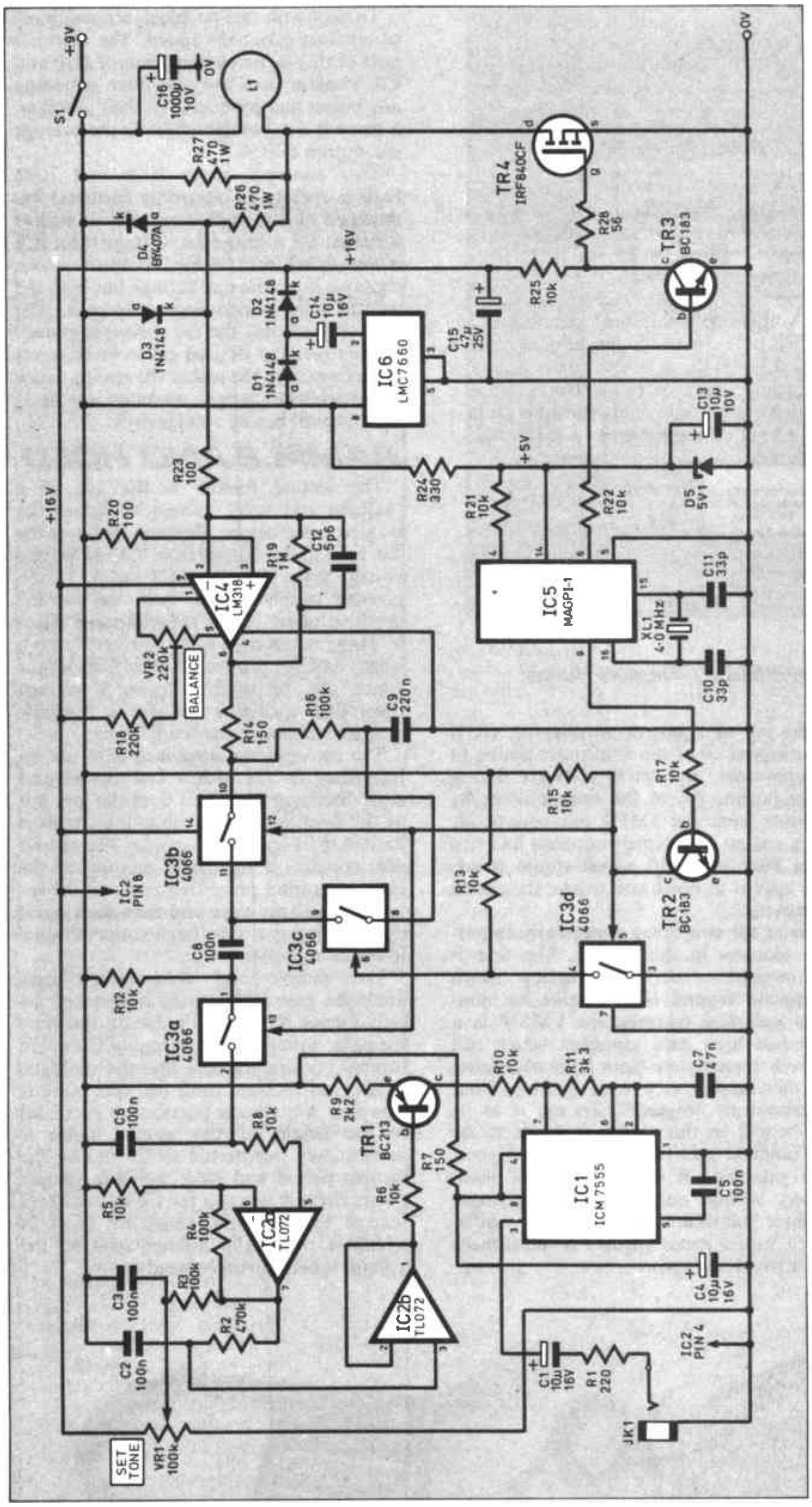


Fig. 3. Full circuit diagram of the Treasure Hunter.

This is a major improvement over the conventional integrator because it maintains a constant voltage between pulses instead of drifting slowly. The result is that the frequency heard by the operator sounds smoother, and that the circuit responds very quickly and equally to increases and decreases in the pulse height as the search coil moves over metal.

CIRCUIT

The full circuit diagram is shown in Fig.3. It appears very complicated as a whole, but each section is fairly straightforward and will be described separately. Apart from the main 9 volt battery supply there are two other voltages required by the circuit. The first is 5 volts for the microcontroller i.c. This is produced by D5, a simple shunt Zener diode regulator fed with around 10mA via resistor R24. IC5 draws only 2mA and so most of the current passes through D5 giving good solid regulation. Decoupling capacitor C13 maintains a low supply impedance at high frequency to keep IC5 stable.

The second supply required is higher than the battery voltage and is necessary so that IC2, IC3, and IC4 can be operated with their inputs and outputs at, or close to, the battery supply voltage. Providing plenty of "headroom" like this is very useful in pulse circuits as it ensures that clipping and other forms of voltage limited distortion are eliminated.

The supply is provided by a simple voltage doubler circuit built around "Charge Pump" circuit IC6. This type of i.c. is extremely efficient and versatile, it contains an oscillator driving a number of internal switching devices. In this arrangement C14 is fully charged via D1 and then switched so that its voltage is added to the battery supply and delivered to smoothing capacitor C15 via D2.

The circuit operates at 10kHz and so only small capacitor values are needed to give a ripple free output of the 10mA or so required by the circuit. The two voltage regulators are independent circuit blocks and so will work, and can be tested, on their own.

TIMING AND PULSE GENERATOR

The timing and pulse generation is a very simple application for a microcontroller i.c. but the ease with which such a device can be used to provide carefully timed pulses is justification in itself. Added to that is the benefit of being able to vary the timing during the development simply by altering the software until the optimum values were achieved. The device is a One Time Programmable (OTP) chip which has a section of EPROM but without a window. Once programmed it becomes dedicated to this application.

The timing is derived from the microcontroller clock which is provided by 4MHz crystal XL1 and its associated capacitors C10 and C11. Resistor R21 ensures that IC5 resets properly and begins running its program immediately power is applied. There are two pulse outputs, one is to the main coil switching circuit via R22 and the other to the signal processing circuits via R17.

Because the microcontroller runs from only 5 volts it is necessary to add transistors TR2 and TR3 which act as "level shifters" for the pulse outputs, producing pulses which swing from 0 to 16 volts across their collector loads R15 and R25.

COIL DRIVE CIRCUIT

The search coil is energised from the 9 volt battery rail. Current is switched on via a high voltage power MOSFET TR4 which is driven from IC5 via TR3. The 16 volt positive pulse at the collector of TR3 ensures that TR4 is fully turned on and has a very small voltage drop. The turn on of TR4 is relatively slow as its gate capacitance is charged via R25, but the turn off is much quicker because TR3 is turned on and provides a low resistance path for the gate capacitance to be discharged to 0 volts.

Resistor R28 limits the TR4 gate current during switching, and protects TR3 in the event of a power device fault. Supply decoupling capacitor C16 provides a reservoir from which the high pulse current can be drawn without causing a huge dip in the supply voltage.

The search coil current builds up to several amps during the time that TR4 is turned on. Immediately after TR4 is turned off a high voltage positive spike appears across the coil as the current decays via damping resistors R26 and R27. Diodes D3 and D4 clip the voltage spikes via R26 to less than one volt peak-to-peak. After the spikes, as the voltage decays into the sampling area, it is way below one volt and the diodes are completely non conducting and so have no influence on the circuit.

COIL VOLTAGE AMPLIFIER

The clipped coil voltage is amplified by IC4 which has its inverting gain set by feedback resistor R19 and the effective pulse source resistance R23 + R26. Feedback capacitor C12 improves the stability and speed. The non-inverting input of IC4 is connected to the other end of the coil (which also happens to be the battery positive rail) via R20.

The connection point of R20 is very important, and must be close to the coil so that IC4 amplifies the difference in voltage between the coil ends, and does not also get unwanted voltage drops from current drawn in the rest of the circuit from the battery positive rail.

Preset VR2 and R18 allow the output of IC4 to be set to zero when there is no input. This adjustment is to compensate for production differences in the i.c.s input offset voltages and currents and once set should require no further adjustment. The term "zero" should not be taken literally here, as both inputs of IC4 are at the positive 9 volt supply rail and VR2 should be adjusted so that the output is also at this voltage.

PULSE SEPARATION

The wanted part of the pulse from IC4 is selected by a time delayed signal from IC5 which is coupled via TR2 to analogue gate IC3b. The timing is such that IC3b is turned on only during the required part of the amplified decaying coil voltage. IC3d is used to invert the phase of the pulse from TR2 which is then used to drive another analogue gate IC3c which is turned on whenever IC3b is turned off. IC3c has as its input an average voltage derived from the output of IC4 after filtering by R16 and C9.

The combined output of the two analogue gates IC3b and IC3c consists of the wanted part of the decaying pulse, and in between, the average d.c. level to which the decaying pulse eventually settles (this has been explained more fully in the Design Features section). Capacitor C8 removes the d.c. level but passes the pulses, and R12 re-inserts a new d.c. level which is equal to the battery supply voltage. The signal across R12 is simply negative going pulses, the height of which depends on how much metal is near to the search coil.

SAMPLE AND HOLD

Analogue gate IC3a is switched so that it is open during the wanted signal pulses and closed the remainder of the time. During the time that it is open, the wanted pulse voltage charges C6. Once the gate closes the voltage on C6 is held steady because there is no available discharge path – either back through the gate, or into the very high input impedance of IC2a. The result is a stable voltage that is adjusted to each new pulse level. If the pulses do not change in height, the voltage remains the same.

D.C. AMPLIFIER AND V.C.O.

The signal across C6 is further amplified by IC2a which is configured as a non-inverting d.c. amplifier with a gain which is set to 10 by R4 and R5. To allow the output voltage of IC2a to be adjusted so that the output signal tone can be set, a d.c. voltage is inserted from control VR1 via R3. Capacitor C3 decouples the adjusting voltage to ensure that interference is not introduced.

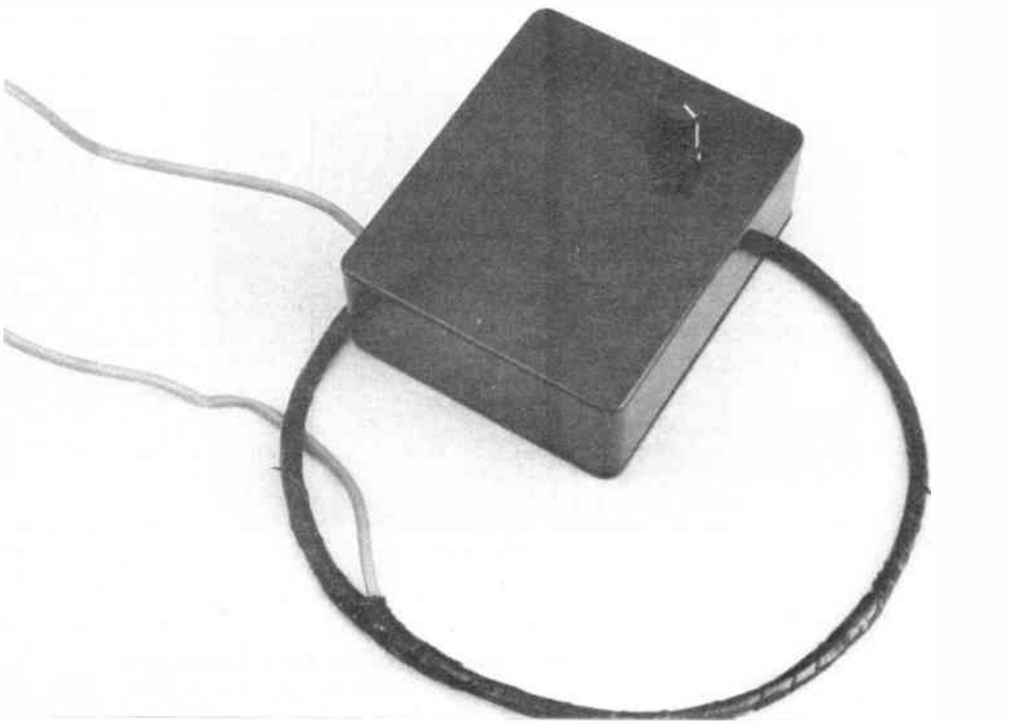
From IC2a the amplified d.c. signal is filtered via R2 and C2 and buffered by IC2b which acts as a unity gain non-inverting amplifier. The output is then used to drive TR1 which adjusts the charging current of C7 and hence the oscillation frequency of IC1 which is a standard low power CMOS 555 timer thus providing a voltage controlled oscillator (v.c.o.).

The output from IC1 is connected to the headphone socket via C1 and R1 and provides more than enough signal for small personal stereo headphones. Resistor R7 and C4 decouple the supply to make sure that the output signal is clean and does not interfere with the rest of the circuit.

CONSTRUCTION

The circuit is based on a single printed circuit board, and involves very little wiring. The component layout and copper foil pattern are shown in Fig. 4. Sockets can be used for all of the i.c.s and make fault finding a lot easier.

Although the circuit is complicated, the final board layout is not overcrowded and is easy to assemble. Before inserting any components, decide how the board will be fitted into the case, and use it as a template for any case drilling. The prototype board was mounted by the bush of VR1 without



COMPONENTS

Resistors

R1	220
R2	470k
R3, R4, R16	100k (3 off)
R5, R6, R8, R10, R12, R13, R15, R17, R21, R22, R25	10k (11 off)
R7, R14	150 (2 off)
R9	2k2
R11	3k3
R18	220k
R19	1M
R20, R23	100 (2 off)
R24	330
R26, R27	470 5% 1 Watt metal film
R28	56

All 5% carbon film 1/4 Watt except R26 and R27.

See SHOP TALK Page

Potentiometers

VR1	47k to 220k lin. switched carbon
VR2	220k miniature preset

Capacitors

C1, C4, C13, C14	10µ radial elect. 16V (4 off)
C2, C3, C5, C6, C8	100n ceramic multilayer (5 off)
C7	47n ceramic multilayer (5 off)
C9	220n min layer type polyester
C10, C11	33p ceramic plate (2 off)
C12	5p6 ceramic plate
C15	47µ elect. 25V
C16	1000µ radial elect. 10V

Semiconductors

IC1	ICM7555 low power CMOS timer
IC2	TL072 CP dual BIFET op. amp
IC3	4066 or 4016 quad analogue gate
IC4	LM318 fast bipolar op. amp
IC5	MAGPI-1 programmed microcontroller (see *Shoptalk*)
IC6	LMC7660 voltage converter
D1, D2, D3	1N4148 signal diodes (3 off)
D4	BY407A high speed diode
D5	5V1 500mW Zener
TR1	BC213 *pnp* transistor
TR2, TR3	BC183 *npn* transistor (2 off)
TR4	IRF840CF high voltage enhancement mode MOSFET

Miscellaneous

XL1	4MHz crystal
L1	20 metres of 0·71mm diameter enamelled copper wire for search coil
JK1	3·5mm headphone socket

6 x AA battery holder and connecting clip; case for control board; knob for VR1; i.c. sockets; search head, handle, and stem hardware kit. Printed circuit board available from *EPE PCB Service*, code 882.

Approx cost guidance only **£65**

any other support, but space has been allowed on the final board layout for additional fixing screws, and VR1 may be mounted elsewhere, off the board if an alternative layout is preferred. Remember before drilling that the board is fitted into the case with its track side down!

The case requires other holes to be drilled to fit two saddle clips, the headphone socket, and for the search coil connecting lead. The positioning of these is left to individual choice, but it is a good idea to keep the socket and search coil holes facing downwards in case of rain.

BATTERY HOLDER

There is space over the main board for a 6 × AA battery holder. Alkaline batteries give the best performance, but rechargeables or standard zinc carbon cells can also be used. The battery space can be separated from the board by a layer of sponge plastic. This holds the batteries in place and protects the board and components.

Once the hardware layout for the case has been sorted out, assemble the printed circuit board. Fit all of the resistors and diodes first, followed by the i.c. sockets, and the capacitors. The i.c. sockets have a notch to indicate which end pin 1 of the i.c. will be fitted and so should be fitted the correct way round. There are several electrolytic capacitors which must be fitted the right way round – usually the negative lead is indicated by a line marked down the side of the case.

The crystal and MOSFET should have their leads bent to 90 degrees so that they can be laid flat on the board. A small dab of glue will hold the crystal down to the board surface. The MOSFET must be fitted with its metal tab closest to the board but does not need any extra support as its leads are quite stiff. TR1 must be a BC213, TR2 and TR3 must be BC183. These have the standard e-b-c pin out. Do NOT use BC183L or BC213L types which look the same but have the collector lead in the centre. All three transistors must be fitted with their flat side as shown on the component layout.

INTERWIRING

There are five connections to VR1, three to the potentiometer section and two to the switch. The three potentiometer connections are self explanatory as they are positioned appropriately on the board. If VR1 is to be mounted on the board, short lengths of tinned wire can be used to make the three connections. For off board operation the three connections need to be made with flexible insulated 7/0.2 or similar wire. The routing of the wire is not critical as it is only carrying d.c. control voltages, but keep it away from the drain of TR4 because of the very high voltage pulses that are around. The connections to the switch section are made by the leads from the battery connectors as shown in the wiring diagram, Fig. 5.

Fit two terminal pins to the board for the search coil connections, as this will allow the search coil to be connected without access to the underside of the board. All of the other off board wiring connections, to the battery leads, the headphone socket, and VR1, if it has been mounted remotely, are best done by soldering the wires directly to the board by stripping a short length of insulation, passing the bared wire into the board from the component side, and soldering it on the track side.

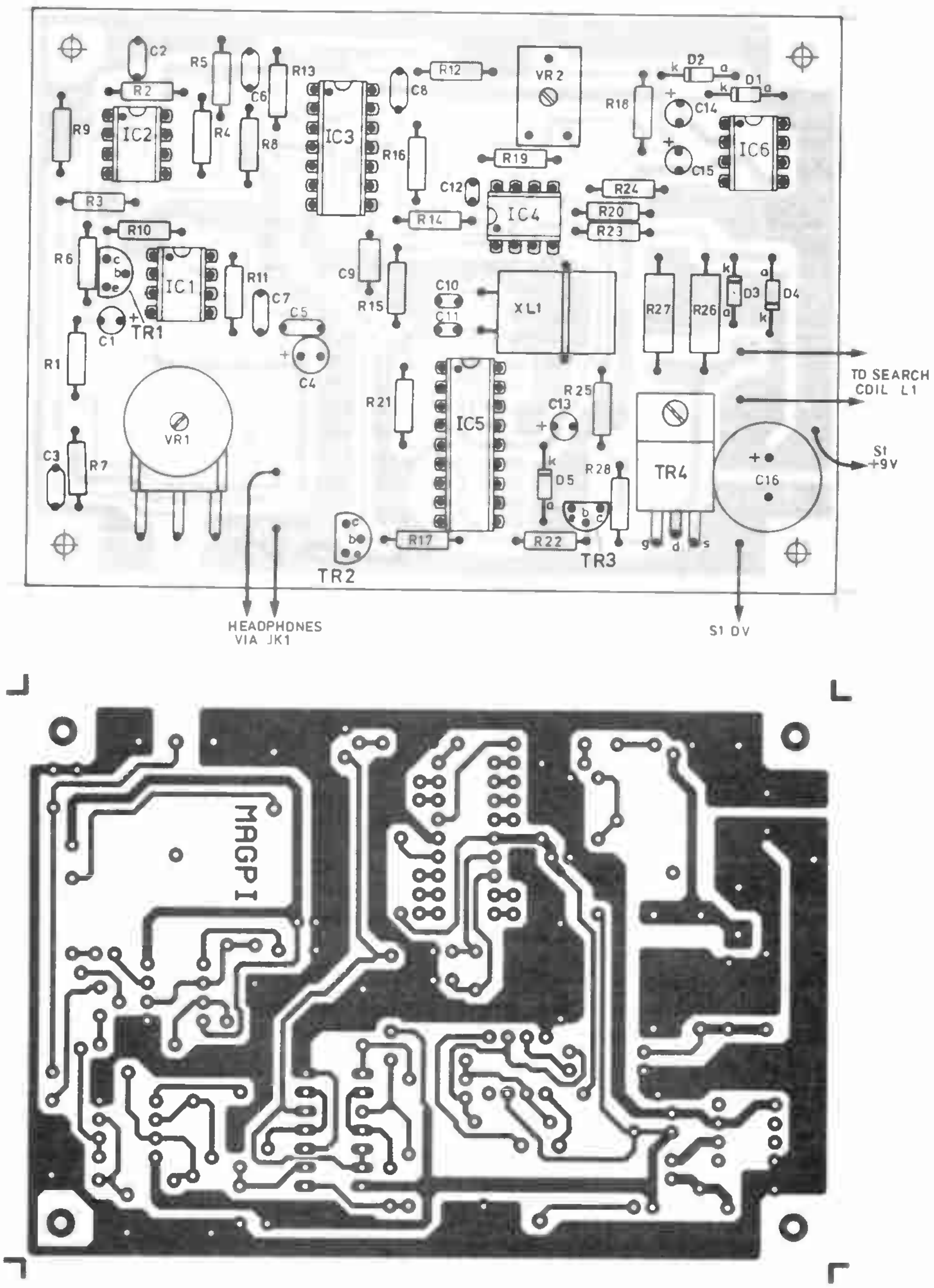
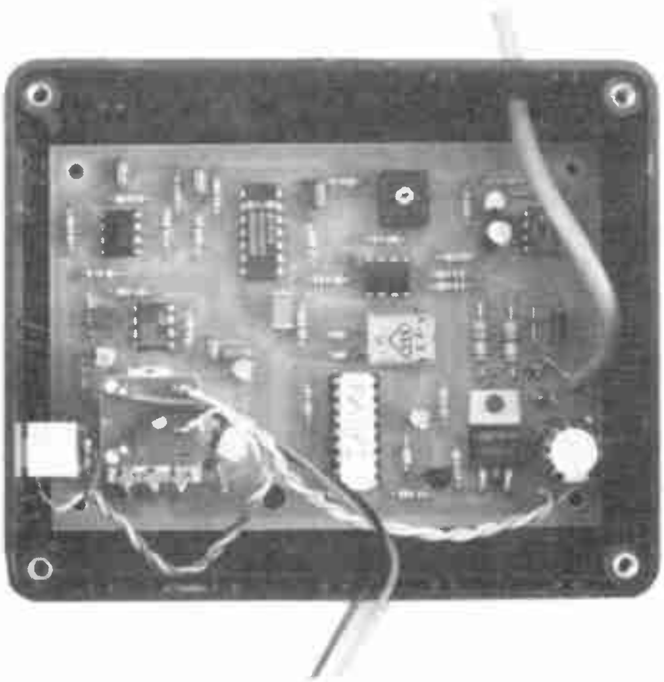


Fig. 4. Printed circuit board design and layout for the Treasure Hunter.



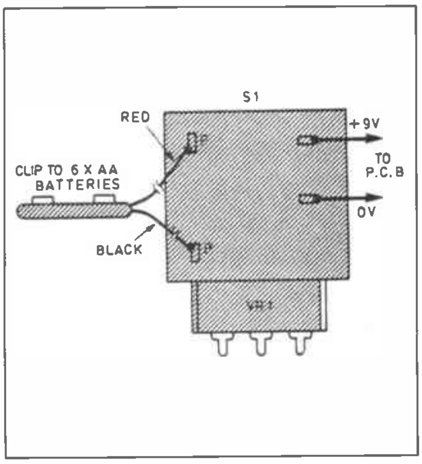


Fig. 5. Supply wiring to S1 and the p.c.b.

SEARCH COIL

The search coil is a simple winding of 27 turns 190mm in diameter. A coil former can be made by marking a 190mm circle on a piece of wood and inserting a 16 panel pins or small nails equally spaced around the line leaving at least 10mm clear above the board. Cover each pin with tape or sleeving to protect the wire, leave 1·5 metres free at the start, and carefully wind 27 turns of 0·71mm diameter enammelled copper wire around the loop leaving 1.5 metres free at the finish. It is not necessary to layer the winding neatly as it will be bunched into a circular section.

Secure the ends with p.v.c. insulating tape, and then carefully slip short lengths of tape under the windings between the nails and fasten the ends together. Fit at least eight pieces of tape and then remove the coil from the board by bending or pulling out some of the pins. The result should be a neat coil that can now be bound with a spiral of tape to enclose it completely.

The start and finish of the winding must be at the same point and should be threaded together through a one metre length of p.v.c. sleeving. The end 30mm of the sleeving should be bound to the coil and the whole coil bound with a further layer of tape spiralled in the opposite direction from the original layer.

Once completed, the two ends of the coil should have their insulating enamel stripped – by using sandpaper, or scraping with a knife. Some types of enamel are solderable, and so can be stripped by applying a hot soldering iron for a while. The bare ends should then be tinned ready to be connected to the pins on the circuit board for testing.

Once the coil has been tested and found to work correctly with the circuit, it can be finished by brushing or dipping it in clear lacquer. Apart from the drying time, this method is simple and effective and if several coats are used will provide adequate protection for use under water.

TESTING

Before connecting the search coil it is useful to make a number of general checks to the circuit. Begin by checking the board thoroughly for dry or missed joints, incorrectly fitted components, and solder bridges. Check also that all of the i.c.s are the right way round, and in their correct places. A simple multimeter that can read volts from 0 to 25 and milliamps from 0 to 100 is extremely useful for testing. If the circuit has been constructed correctly and works first time, test equipment is not needed at all, and it is simply a matter of setting up VR2.

Apply power to the board from six AA cells via a small value (10 ohms or so) protection resistor or a bulb. Connect a pair of headphones, set VR2 to mid position, and adjust VR1 until a steady tone is heard. It should be possible to vary the pitch of the tone right down until it becomes a slow regular clicking sound. If all is well so far, switch off remove the protection resistor, and connect the search coil. Position the search coil on a cardboard box well away from any metal, switch on, and re-adjust VR1 for a slow clicking sound.

Moving a metal object near to the coil should result in a immediate increase in the click rate. If not, VR2 needs adjusting. The best way to do this without test equipment

is to turn VR2 slowly from end to end. As each end is approached there will be a point beyond which there is no effect on the output tone. The correct position should be half way between the two.

If a multimeter is available, then adjust VR2 until the voltage on pin 6 of IC4 is equal to the battery positive (9 volt) supply. Check also the 16 volt boosted supply and the 5 volt supply across D5. The circuit will draw approximately 100mA when operating normally.

If an oscilloscope is available then the circuit waveforms and pulses can be checked. This is a very interesting and informative exercise, and will help to give a good understanding of the operation of the whole circuit.

HARDWARE CONSTRUCTION

The hardware kit is straightforward to assemble. It is supplied as a pre-formed handle section, a straight tube coupler, a straight lower stem extension, and a search head disc. Plastic brackets and nylon screws and nuts are also supplied to make a corrosion proof model which is lightweight and strong. Two brackets should be fitted to the search head spaced apart by the thickness of the stem tube. Use two short screws for each bracket and do not tighten them as the brackets need removing again to drill them for the lower stem fixing.

Take care when drilling the search head disk as it will crack quite easily if not supported underneath the point of drilling. The bracket in the prototype was offset from the disc centre to help minimise the folded up length. This is not necessarily the best position however, and a position nearer the centre may be used if the balance is preferred.

Drilling the brackets to take the lower stem fixing bolt is best done, with the brackets off the search head, by aligning and drilling through both together. The lower stem tube should be drilled diametrically with the same size hole 10mm from the lower end.

Corners may be filed on the brackets and the stem tube end to improve appearance and ensure that the assembly swivels properly. The kit includes a nylon wing nut for the search head fixing so that it can easily be slackened and rotated from the storage position to the operating one.

The case containing the electronic components fits inside the fold of the handle section and is fastened by two saddle clips on opposite sides. This arrangement helps to stiffen up the handle assembly. To prevent the saddle clips from rotating, a small amount of glue should be used as well as the contersunk fixing screws and nuts supplied.

HEAD CONNECTION

The search head connecting lead can be routed by any suitable means up to the control board. Either by threading it up through the stem, or taping or clipping to the outside. Leave enough slack to allow the centre stem coupling to be pulled apart so that the detector can be bent double for transporting. If preferred, flexible leads can be soldered to the ends of the search coil inside the search head and used for the connections to the board. Do not use screened cable for this as the extra capacitance is better avoided.

The length of the stem has to be pre set, as any sort of telescopic fitting would be expensive. For regular users of different height it would be possible to have two lower stem pieces, and change them accordingly – provided the search coil wire is run up the outside.

IN USE

The unit is basically automatic in use, the optimum operating conditions having been set into the microcontroller software, this makes it very easy to use in all situations. Simply switch on, adjust VR1 for a slow clicking sound and start hunting. □

Innovations

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

NEW BRITISH INVENTION WILL TRANSFORM EFFICIENCY OF D.C. MOTOR CONTROL

by Hazel Cavendish

A novel power controller which uses an ingenious combination of switching components to produce a compact control unit for electronic motors has been developed by a team of engineers working at GEC-Marconi in Waterlooville. Based on newly patented switching characteristics, which reduce power losses, the controller offers striking economies of use. By employing a memory chip with a "personality module" it possesses useful adaptability to suit a wide variety of motors.

Professor Martyn Harris, who has the chair of Electrical Engineering at Southampton University, describes the invention as "a very innovative concept with considerable potential in its application." He was particularly impressed by the new controller's clever use of the best properties of MOSFET and IGBT devices to effect the innovative switching which is a dominant characteristic of the invention.

"It makes use of these devices in a very intelligent way" he says. "The traditional motor possessed a commutator – a complicated arrangement of copper segments with carbon graphite brushes. As the motor rotates you get a continuous switching action. The modern trend has been to do away with that commutator and replace it with electronic equivalents – the so-called 'brushless motor'.

The application of this device gives a new lease of life to the old brushed motor because it makes for high efficiency and light weight in providing power for that motor. On the other hand one can also see an opportunity for the use of more complicated electronics which could supply a brushless motor in due course."

EFFICIENCY

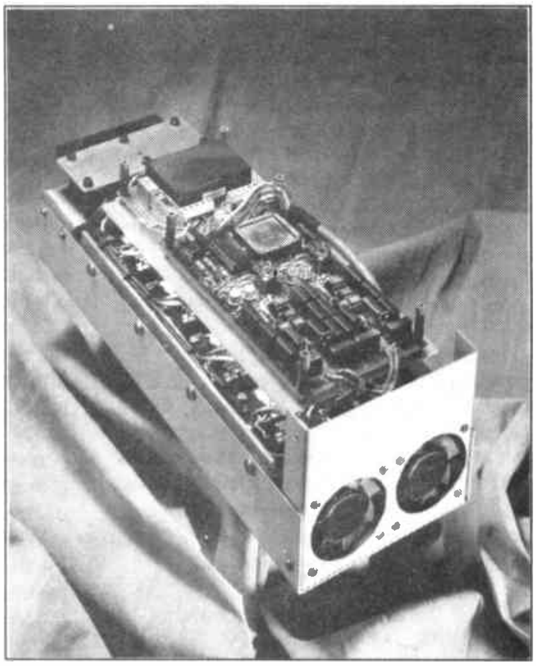
"An important plus with this device is that the inverter efficiency will exceed 99 per cent, whereas one would otherwise have efficiency of only 95 to 97 per cent. When one is talking about large amounts of power that is a very important gain.

A high switching frequency of 25kHz or even 50kHz should be possible, which keeps down the size and cost of other circuit components."

The combining of the two transistor types is the seed from which the invention grew and the team has named it "The Portsmouth Pair". The original concept is the brainchild of a brilliant young Honours graduate from Portsmouth University. Steve Brittan, a Havant resident, cracked the problem which had baffled engineers for some years – how to reduce the size and improve the performance of a d.c. motor controller.

Steve's astute brain worked out how it could be done, but when he moved on to other things he handed the idea over to the appropriate team at GEC-Marconi, headed by Andrew Hay. Mr. Hay enlisted Stuart Aplin, another talented graduate from Portsmouth University, to take on the considerable technical work of the project, and together with other researchers they worked their way through it, ironing out any wrinkles, and finally applied for patents.

In the process of doing so they were pleasantly surprised to find they really had scored a "first" in the field. The only attempt at anything similar had been made by a German engineer sometime previously, but his product was considered rather crude by the Hampshire team, and he had approached the problem in a different way and not at the same power levels; it had not been taken up by any country, so the market was wide open to the "Portsmouth Pair".



TIMING

"It is the timing in the unit itself that is vital" says Hay. "Another young man on our team spent long hours in the lab getting the switch timing 'just right'. The whole success of the invention lies in how one switches the two transistors, and the time difference between switching the two.

Essentially, the MOSFET does the on/off switching with low loss of power, but while the full current is flowing the MOSFET is inefficient and produces large losses. The IGBT is the opposite; it produces large losses when switching on and off, but is highly efficient during the time the current is being held on. It was by carefully organising the way the switches are driven that we were able to get the best of both worlds, and now rejoice in such high efficiency – 99 per cent, believed to be the greatest ever achieved by such a controller."

In order to achieve adaptable programming, the team used an EPROM to command switch functions. By changing the EPROM program it is possible to change the "personality" of the controller so that it is equally happy with a variety of different electric motors.

Undoubtedly one of the main achievements of the new controller is its size (see photo). A 40kW controller for d.c. vehicles previously weighed about 45Kgs with a volume of 76 litres. The new invention weighs only 4Kgs approximately, with a volume of only 4 litres (about the size of a shoe box). The heat reduction is over 80 per cent and there is a saving of 5 per cent in batteries.

Inevitably the new invention prompts the question: will this advance the day of the electric car? Andrew Hay does not think so.

"Although a lot of research is going into the electric car in California, Germany, France and Spain, where they already have 'charging cities' where vehicles can be plugged into various points provided in different places in those cities, I personally believe there is a long way to go before the difficulties are overcome.

The electric car has a mountain to climb in terms of battery storage, except for those commuter cars travelling limited daily distances in city centres, delivery vans operating in city areas where cars are banned, and certain small electric buses on city routes. But as for the equivalent of your family car – no, I can't see it happening in this century.

However, I am confident that our new controller provides a real step forward by greatly increasing the economy and efficiency of tomorrow's d.c. motor systems."

New Technology Update

Ian Poole investigates the latest research developments in Flash memories, and a new way of cleaning i.c. wafers.

FLASH memories are now finding their way into many new computerised products. In fact Intel, the primary manufacturer of the 80*86 series of microprocessors has stopped making EPROMs and is concentrating purely on Flash devices for this type of storage. Naturally when this decision was made it sent ripples across the whole of the electronics industry. It meant that one of the major EPROM manufacturers was ceasing its production almost overnight. Other manufacturers are picking up the shortfall in capacity, but this is not happening immediately, and in the short term some of these devices are difficult to buy.

Intel made this decision because they predicted that the future of this area of memory manufacture lay with Flash memories because of their advantages over the more familiar EPROMs. They offer a cost close to a standard EPROM, whilst being much easier to reprogram.

Flash Techonolgy

Flash technology is based on that of the EEPROM (Electrically Erasable Read Only Memory), but it is considerably cheaper. EEPROMs are nowhere near as common as EPROMs, but they find uses where non-volatile storage of data is needed. For example one common use is in retaining the last settings of a piece of equipment.

The basic memory cell of the Flash device uses only a single transistor instead of the two used by an EEPROM. By using less components, more memory cells can be placed on a single chip, or the cost can be reduced for an equivalent size of memory.

Unfortunately Flash memories do not allow data to be rewritten directly into a particular location. First the cell must be erased, and only then can the new data be entered. In the early memories made in the late 1980s it was only possible to erase the whole chip. Now they are partitioned into a number of sections, normally less than 64 kbytes in size. By doing this it is easy to erase any block and enter new data into it.

Reliability

Like EEPROMs, Flash memories have a limited life in terms of the number of read/write cycles. Work on this aspect is being given a high priority. As a result their reliability is increasing quite considerably. Early memories would typically be able to withstand only 1,000 cycles. Now some of the latest versions are quoted as having a life of over 100,000 cycles.

For the circuit designer, Flash memories offer a number of advantages. The cost is about twice that of an existing EPROM. However there are a number of advantages which can outweigh this cost penalty. Unlike EPROMs, Flash memories do not need to be removed from the circuit to be reprogrammed. They also do not need to be exposed to ultra violet light to be erased. Finally they can be programmed a lot faster.

A standard sized EPROM can take many minutes for all the data to be loaded into it. An equivalent sized Flash memory will take about one tenth of the time. Time reductions like these can be converted into cost savings which can more than pay back the increase in cost of the chip.

With the current industry bias towards Flash memories it is likely that their performance will be greatly improved in the coming years. Their use will also increase, but it is unlikely that the trusty old EPROM will disappear from the scene for many a long year.

Cleaning I.C.s

One very important, and often over looked process in i.c. manufacturing is that of cleaning. With "green" pressures being applied to manufacturers these days, it is becoming increasingly difficult to adopt efficient methods of cleaning which do not adversely affect the environment. But now a new method has been developed which can clean a variety of materials including silicon and gallium arsenide without any adverse affects on the surroundings. In addition to this it has been shown to be even more effective and cheaper than current methods, and this makes it a very exciting and attractive development.

Whilst cleaning may not appear to be one of the most important aspects of i.c. technology it can be the key to success or failure. When making the bulk semiconductor, very high degrees of purity need to be achieved if the final devices are to stand any chance of working. It is also true that very high degrees of cleanliness are required in the manufacturing process if acceptable yields are to be achieved. This means that any cleaning processes must be very efficient, removing even the smallest of particles, along with any larger ones.

With the drive for ever smaller sizes on i.c. architectures, even particles as small as 0·1μm can have significant effects. This means that manufacturers have to spend colossal amounts of money on their cleaning processes. Typically costs of £3 million or more might be have to be paid to install equipment for a single plant. These installation costs, together with the running costs naturally reflect in the cost of each i.c. With some i.c.s only showing a small profit on each device cost is very important.

In view of the very high costs of the cleaning plant, methods of reduction are of great interest, and this has been one of the driving factors of this new idea.

UV Light/Gas Process

The way in which this process works is totally new. Despite this its concept is quite simple, making it a very elegant idea. Instead of using a cleaning solvent an inert gas is passed over the wafer at the same time light photons from a deep ultraviolet light are made to strike the surface of the wafer. This serves to loosen the unwanted particles by breaking the bonding forces and lifting them off the surface of the semiconductor. Once off the surface they are removed by the stream of inert gas.

In using relatively low cost items the new system is much cheaper than normal processes. Also the inert gas which is normally nitrogen or argon is cleaned and then reused.

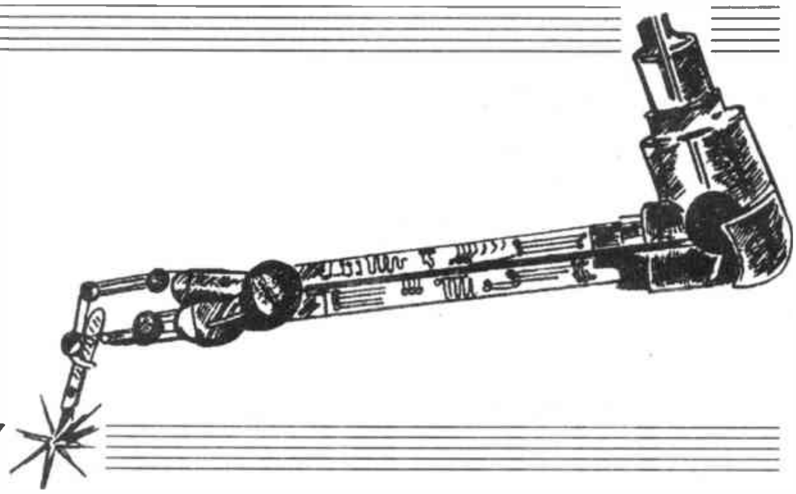
The new system has a number of advantages. Contaminants up to a size of 80μm can been removed using the system. However in i.c. manufacture it is normally used for particles up to about 5μm. It is also found that the new system can remove unwanted materials which current cleaning systems cannot remove, and all this can be accomplished at a reduced cost.

Cost Savings

As an example it normally costs about £3 to clean a standard wafer. However using the new UV light/gas flow system this cost is reduced to about £1. Much of this reduction comes from the fact that expensive de-ionisation and waste treatment plant is not required.

In view of the considerable cost reductions afforded it is likely that the new process will find extensive use within the semiconductor industry. In addition to this it is expected that many other new and interesting uses will be found for it in other areas of industry.

CIRCUIT SURGERY



ALAN WINSTANLEY

Circuit Surgery is our column which helps readers looking for answers in electronics. Sooner or later there will be something which appeals to you. This month, an adaptable Bilge Pump Controller for boats, with other applications, and a money-saving device which extends the life of halogen desk lamps.

Halogen Lamp Protector

Let's start by "shedding some light" on a problem which is causing ***Mr. Robert Baker*** of London a few headaches. Expensive ones, too!

I do voluntary work for a small charity where we've recently purchased several low-voltage halogen desk lamps. They seemed a good idea but they've already blown two bulbs in as many months! Would it be possible to prolong life with a simple bulb protection circuit, perhaps giving a switch-on delayed over a few seconds?

I sympathise! I own a similar lamp which I use when I perform any delicate bench work. They're ideal because they are less obtrusive when doing close-up work, unlike an ordinary desklamp. The down-side is that those halogen capsules can retail at over £5 so anything which extends their life and saves money will doubtless be welcome.

Halogen bulbs run at a low voltage (about 12V r.m.s.) and therefore require a transformer for mains operation. The solution to Mr. Baker's problem is actually very simple. I performed a few quick experiments using a variety of "In-Rush Suppressors" available from RS (Electromail). These are negative temperature co-efficient devices which initially have a resistance of say 10 to 20 ohms at room temperature. As they warm up due to self-heating, their resistance plummets to a fraction of an ohm, permitting an increase in current flow.

By inserting a suitable type in *series* with the low voltage a.c. output of the lamp transformer, they very effectively limited the switch-on surge of current. Mr. Baker explained that their lamps use a transformer adapter fitted with a two pin socket, into which the lamp is plugged.

Mine's the same, with a two-pin 'speaker DIN plug (and, happily, a thermal fuse, see last month). It is therefore straightforward to place the surge suppressor in series with the 12V bulb by building a small in-line unit. Mount the component on a piece of tagstrip and enclose it in a small box, see Fig. 1 for the circuit schematic diagram.

I suggest using the current suppressor which is rated at 3A (Electromail, code 210-702). This will easily be adequate for the average 20W 12V G4-type (bi-pin) halogen capsule found in desk lamps. It causes the lamp to take one or two seconds to illuminate, brightening to maximum level within 10 seconds or so.

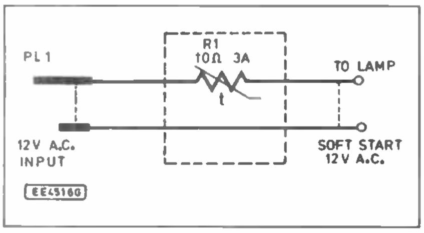


Fig. 1. Halogen bulb protection.

The device's resistance is 10 ohms initially, falling to 0·3 ohms at 3A. It will however cause a very slight but acceptable reduction in light output (say 5%) because of the series resistance it introduces. This will actually increase bulb life even more! The slightly more expensive 210-689 version is rated at just 2A and produced delays of about five seconds – even better protection but perhaps a bit slow for practical use.

I am sure that the Lamp Protector will soon pay for itself, I reckoned on a total cost of about £2.50 based on a small box with a chassis or in-line socket and a short lead terminated in a DIN plug. One final *caveat*, the suppressors become extremely hot during operation, so they must not be allowed to touch plastic or insulation, and they will only offer full surge protection when *cold*.

Tip: If you use those expensive dichroic halogen ceiling downlights (typically four 12V 50W lamps to a 200VA transformer), then you should replace any failed bulb *immediately*. If you have an ordinary lighting transformer, the reduction in load current caused by the blown bulb means that the secondary voltage of the transformer will ***rise***, so the remaining bulbs will be driven by a marginally higher voltage, which will shorten their life. A mere five per cent voltage over-rating decreases bulb life by ***half***. More gen. on lighting a little later on.

Man the pumps

From ***Mr. Edwin Flett*** of Banffshire came the following suggestion which might appeal to boating enthusiasts, but it could readily be adapted to other needs.

I own a 7-metre open boat which tends to fill up with rain water on a regular basis. This necessitates pumping out by hand almost daily during the winter months. Could you help me with an automatic pumping system operating from the 12V starter battery? The circuit would need to switch on when the bilge water had reached a pre-determined level and remain on until the water had been pumped out.

Fortunately this is an easy problem for us to solve, Mr. Flett. Water level detection is a very popular example of the application of electronics, previously having featured in one form or another, perhaps as a Rain Alarm or Flood Alarm, or a gadget for watering plants automatically. They use a "probe" to check for the presence of water, which actually has an electrical resistance. A sensor circuit can detect this resistance and operate a load such as an alarm system or a pump.

Stripboard has sometimes been used to form a simple probe by linking alternating copper strips together to form a series of parallel conductors. By dipping the probe into water, the strips are shorted together by the water, so the resistance of the probe drops from infinity (air) to a few tens of kilohms.

It's easy to use this "stripboard probe" with a simple transistor switch, such as that shown in Fig. 2. Transistor TR1 will turn on when water bridges the probes, and will drive a relay – or it could be an l.e.d. with resistor or a buzzer instead. Capacitor C1 introduces a time delay to prevent nuisance triggering by occasional droplets. A Darlington transistor will provide higher gain whilst simplifying construction. This circuit could form a basic water level or rain alarm for example.

The biggest problem is that when sensing the water's resistance in this way, a small d.c. current flows between the probes through the water, which sets up an electrolytic effect. Gradually the probes deteriorate because of chemical decomposition, to the point where the probes may be eroded altogether.

In a marine environment the problem will be worse, because of the reaction with salt water which actually becomes Sodium Hydroxide – caustic soda – under electrolysis. Fear not – several integrated circuits are available which solve this problem!

Bilge Pump Controller

The National Semiconductor LM1830N Fluid Level Detector and the Allegro (Sprague) ULN2429 are two such chips (neither compatible with the other). The Allegro device has far superior output ratings but is more difficult to obtain. Instead, Fig. 3 shows a circuit for an experimental Bilge Pump Controller using the '1830 chip, in effect forming a "high water level" alarm.

Like the Allegro device, the main feature of the LM1830N is that it passes an *alternating* signal between two probes with no net d.c. current flowing. This eliminates the electroplating effect of the probes.

An internal oscillator, within IC1, operates at a frequency determined by capacitor C4, here about 6·6kHz. The oscillator output is decoupled by capacitor C3 which blocks any d.c. content, before passing an a.c. signal through two probes positioned in the bilges. The chip has an internal 13k (kilohm) reference resistor so if the resistance of the probes is *greater* than 13k, the output pin (12) goes low and sinks current to 0V via resistors R2 and R3. Therefore this happens when the probes are dry.

The *npn* Darlington transistor TR1 acts as a switch which can be used to drive a heavy load such as a 12V pump, via a relay for flexibility. Under "dry" conditions, the transistor's base current is diverted into pin 12 towards 0V, thereby preventing TR1 from turning on. When water bridges the two probe contacts, IC1 switches pin 12 high. TR1 turns on which completes the circuit to the relay, powering the bilge pump until the water level has dropped below the probes again.

A short delay of about one second is introduced by capacitor C6. This prevents the pump from operating if the probes detect "nuisance" splashes caused by bilgewater slopping about, a welcome feature in an unsteady boat. Because the i.c. *sinks* current under "normal" (dry) conditions, a Darlington transistor was used so that the base resistor R3 can be relatively high, reducing overall current consumption.

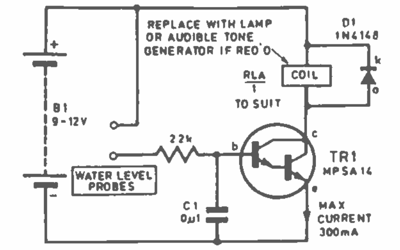


Fig. 2. Simple water level detector circuit.

The circuit draws about 5mA total without the relay functioning. The transistor will handle 1A directly and could be substituted with any convenient alternative. Select the relay contacts to suit the pump, which may need a small suppressor capacitor.

By removing the filter capacitor C5, the i.c. output becomes a 12V square wave of roughly 50:50 duty cycle, of the same frequency as the oscillator. When the probes are wet, pin 12 will be high (+12V) – but in the absence of water, the output generates a square wave signal. This could be adapted to form an audio alarm.

The Bilge Pump Controller can be assembled on stripboard, housed in a small sealed box to prevent water ingress from affecting the circuit board. The circuit should operate quite happily from the 12V starter battery, noting the nominal standby current, so don't allow your battery to discharge accidentally.

The probe could be made from a length of twin-core wire with the ends bared. Fix the probe at the height at which you require the pump to *stop*. Above this height, the pump will switch on automatically and pump away the excess. Happy sailing!

Other applications – water tank level control, horticultural use (auto plant watering using *normally closed* relay contacts to drive a small pump or solenoid valve), fishpond or water barrel automatic overflow... can you think of more?

Shed some light

Back to lighting, I have included the following "electrical" question for its general interest value. Subscriber ***Mr. E. Ford*** of Mallorca, Spain asks:

Fluorescent lamps are rated at 18, 20 or 40 Watts, yet whenever I have tried to ascertain their consumption, nothing tallies! Whether by a True Watt Meter or calculation or monitoring a meter over a long period, I obtain a power consumption figure of around double the wattage!

I am sure everyone thinks a 40W tube uses 40W of power. An answer in your excellent magazine would be appreciated.

Thanks for the compliment and the intriguing question. The average consumer can be forgiven for thinking that the lamp consumes just 40W or whatever rating is printed on the tube. The problem is, the wattage quoted on the glass tube itself does not take into account the losses incurred in the associated control gear (the ballast etc.) which itself dissipates a nominal power. The "extra" power consumed depends on the type of control gear used.

None the less, a fluorescent tube is pound for pound more economical than a tungsten filament bulb and a larger proportion of its total energy consumption is converted into light. An ordinary bulb may only be some 5 to 10 per cent efficient in terms of light output, and they are relatively short lived. They make better room heaters!

In recent years there has been a move towards the compact fluorescent light fitting, a small tube which has an electronic ballast and replaces an ordinary bayonet cap bulb altogether. It's claimed they have a much longer lifespan (8,000 hours or more) and offer 80 per cent power saving over incandescent bulbs of the same wattage. An 18W compact is directly comparable to a 100W filament bulb in power consumption and output, which is where real savings can be made – even if they do cost ten times more.

Next Month: I'm hoping to describe a simple Car Electrics Probe, plus a quick look at 555 timer triggering techniques. Don't forget – I am still collecting readers' Hints and Tips to share with everyone.

Come on readers – if you have any ideas or advice to pass on, write in! Our Education Service supports teachers and students in electronics foundation courses such as GCSE or GCE "A" Level or similar, we will try to help with the practical and theoretical aspects of these syllabuses where possible.

If you have any queries or suggestions for possible inclusion in this column, please write to me: Alan Winstanley at *Circuit Surgery*, 6 Church Street, Wimborne, Dorset BH21 1JH. I cannot guarantee a personal reply but I read every letter.

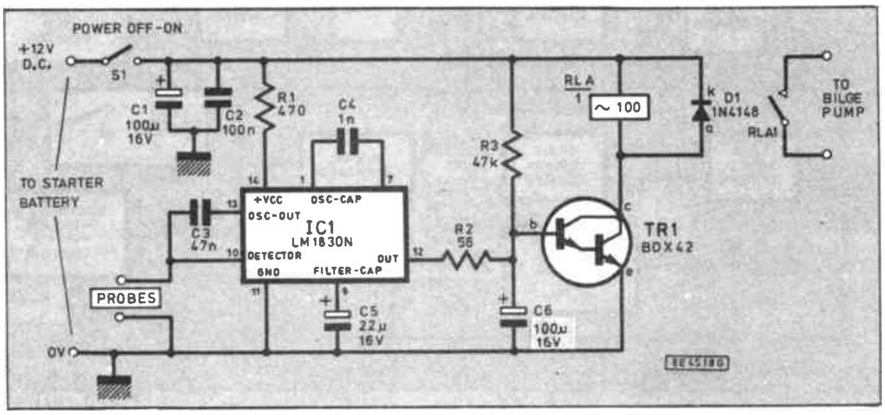
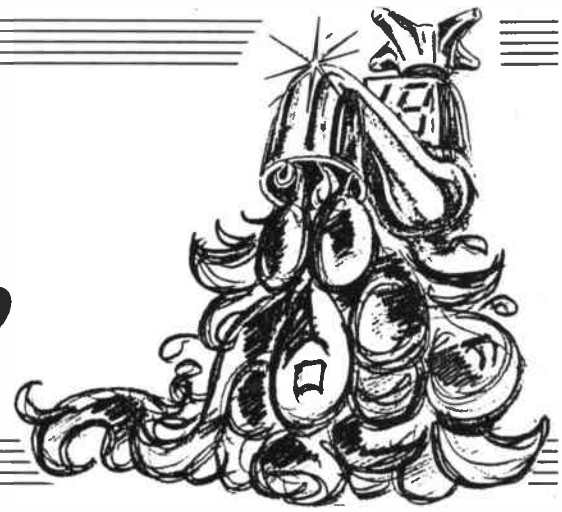


Fig. 3. Circuit diagram for a Bilge Pump Controller.

DIGITAL WATER METER



JOHN BECKER

Plumb potential leaks in your water budget with the help of this H_2O meter.

LATELY there has been much publicity concerning conservation of water supplies and the rates charged by regional water companies. It is becoming increasingly obvious that not only must we decrease our water consumption for ecological reasons, particularly in Southern England, but also for reasons of cost.

The Digital Water Meter described here is intended for use by anyone who is interested in monitoring their water consumption for either of the above reasons. It will also provide advance cost guidance to those who may be considering having a Water Company meter installed.

MONITORING OPTIONS

There are two ways in which the meter can be used. The sensor may be plumbed into the main domestic water input pipe as a permanent fixture somewhere after the Water Company stop-cock. Alternatively, using a push-on rubber connector, the sensor may be temporarily attached to the output of almost any tap.

In either instance, the electronics which monitor the sensor can be mounted as a fixed unit anywhere in the house, or used as a roving meter which can be placed near a particular water output being monitored.

Within reason, there is probably no practical limit to the length of 3-core cable used to connect the meter to the sensor between any points around an average house. The test model has been used satisfactorily with cable lengths in excess of 30 metres (100 ft.)

The meter uses a 4-digit liquid crystal display (l.c.d.) and has two display modes, each having two ranges. Mode one displays water consumption in litres, up to a maximum of 99999 litres. Mode two shows the cost of the water measured, up to a maximum value of £999.99.

The cost per unit of water volume (1000 litres) can be set by switches within the meter case from 1p to 255p per unit, allowing plenty of scope for variation between Water Company prices, and for inflation! If the cost monitoring function is not required, it may be omitted.

WATER FLOW SENSOR

The flow chart/block diagram for the complete Digital Water Meter is shown in Fig. 1. The flow sensor (transducer) has been designed for use with mains and heating system water supplies up to a temperature of about 70°C. However, it *MUST NOT* be used to monitor drainage water sources, such as the outputs of kitchen sinks, baths, washing machines or similar, since it could become blocked.

Basically, the sensor is a pipe containing a small turbine mounted on sapphire bearings. Attached to the turbine in a water-resistant housing, is a small electronic circuit, as shown in Fig. 2. Water flowing through the pipe causes the turbine to rotate at a rate proportional to the flow rate.

Within the housing are an l.e.d. and a light-sensitive diode. As the turbine blades rotate, they repeatedly interrupt the light path between the l.e.d. and the photo diode. The resulting voltage changes across the diode are amplified by the sensor's

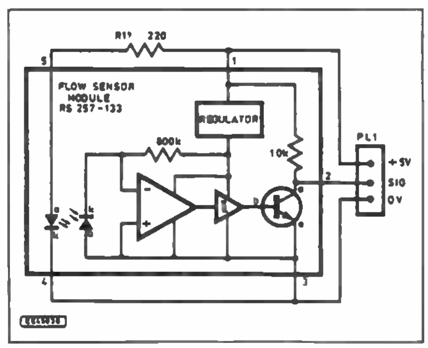


Fig. 2. Flow Sensor circuit.

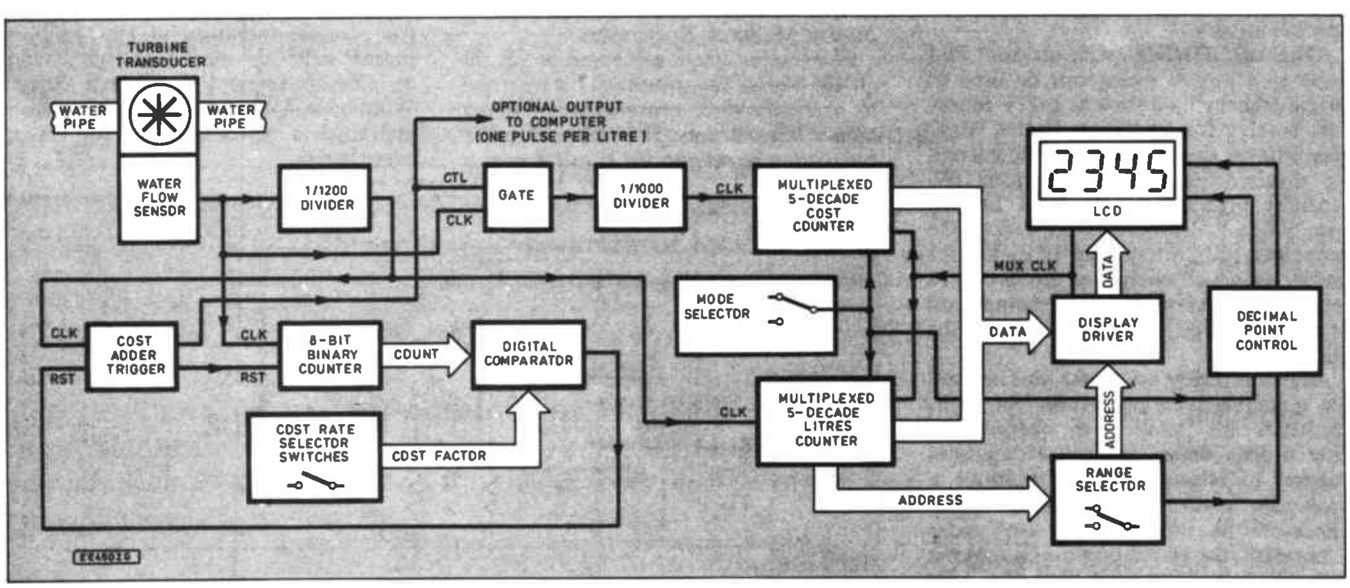


Fig. 1. Flow chart for the complete Digital Water Meter system.

op.amp, shaped by the Schmitt trigger and output at the transistor's collector (c).

The maximum output pulse level is that of the supply line which, in other applications, may be between about 4·5V to 16V. For the water meter, the level is nominally +5V. An internal regulator drops the supply voltage to a fixed level suitable for the photodiode, op.amp and Schmitt trigger.

The sensor's l.e.d. has to be used with an external series resistor, R11, whose value is chosen to suit the supply line. The maximum recommended l.e.d. current is 30mA, though with the test model a current of about 22mA, as set by R11 at 220 ohms, was satisfactory. Note that the sensor's circuit housing is not totally light-proof and that too high an l.e.d. current in the presence of high ambient light levels could cause the output signal to stay high.

A graph of the sensor output pulse rates plotted against water flow rates is shown in Fig. 3. It also shows the typical output pulse waveform.

The sensor is capable of monitoring flow rates of about 1·5 to 30 litres per minute. Full scale frequency output is approximately 600Hz. Typically, the number of pulses per litre of flow is 1200. It is this latter figure which is used in the calculations made by the water meter circuit.

LITRES AND COST SCALING

The Litres and Cost scaling circuit diagram is shown in Fig. 4. Converting the sensor output to a litres count equivalent is simply a matter of dividing the pulse rate by 1200, since that is the sensor's defined rate.

The division is performed by counter IC1 and AND gate IC2a. The AND gate detects when the count has reached 1200, at which point its output is triggered high, thus resetting counter IC1 back to zero, whereupon the count recommences.

The AND gate's output pulses are counted by another stage (see Fig. 5) from where the total can be fed to the display unit. The gate's pulses also trigger the first stage of the cost scaling circuit.

Costing is achieved by increasing a counter value by a set number of pulses for each litre pulse received. The number of pulses added each time is set by a bank of switches, S1 to S8, and represents the cost of 1000 litres of water (one cubic metre or 220 gallons) as charged by the local Water Company.

Charge rates vary across the country, ranging from 37·10p per cu/metre for

STATISTICS

The following statistics were variously supplied by Ofwat and the Water Services Association, to whom the author expresses his thanks.

Domestic Water Usage

Appliance	*Average Occasions Used Per Day*	*Average Water Consumption (Litres)*	*Percentage of Average Total Consumption*
Washing Machine	0.75	110	12%
Dishwasher	0.8	55	1%
Bath	0.6	80	} 17%
Shower	0.55	35	
WC	10.5	9·5	32%
Garden Hose	–	540 per hour	3%
Drinking/Cooking	–	–	2·5%
Miscellaneous	–	–	32·5%

Average water use per household per day: 380 litres.

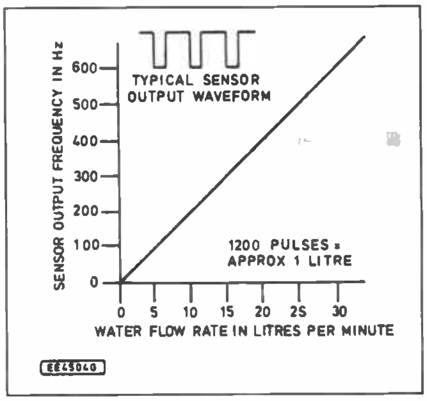


Fig. 3. Sensor output pulse rates plotted against water flow.

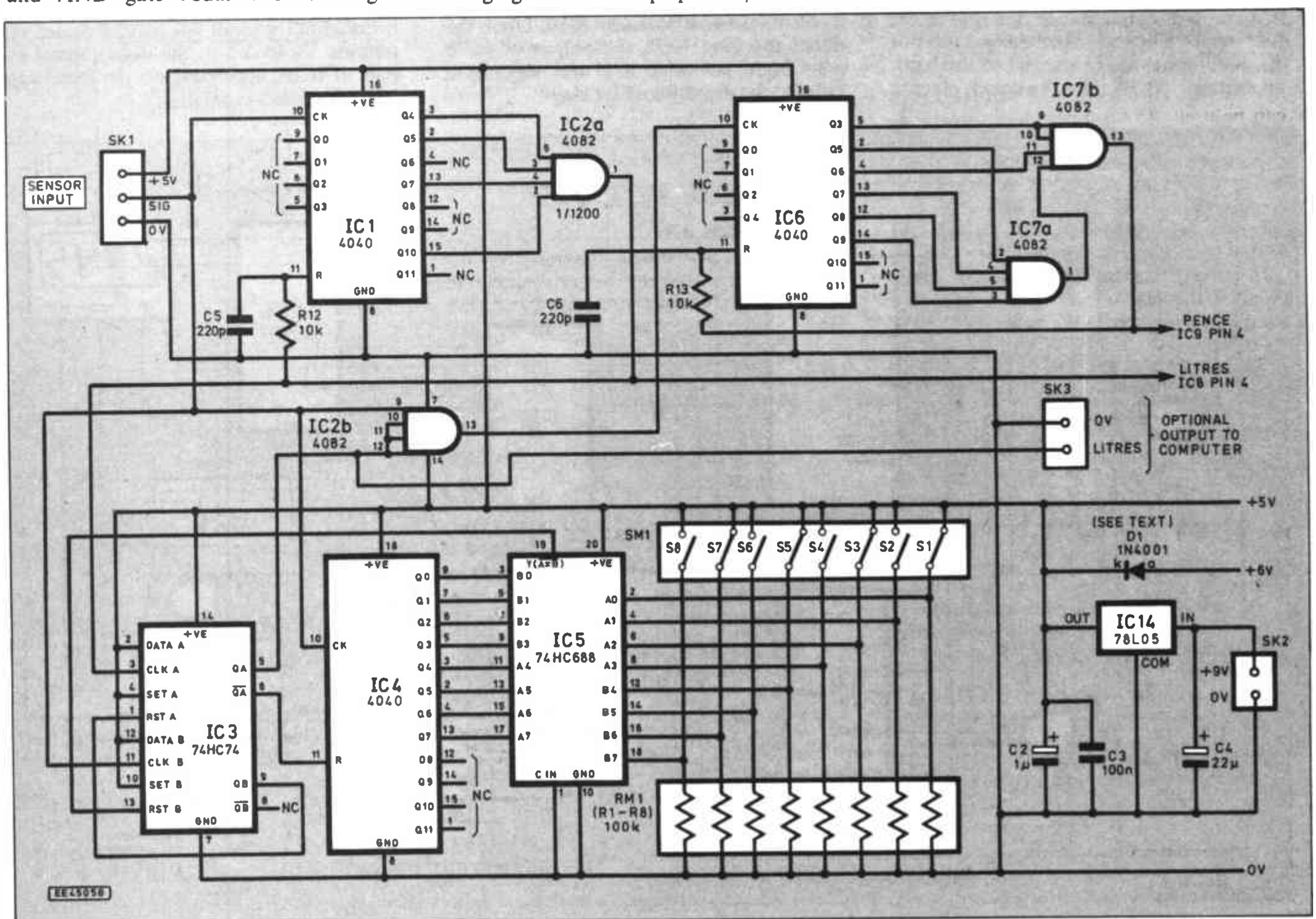
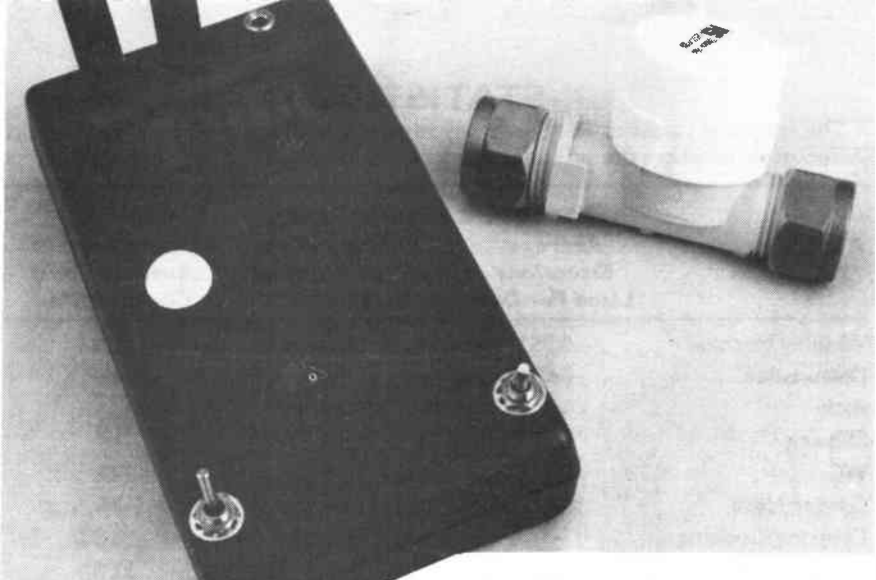


Fig. 4. Litres and Cost Scaler circuit for the Digital Water Meter. Note that the d.i.l. switches S1 to S8 are shown set in binary bit order for decimal 85.



Portsmouth to 100·00p per cu/metre for Mid-Sussex (source: Ofwat 24th Nov 93). The charge rate for your region can be obtained by telephoning your Water Company. Although charge rates are quoted to decimal places the meter's switches can only be set for whole pence values.

The output of IC2a is connected to the clock input of flip-flop IC3a. When IC3a is in an untriggered state, a positive going clock pulse triggers its QA output (pin 5) high and its $\overline{QA}$ output (pin 6) low. The high level of QA allows AND gate IC2b to pass sensor pulses through to the counter clock input of IC6. The low level of $\overline{QA}$ allows IC4 to start counting pulses directly from the sensor.

Binary comparator IC5 has eight sets of dual inputs. The first eight outputs of IC4 are each connected to one side of the dual inputs. The equivalent second sides of the dual inputs are connected to the bank of switches S1-S8. The switches place a selected binary code, representing the cost rate, onto the comparator.

At the point when the output logic of IC4 matches the logic set by S1 to S8, the output of IC5 (pin 19) goes low, taking flip-flop IC3b out of reset mode. At the next positive-going pulse from the sensor, IC3b is triggered and its QB output goes high, resetting IC3a. Consequently, the logic states of IC3 QA and $\overline{QA}$ are inverted, respectively closing gate IC2b and resetting counter IC4.

While IC3a remains triggered following the single litre pulse, IC2b allows IC6 to count pulses synchronously with IC4. If S1 to S8 are set as shown in Fig.4, the total number of pulses counted would be 85 (binary 01010101). As yet, though, (and hopefully never so!) it is not a single litre of water that might cost 85p, it is 1000 litres.

The purpose of IC6, therefore, in conjunction with AND gates IC7a and IC7b, is to divide the cost count by 1000. Upon the count reaching 1000, the output of IC7b goes high, resetting IC6 and sending a pulse to the display counter stage.

Two resistors and two capacitors, R12, R13, C5 and C6, are included in the reset paths of IC1 and IC6. These slightly delay the time that it takes for the counters to be reset when their respective AND gates are triggered. This action extends the pulse durations to suit the needs of the display counter stages.

DISPLAY COUNTERS

Referring to Fig. 5, two multiplexed 5-decade counters, IC8 and IC9, respectively tot-up the litres and pence counts. The type 4534 chip used for both counters has five internal count registers whose binary-coded-decimal (BCD) outputs can be separately switched to the Q0 to Q3 outputs by an internal digit-select (DS) counter.

The DS clock pulse is derived from the l.c.d.'s backplane (BP) clock generator. Each clock pulse steps the DS counter on by one place, each time presenting, in sequence, a different register's contents to the Q outputs. Simultaneously, the respective DS output (DS1 to DS5) is taken high.

The Q outputs from IC8 and IC9 are fed to the data inputs of the l.c.d. driver chip IC13. Via path-selector IC10, four of the DS outputs control IC13's address-selector inputs LSD to MSD (pins 31 to 34), so routing the Q count data to the correct l.c.d. digit segments.

RANGE SWITCHING

Range selection between count digits 1 to 4, and digits 2 to 5 is performed by IC10 under control of switch S11. The chip has two sets of 4-input lines, A0 to A3 and B0 to B3, to which the DS outputs of IC8 are selectively split.

Either of the input sets may be routed via outputs Y0 to Y3 to the digit control inputs of IC13, depending on the logic state of IC10's Select input pin 1.

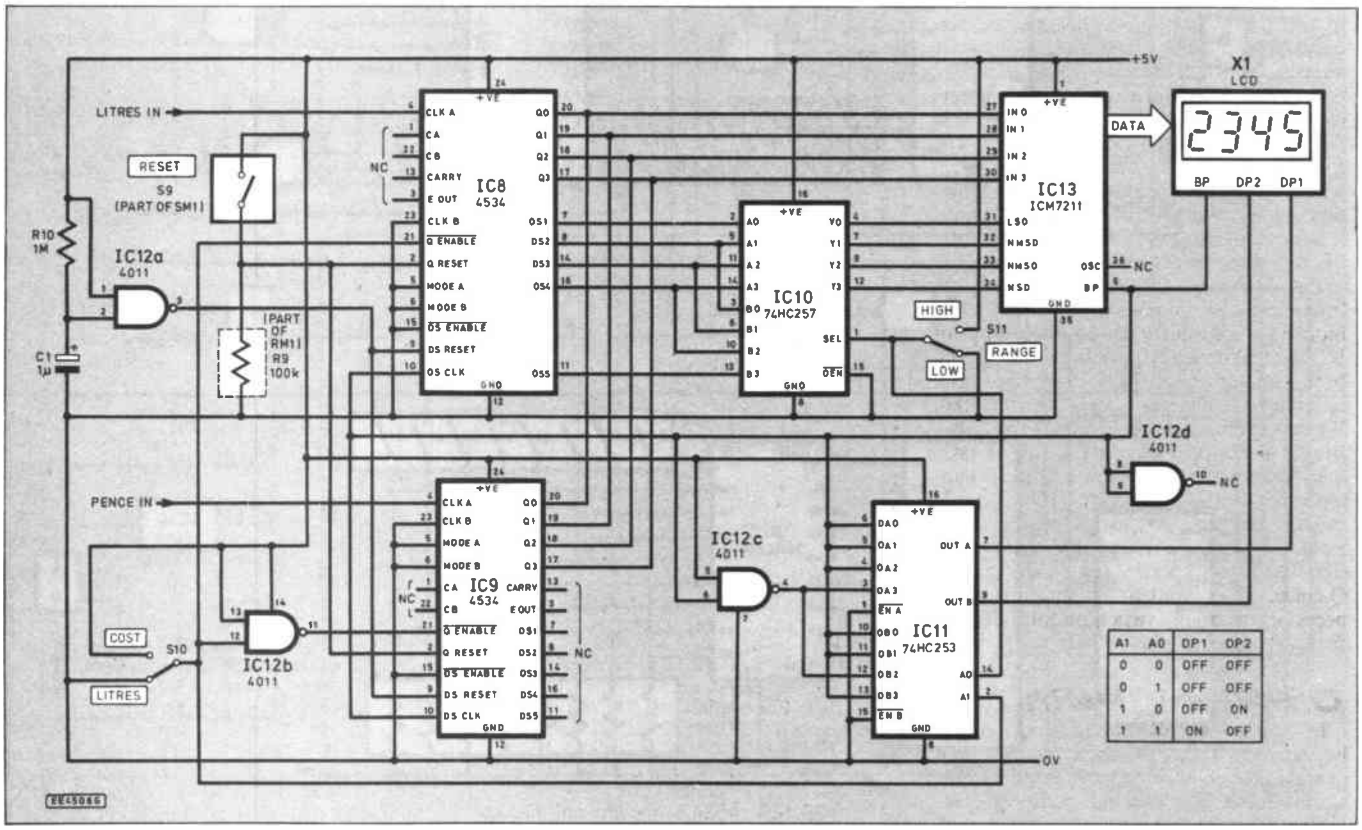


Fig. 5. Circuit diagram of the Litres and Cost Counter stages of the Digital Water Meter.

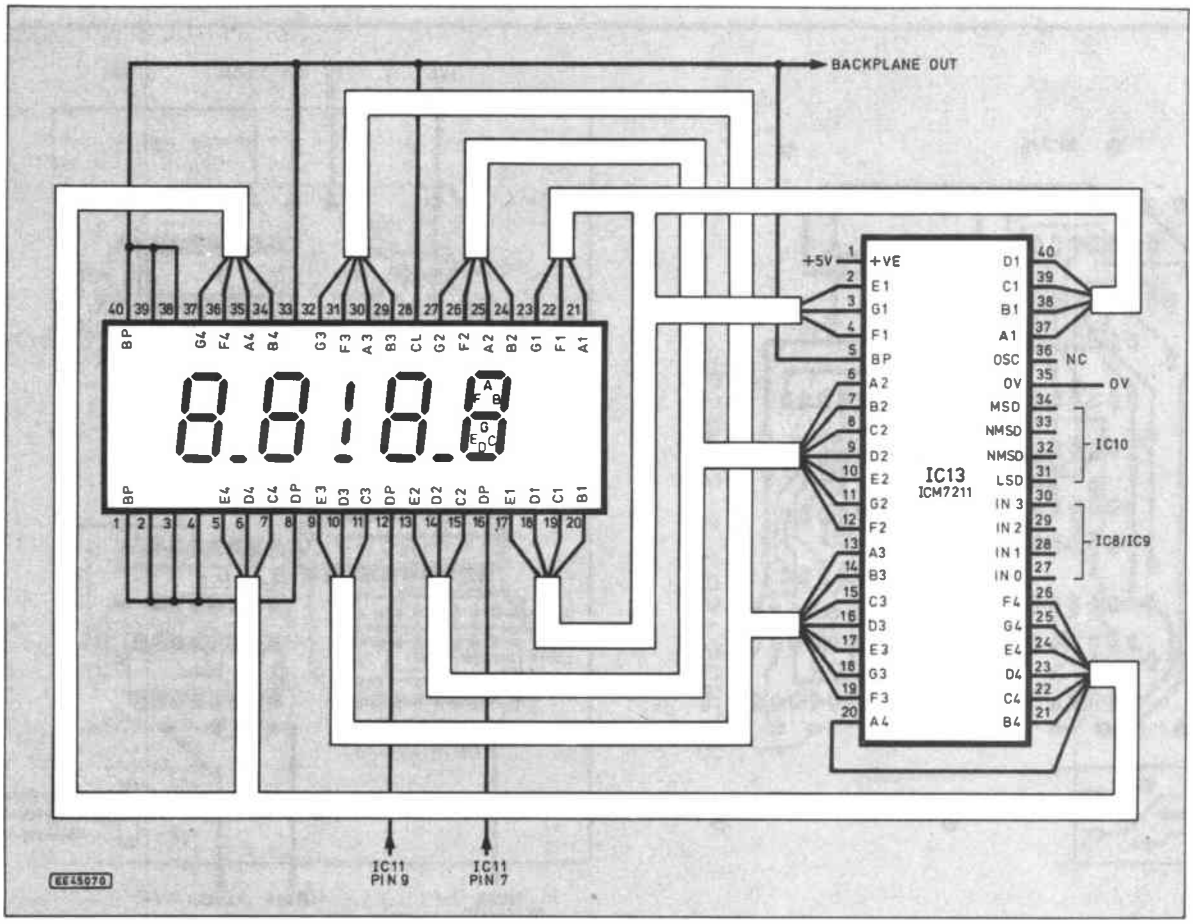


Fig. 6. Detailed pin connections for the l.c.d. module and its display driver i.c.

PENCE COUNTER

Whereas IC8 counts the Litres, IC9 counts the Pence pulses. Since the 4534 counter chip has tri-state Q outputs and a Q-enable control pin, similar Q outputs of both IC8 and IC9 are connected together. Using S10 and NAND gate IC12b as an inverter, the chips are connected so that only the required output set is actively selected.

As both chips have their DS counters clocked by the same signal, it is only necessary to use the DS outputs of IC8. Synchronisation of the decade registers within both chips is ensured by the simultaneous clocking, and by simultaneous resetting of both DS counts at the moment of unit switch-on.

The circuit around NAND gate IC12a provides the initial resetting control. At the moment of power switch-on, the output of IC12a automatically goes high, so holding both counters reset. Following switch-on, capacitor C1 charges up via resistor R10. When the charge voltage passes the gate's trigger threshold, the gate's output goes low, setting the two counters into count mode.

Although many readers will probably want to keep the meter operating continuously, switch S9 has been included as a Q-count reset control. It may also be necessary to briefly switch on S9 following first power switch-on.

DISPLAY POINTS

In the Cost Display mode, the l.c.d. can be range-switched to show pounds and pence up to 99·99 or 999·9. In the Litres Count mode the decimal points are inhibited. No visible indication of which litres range has been selected is provided, other than examination of the switch setting and intelligent inspection of the displayed numbers.

The decimal points have to be clocked in antiphase to the l.c.d.'s backplane (BP) clock for On, and clocked in phase for Off. IC11 controls the phase switching and is a dual 4-input data selector.

The routing of which input goes to the corresponding output is determined by the logic on the A0 and A1 control inputs. Six of the data inputs are connected directly to the BP line, the other two are fed from NAND gate IC12c which inverts the BP phase. Switches S10 and S11 set the control code on the A0 and A1 inputs of IC11. The truth table alongside IC11 shows the decimal point responses.

The detailed pin connections for the l.c.d. and its driver chip IC13 is shown in Fig. 6.

COMPONENTS

Approx cost guidance only **£70**

Resistors

R1 to R9 (RM1) 100k 9-commoned resistor network module
R10 1M
R11 220
R12, R13 10k (2 off)
All 0·25W 5% carbon film or better, except resistor network

See SHOP TALK Page

Capacitors

C1, C2 1µ radial elect. 63V (2 off)
C3 100n polyester
C4 22µ radial elect. 16V
C5, C6 220p polystyrene (2 off)

Semiconductors

D1 1N4001 rectifier diode (see text)
IC1, IC4, IC6 4040 12-bit binary ripple counter (3 off)
IC2, IC7 4082 dual 4-input AND gate (2 off)
IC3 74HC74 dual flip-flop
IC5 74HC688 8-bit equality comparator
IC8, IC9 4534 5-decade multiplexed BCD counter (2 off)
IC10 74HC257 quad 2-input data selector
IC11 74HC253 dual 4-input data selector
IC12 4011 quad 2-input NAND gate
IC13 ICM7211 4-digit l.c.d. display driver
IC14 78L05 100mA 5V regulator (see text)

Miscellaneous

SK1 to SK3 3·5mm stereo jack socket and plugs (3 off each)
S1 to S9 (SM1) 10-way s.p.s.t. d.i.l. switch module
S10, S11 sub-min s.p.d.t. toggle switch
X1 4-digit l.c.d. display

Liquid flow sensor (RS 257-133); printed circuit boards available from *EPE PCB Service*, codes 878 (Scaler) and 879 (Counter/Display); handheld plastic case, size 80mm x 145mm x 35mm (with l.c.d. viewing cutout); 14-pin d.i.l. socket (4 off); 16-pin d.i.l. socket (5 off); 20-pin d.i.l. socket; 24-pin d.i.l. socket (2 off); 40-pin d.i.l. socket; connecting wire; cable; solder etc.

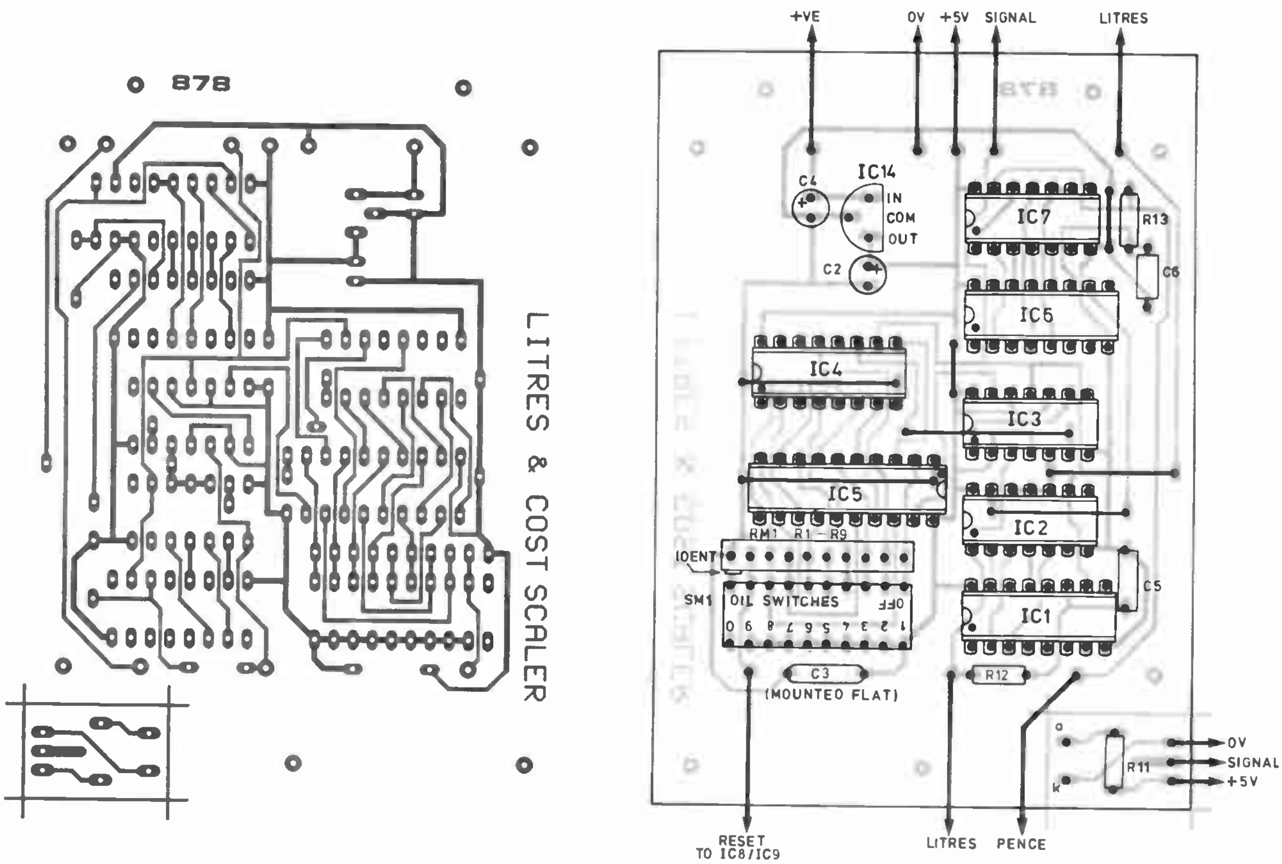


Fig. 7. Printed circuit board component layout and full size copper foil master pattern for the Litres and Cost Scaler board. Note that the sub-assembly board, shown at one corner, is mounted trackside upwards on the Sensor module, looking at the connecting pins.

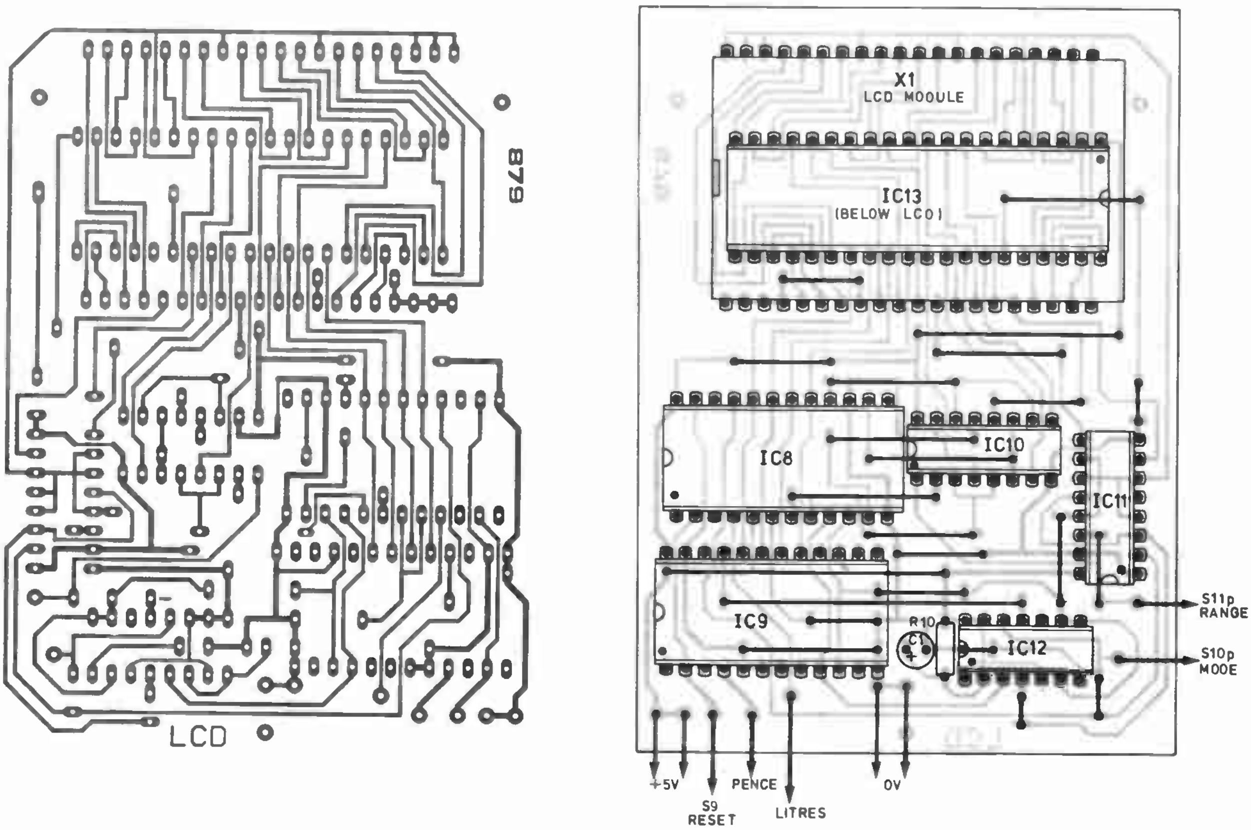
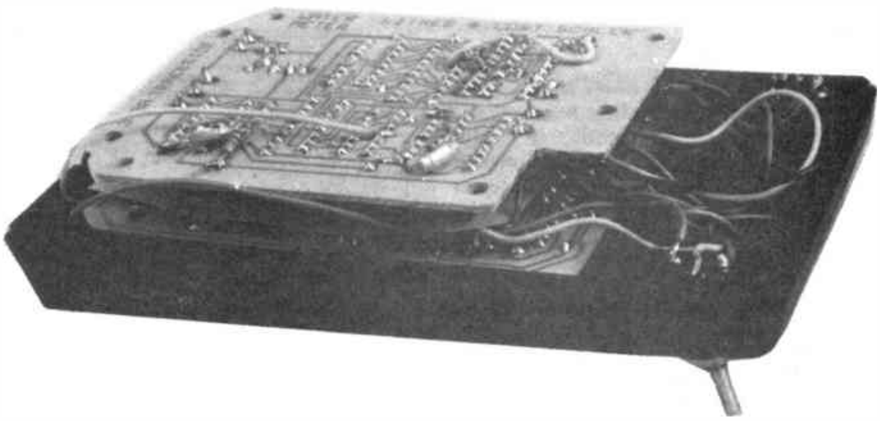


Fig. 8. Topside component layout and full size copper foil master pattern for Counter/Display printed circuit board.

POWER SUPPLY

If regulator IC14 is used (see Fig. 4), the meter and sensor can be battery powered between about 7V and 12V, or powered by a 9V mains adapter (battery eliminator). Alternatively, the unit may be powered by a 6V battery via a 1N4001 diode in place of IC14. Consumption is about 24mA for the sensor and 3·6mA for the Meter.

Since consumption for the sensor is relatively high, some readers may prefer to use a separate battery for it. This is permissible as long as the maximum output pulse voltage is kept within the range of +5V and +6V. The value for resistor R11 should be recalculated to suit the sensor's battery voltage.



CONSTRUCTION

The Digital Water Meter is built on two printed circuit boards (p.c.b.s) and a very small sub-assembly board. The top side component layout and full size copper foil master pattern for the Scaler p.c.b. is shown in Fig. 7. The component layout and foil master for the Counter/Display board is shown in Fig. 8. The boards are available from the *EPE PCB Service*, codes 878 (Scaler) and 879 (Counter/Display).

At one corner of the Scaler p.c.b. is a small sub-assembly board, see Fig. 7. This is for use with the Water Sensor Module and should be carefully cut off before component assembly.

The first step in board assembly is to insert and solder wire links where shown. Tinned annealed copper wire size 24 s.w.g. is recommended for the links.

The Display board has been designed so that the l.c.d. is mounted above IC13. However, in order to allow both p.c.b.s to be housed in the same type of handheld box used for the test model, IC13 cannot be mounted in a socket. It has to be soldered directly into the board. The l.c.d. is then mounted in a socket formed from a normal 40-pin socket cut into two halves lengthwise. It is preferable to use sockets for all the remaining d.i.l. chips.

Because of its height, the d.i.l. switch SM1 (S1 to S9) should be soldered in without a socket if the suggested box is used. For the same restricted height reasons, voltage regulator IC14 and all capacitors should be mounted flat on the board.

Using a close-up high magnification eyeglass, examine the assembled boards for solder shorts between tracks. Cautious use of a good quality solder-braid will remove any shorts found. Take care not to damage the copper tracking by using excess soldering iron pressure on the braid.

CASE DETAILS AND INTERWIRING

Once all components have been inserted on the p.c.b.s, the case can be prepared and final interwiring commenced. Drilling positions for the switches and sockets can be seen in the photographs of the test model.

The interwiring between case mounted components and the two p.c.b.s is shown in Fig. 9. First solder connecting wires between sockets and switches, plus the other socket wires but leaving their other ends unconnected.

Place the Display board face down into the top half of the box, ensuring that the l.c.d. fits snugly into the "window" aperture. Wire the board to the switches, making the soldered connections on its *trackside*.

Now place the Scaler board on top of the Display board, *trackside upwards*. Connect up the remaining wires. These may either be soldered to the trackside or, if terminal pins are used, to the normal component side, as you find most convenient.

When assembly is complete, it may be necessary to trim parts of the box's interior mouldings to allow the box to close.

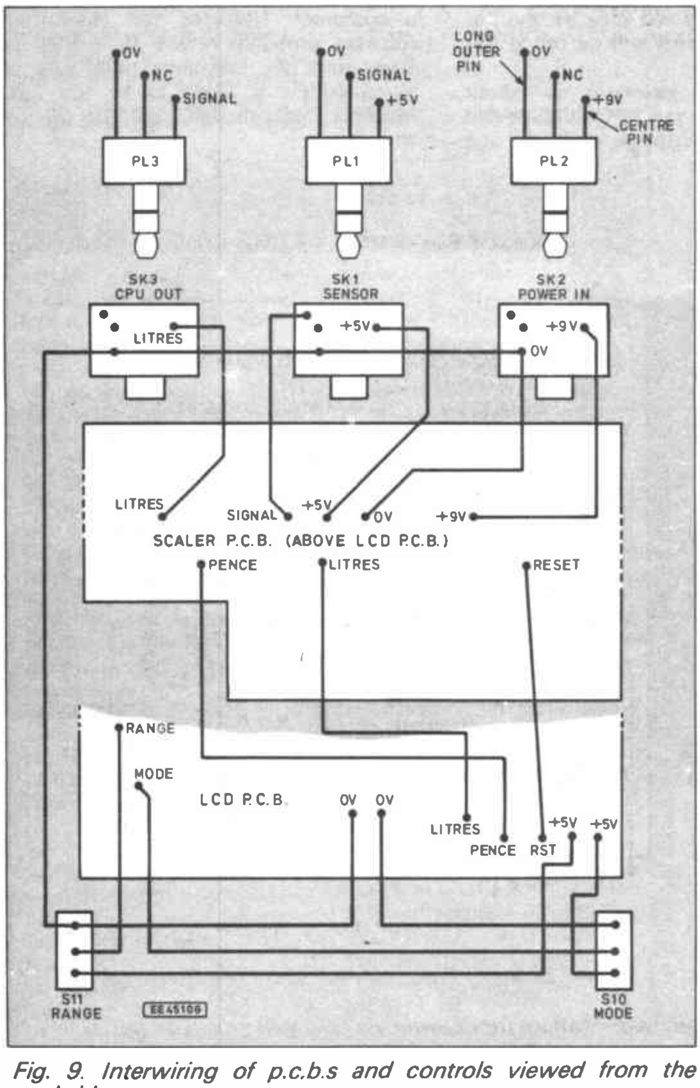
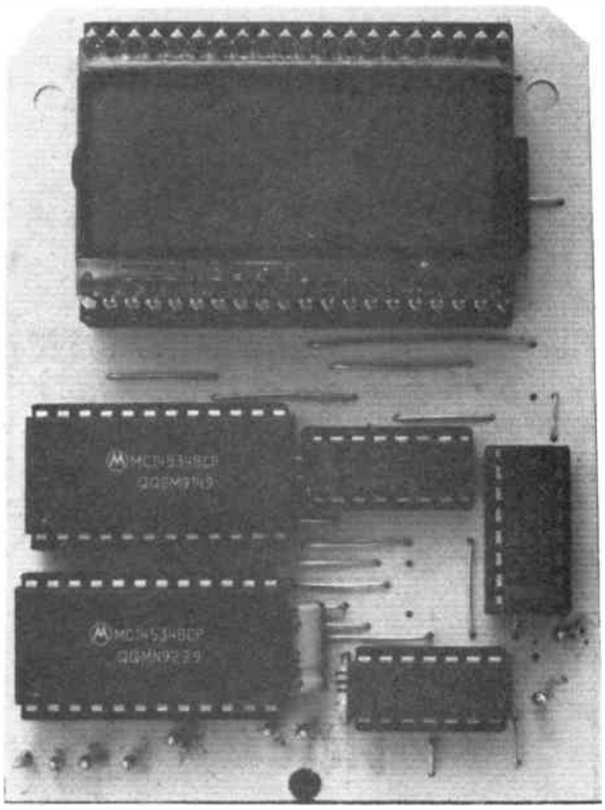


Fig. 9. Interwiring of p.c.b.s and controls viewed from the trackside.



SENSOR CONNECTIONS

A schematic drawing of the Sensor housing is shown in Fig. 10. Gently, but firmly, prise off the cap on the Sensor housing using a thin-bladed tool. Inside will be seen five rigid wires. Carefully push these into the holes of the small sub-p.c.b, which should be trackside upwards, and solder them in position.

Also, solder resistor R11 to the trackside, having first pushed its trimmed leads through the holes. Solder a reasonable length of 3-core cable to the board and solder plug PL1 to the other end.

Do not connect the Sensor Module to the water supply yet.

CHECKING OUT

If available, use a 9V Bench Power Supply (p.s.u.) and a Digital (+5V peak) Signal Generator to assist in checking the meter.

Switch on the p.s.u. and immediately check that +5V is present at the output of the regulator IC14. If the voltage differs significantly (by more than about five per cent), switch off and recheck the assembly. Also switch off and recheck everything if the following tests reveal unexpected results.

The d.i.l. switches S1 to S9, as viewed when the box is positioned with the display uppermost, shown in Fig. 11. Set Reset switch S9 off. Set Cost selector switches S1 to S8 to any non-zero value, 01010101 (85 decimal) for example.

Connect the signal generator, set to about 12kHz. With the Water Meter switched to Litres, switch back and forth between "high" and "low" ranges. The l.c.d. should be seen incrementing its display count at about one unit per second

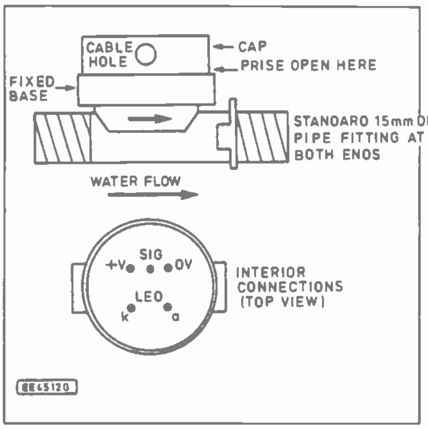


Fig. 10. Schematic diagram and connecting details for the Flow Sensor.

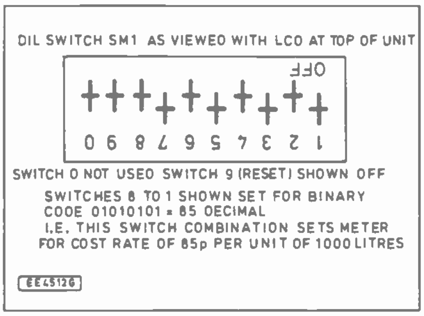


Fig. 11. D.I.L. switch details.

on high range, and ten times faster on the low range. The count should appear to have shifted left by one digit on the low range. Decimal points will be off in this mode.

Set the signal generator to about 120kHz, switch the unit to Cost mode and similarly check the displays for "high" and "low" ranges. In this mode the decimal point should be on, in the right hand position for high range, and in the middle for low range.

Switch S9 on and off to reset the counters back to zero. With the signal generator still running, periodically switch between the Litres and Cost modes and check that the cost rate appears to be sensibly increasing in relation to the litres count by the value set by switches S1 to S8. More precise litre/cost checking can be done if the generator is switched to a slower rate.

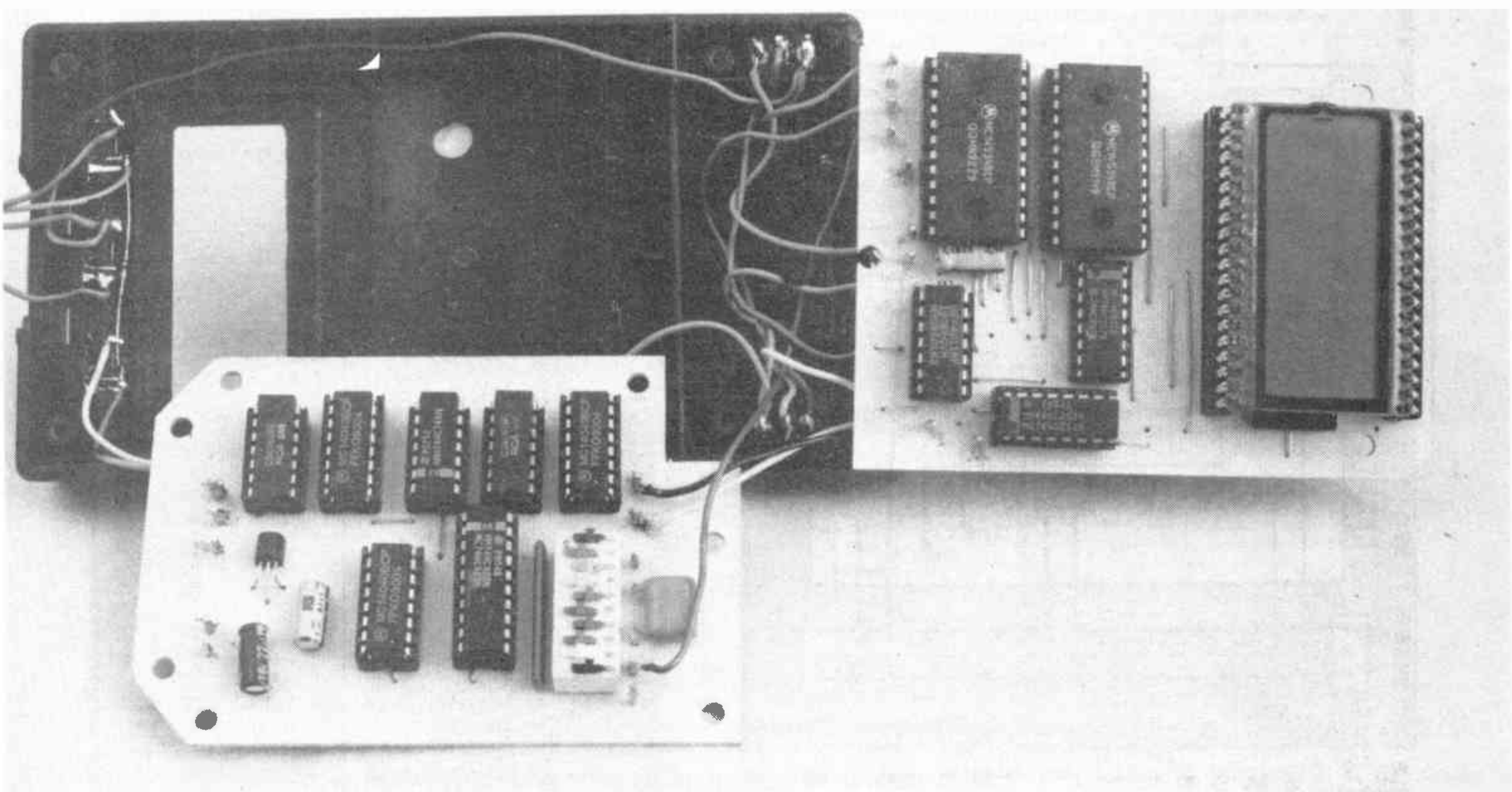
Disconnect the signal generator and plug in the Sensor, still unconnected to the water supply. Switch the meter to Litres low range. Noting the flow direction arrow moulded on the sensor housing, place the input pipe in your mouth and blow through it (*not too hard*) while observing the l.c.d. The display should change at a rate corresponding to your blow power! DO NOT use an air line with the Sensor.

The Digital Water Meter is now ready to be plumbed in and used.

Modern plumbing materials with their compression fittings are very easy to use and are readily available from major DIY centres. However, make sure that your house water pipes are of a standard size before trying to insert the Sensor into the system!

COMPUTER CONNECTION

In principle, if the Sensor output is restricted to a maximum of +5V, the pulses can be monitored directly by a computer. However, the monitoring software probably cannot be written in Basic since the maximum pulse rate of about 600Hz is likely to be too fast. Machine Code, though, could do the job with ease.



Listing 1: PC-COMPATIBLE BASIC LISTING EXAMPLE FOR WATER METER MONITORING

(Written in GWBasic but compatible with QuickBasic.)

```
10  CLS:LOCATE 2,25:PRINT "WATER USE MONITOR"
20  PRICE=85.12:REM AMEND THIS PRICE TO SUIT
30  S$="          "
40  REM CALCS MADE AFTER DOWNWARDS TRANSITION
100 A=INP(&H304) AND 1:IF A=B THEN 100
110 B=A:IF A=1 THEN 100
120 LITRES=LITRES+1:COST=PRICE*LITRES/1000
130 GALLONS=LITRES*0.219969
140 LOCATE 5,25:PRINT "LITRES ";LITRES;S$
150 LOCATE 7,25:PRINT "GALLONS";GALLONS;S$
160 LOCATE 9,25:PRINT "COST   ";COST;S$
170 GOTO 100
180 :
200 CLS:PRINT "DECIMAL TO BINARY CONVERSION"
210 PRINT:INPUT "DECIMAL";Z:D=Z
220 FOR T=7 TO 0 STEP-1:A=2^T:W=D/A
230 IF W>=1 THEN D=D-A:B$=B$+"1" ELSE B$=B$+"0"
240 NEXT:PRINT Z,B$:B$="":GOTO 210
```

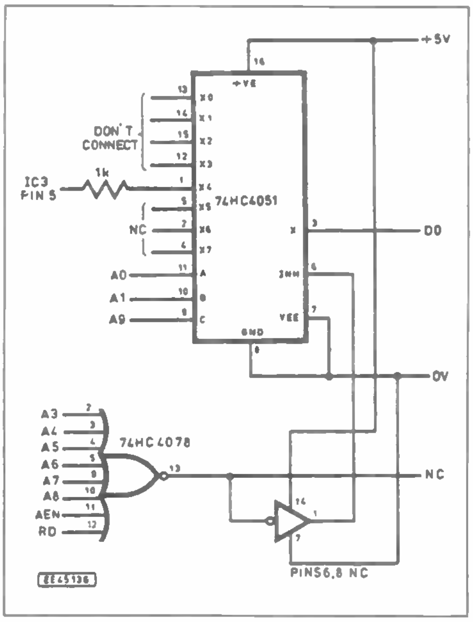


Fig. 12. Experimental circuit for a simple PC-compatible Interface for monitoring Litres output.

For monitoring the Water Meter from Basic, the Litres output at socket SK3 may be used. With some computers the output can be connected to a User port without an additional interface.

PC-compatible computers, though, need an addressed interface. Several examples of PC-compatible interfaces have recently been published and discussed in *EPE* (*Biomet* March '93; *PC Scope* October '91; *TV Camera Frame Grab* April '94). I refer interested readers to those articles and will not discuss the subject here.

Readers already familiar with PC-interfacing may also like to experiment with the simple interface circuit shown in Fig. 12. No p.c.b. is offered for this circuit, but it may readily be built on copper-tracked stripboards.

The circuit has been designed so that the Sensor output may be read at the X output of the 74HC4051 via computer data line D0 addressed at &H304. Listing 1 shows a simple Basic routine for inputting and processing the data. Lines 200 to 240 show a decimal to binary conversion routine which will be useful when setting cost codes on switches S1 to S8.

Special Series

THE BEST OF BRITISH

TERRY de VAUX-BALBIRNIE

Where is Britain's place in the world scene?

This is the third in a four-part series about the British electronics industry. Last month we examined British audio products. This time we shall look at some British test instrument and soldering equipment manufacturers.

IN THE field of measuring instruments British manufacturers do very well. Who can illustrate this better than *AVO?* Many of us were brought up on the AVO 8 multimeter (the name AVO comes from the first letters of *Amps, Volts, Ohms* – the chief units of electrical measurement).

The AVO 8 is still in production as the Mark 7 – this traditionally-styled analogue instrument is widely regarded as an industry standard. However, priced at about £300, it is really intended for the professional market. Ancient AVO test meters sometimes turn up in charity shops and car boot sales. These generally prove to be a very good investment and often perform well for years to come.

Password for quality

The company *AVO Megger Instruments* is based in Dover, Kent. Operating from a 140,000 sq. ft. facility the company employs around 400 people involved in manufacturing, development work and marketing. The company sells some 50 per cent of production to over 90 countries through a network of appointed distributors.

AVO has over 90 years' experience in the manufacture of high quality measuring instruments (Megger has been the password of the electrical industry since the turn of the century). Many may remember using the old hand-cranked *Megger* – an instrument used for measuring insulation resistances (in *megohms*, hence the name).

In fact, some of the latest models continue to be hand-cranked. Turning the handle operates a generator which produces the high voltage output needed for the test. This has an advantage for long periods of field-work and where running out of battery power would be an inconvenience. Other models use rechargeable batteries.

The company manufactures a wide range of special-purpose test equipment. This includes instruments used for locating cable faults, testing optical fibres and for fault-finding in telecommunications systems. There are also insulation testers, earth testers, continuity testers, portable appliance testers, milli-ohmmeters, chart recorders and instruments used for measuring capacitance and inductance.

All products are ruggedly constructed for a lifetime of field work. Most are hand-held. AVO products all meet the latest safety standards including the requirements of the *European Wiring Regulations* and *16th Edition of IEE Wiring Regulations.*

Computer-aided design is used to optimise printed circuit board layouts and the use of surface-mounted components

The world famous AVO 8 Multimeter Mk7 version.

(Left) Megger BM403 analogue/digital insulation and continuity tester.

(Above) Megger PAT32 Portable Appliance Tester from AVO..

and semi-automatic assembly methods form the basis of production. The latest component and microprocessor techniques are used to give the electrical and electronic engineer the instruments to carry out a test efficiently and accurately. An on-going programme of investment is designed to meet all anticipated future needs.

Working for the future

Another illustration of good British design and manufacturing practice is ***Thurlby-Thandar Instruments Ltd.*** Thurlby-Thandar is an independent company formed in 1989 by the merger of *Thurlby Electronics* and *Thandar Electronics* both established in 1979. Ownership of the company is chiefly with the Working Directors who, together with the Senior Managers have wide experience spanning many years. The company operates from a 26,000 sq. ft. manufacturing facility with on-site development laboratories, administration offices, etc.

The company design, manufacture and distribute a wide range of instruments which includes bench power supplies, logic analysers, LCR (inductance, capacitance and resistance) meters, frequency meters, counter timers, hand and bench multimeters, electronic thermometers, oscilloscopes and digital storage devices. All are designed for high performance, ease of use and reliability.

They export 50 per cent of production and currently sell products to 40 overseas markets through selected agents and distributors. In the UK ordering may be made direct to the factory or through one of a number of major distributors backed up by a team of trained sales engineers. Several products are already established market leaders and an on-going investment in research and development aims to keep them that way.

SM620 dual-trace osciloscope from Thurlby-Thandar.

Thurlby-Thandar TSX3510 d.c. power supply (left) and the TSX310P programmable d.c. power supply (right).

Tools of the Trade

If the man in the street were to be asked which tool or instrument an electronics worker or enthusiast most used, he would probably say the *soldering iron*. Forget the multitester, the bench power supply unit or the oscilloscope – with a soldering iron poised ready for action, anyone can *do* electronics!

We know that there is a lot more to it than this and the electronics student or hobbyist must become familiar with a wide range of instruments and tools. However, it is true that the soldering iron does have particular importance and mystique in electronics work and many people remember their first soldering iron with affection.

A nice bit

Various methods of preparing finished circuits have been tried without the need to solder. However, these have never proved as reliable as properly-formed soldered joints. Examinations Boards usually insist that students build at least one project in a permanent *soldered-up* form. No student is thought to have successfully completed a course in electronics without being proficient at the art of soldering.

Young children are encouraged to learn to solder in Technology classes – The *Tracktronics* system which has been designed to do this as one of its aims, was reviewed by the author in *EPE*, September 1993. There was also a free sample (cover mounted) of the material and projects written for using it in *EPE*, November 1993 issue. There is no getting away from it – the serious constructor *must* learn to solder!

The theory of soldering is that a low-temperature alloy, usually consisting of 40 per cent lead and 60 per cent tin and having a melting point of some 188°C, is heated by the soldering iron bit and made to flow around the joint. This provides the mechanical strength to hold the joint together combined with good electrical conductivity.

Modern solder contains cores of flux which prepare and clean the metal surfaces ready to accept the metal. The flux can be seen burning off as blue smoke when the soldering iron bit is applied.

Early days

With increased sophistication and miniaturisation of circuits, the soldering iron itself has had to evolve to meet modern needs. A soldering iron used, say, 50 years ago was a crude implement. It was not made specifically for electronics work but for general electrical and metalwork assembly. It would have had a very large fixed bit, used a lot of power and would have run very hot.

A modern soldering iron is much smaller, lighter, better balanced and runs cooler. Also, the materials used in its construction will be much improved. Take for example, the handle. The main criterion is that it is made from a material which is a poor conductor of heat. The handle must remain cool even when the soldering iron has been switched on for a long time.

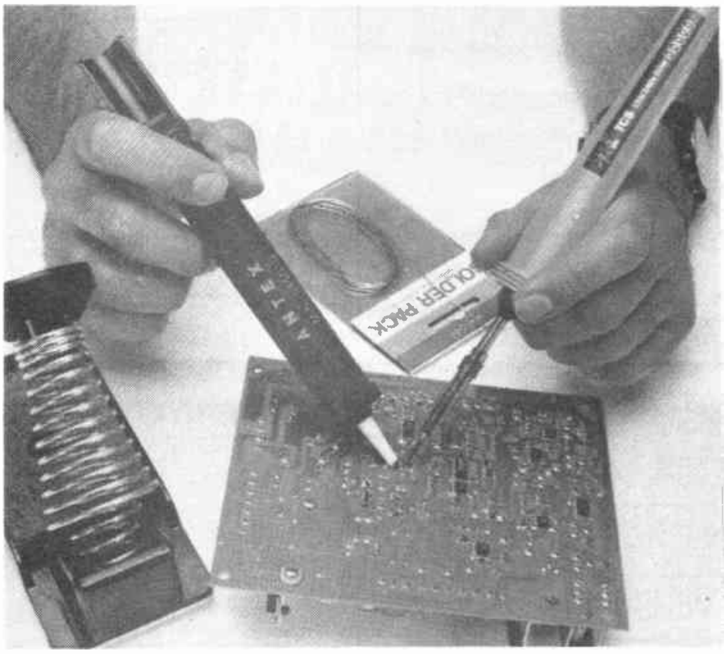
Early soldering irons had wooden handles which split and burned. There was an improvement when Bakelite (an early plastic) was later used. However, this material was easily broken and became more brittle with age. Today, handles are made from modern plastics – such as nylon or polycarbonate – and these will stand up to constant hard use.

The bit in an old soldering iron was, theoretically, removable to replace it when it had worn out. However, with the materials of the day, corrosion tended to set in often making it impossible to remove. Modern materials allow interchangeable bits to be used so that the best one may be selected for the application.

Turning up the temperature

Many middle and top-of-the-range soldering irons feature *fully adjustable temperature control*. This is worthwhile because the temperature will always be right for the job and may be adjusted to suit different solder alloys. The disadvantage is that there is more to go wrong, the soldering iron may be larger and heavier on account of the control circuit and it will certainly be more expensive.

In a temperature-controlled soldering iron, a thermocouple is used to sense the temperature of the bit. The output from this is fed to an electronic circuit which cuts off



Using the Antex TCK-50 soldering kit to remove solder from a joint.

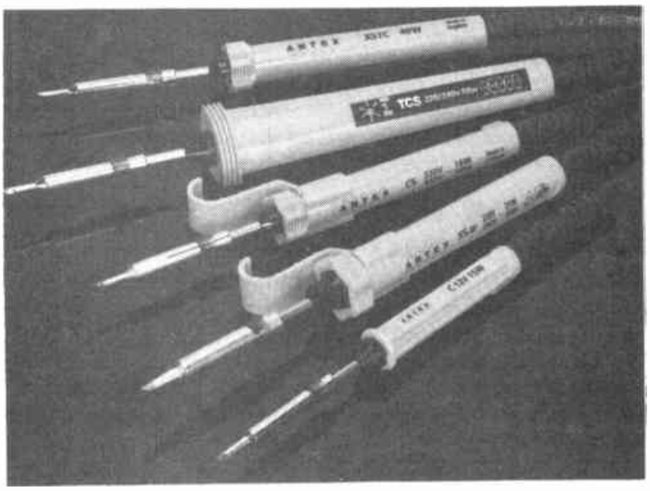
the power when the correct operating temperature is reached. When the temperature drops by a degree or so, the element is switched on again and cycling continues throughout the session.

Some temperature-controlled soldering irons are integrated with a low-voltage (usually 24V) power supply and stand – that is, a *soldering station*. The soldering iron has a thermocouple system which monitors the temperature of the bit. This information is fed back to the main unit which adjusts the power being supplied to keep the temperature steady. It may also supply information to provide a digital read-out of the temperature. Typically, a control on the main unit sets the temperature as required.

Balancing Act

Soldering irons made for hobby or education use do not usually have active (electronic) temperature control. These are sometimes called "fixed temperature" irons (which is a confusing term). These rely on the principle of *thermal balance*.

This simply means that a fixed power is applied to the heating element. The bit temperature rises until the heat is carried away into the air as quickly as it is being formed. At this point the temperature stabilizes usually at around 370° to 420°C. Unfortunately, the temperature of the bit tends to drop when a number of joints are made in rapid succession. This can result in the bit temperature becoming too low to make a satisfactory joint.



Collection of some Antex soldering irons.

This is unlikely to happen with amateurs who usually work slowly enough for the temperature to recover. However, for the professional user, a more rapid recovery time is needed. A temperature-controlled iron will switch the element on for longer periods to accurately maintain the preset temperature.

A fixed-temperature soldering iron is fitted with a low-power element to prevent overeating. Unfortunately, this means that it takes a long time to reach the operating temperature after switching on and this can be inconvenient.

With a temperature controlled iron, the heating element can be of a much higher power – typically 50W – since it will switch off when the preset temperature is reached. This has the advantage that the iron heats up much more quickly. The serious amateur constructor should consider a temperature-controlled soldering iron despite its higher cost.

Nasty fumes

Fume extraction is chiefly aimed at the commercial market because, in industry, it is essential to provide this. The Control of Substances Hazardous to Health (COSHH) regulations (1988) state, in essence, that *every employer must ensure that the exposure of employees to harmful substances is either prevented or adequately controlled.*

Solder contains several harmful substances, some from the metals used – including lead vapour – some from the flux and some fumes produced when plastic wire coverings are accidentally touched by the hot soldering iron bit. Since all these can be injurious to health, the COSHH regulations apply.

The hobbyist is unlikely to come to harm by occasionally breathing small quantities of fumes produced during soldering. Even so, precautions should be taken to provide good ventilation. It would be wise for anyone suffering from asthma or other breathing condition to use some form of fume extraction. More will be said about this later.

One of the first

In the business of designing and manufacturing soldering equipment for over 40 years, ***Antex*** was one of the first companies to produce instruments specifically for electronics purposes. Antex is a private British company operating from a modern manufacturing plant in Tavistock where it is the largest industrial employer. The company designs a full range of equipment for all the world's standards and voltages. Exports account for some 45 per cent of total output and the equipment is supplied to approximately 70 countries around the world.

They manufacture a wide variety of equipment from inexpensive fixed-temperature soldering irons suitable for student use to those designed especially for the professional. Soldering irons are manufactured in the power range of 12W to 50W and all major components are made on-site then assembled with quality control at each stage of production. Each soldering iron is then individually tested.

All models are designed to be lightweight and well-balanced with handles made from polycarbonate – a material which is virtually unbreakable. Antex fit burnproof silicone rubber leads (either as an option or standard on some models) and these will be found useful where students may accidentally touch the wire with the hot bit. There is a wide range of interchangeable soldering and de-soldering bits available.

Certain Antex models feature "in-handle" temperature control – these combine the best features of a soldering station with the free "fixed temperature" iron. With the electronic control circuit housed inside the handle, it is important that it should not be an encumbrance either in terms of weight, size or balance. Antex have therefore used surface-mount technology to minimise the size and weight of the control circuit.

In-handle control provides precise temperature regulation in situations where it would be difficult to use a soldering station – on site or in servicing work. A small screwdriver is used to set the temperature within the range

200°C to 450°C. The *TC240* temperature-controlled iron costs around £37.

For long periods of bench work, a soldering station is convenient. The *U200* with temperature read-out costs around £120. The similar *U100* station but without temperature read-out costs £85. In all Antex temperature-controlled irons, switching occurs at the *zero crossing point* of the mains cycle so reducing radio and TV interference.

Of interest to those teaching Electronics and Technology, Antex have put together some of the most useful tools as kits. The *SK2*, *SK5* and *SK6* are suitable for first-time buyers. These comprise a fixed-temperature soldering iron, bench stand, solder and booklet *How to Solder*. These kits differ chiefly in the power rating of the iron supplied – 15W, 18W and 25W respectively. The kits cost around £14 each including VAT.

The *TCS* is a more sophisticated kit which is suitable for the serious hobbyist. This comprises a temperature-controlled iron with moulded mains plug, a heavy-duty stand, de-soldering pump and a length of solder. The cost is about £40.

Yet a further kit, the *MLXS* contains a 25W 12V soldering iron fitted with crocodile clips which are designed to connect to a car battery. The kit comprises the iron itself, a length of solder and a heavy-duty plastic wallet. This is ideal for emergency repairs on cars, boats, caravans, etc. and costs around £14.

A fume extraction kit is another product manufactured by Antex. This comprises a polycarbonate tube carrier, the extraction tube itself is made of stainless steel flexible tubing and mounting clips. The flexible tubing is then connected to an extraction pump and filter system. The extraction tube is attached to the soldering iron so that the fumes are sucked away at source. The harmful vapour and suspended solid particles are then removed by the filter.

Antex are happy to reply to any technical queries on their product range or general problems about soldering. Their address is given in the panel at the top of the page.

Lite work

Light Soldering Developments is a relatively small company operating in Croydon, Surrey. Established in 1954, they manufacture a full range of high-quality soldering equipment, materials and accessories. however, only a few can be mentioned here. *Litesold* equipment is exported all over the world and total sales amount to almost £40m. Sales are particularly strong in Belgium, Sudan, and Japan each amounting to about £8m.

Litesold is claimed to have pioneered electronic temperature control of soldering irons with the introduction of their *ETC-1* system in 1971. Today, as the *ETC-5*, a sophisticated two-channel thermocouple system is used – that is, one thermocouple being used to control the temperature and the other to provide the temperature readout on a high-brightness l.e.d. display.

ADDRESSES

Avo Megger Instruments Ltd., Archcliffe Road, Dover, Kent, CT17 9EN. Tel: 0304 202620.

Thurlby-Thandar Instruments Ltd., Glebe Road, Huntingdon, Cambridgeshire, PE18 7DX. Tel: 0480 412451.

Antex (Electronics) Ltd., 2 Westbridge Industrial Estate, Tavistock, Devon, PL19 8DE. Tel: 0822 613565.

Light Soldering Developments Ltd., 97-99 Gloucester Road, Croydon, Surrey, CR0 2DN Tel: 081 689 0574.

Temperature control is continuously variable to suit any application and this is maintained to within 1°C. Handles are made of moulded nylon, and shaped so as not to roll around on the bench as well as holding the bit clear of the work surface.

Not only do they manufacture sophisticated temperature-controlled irons for use by professionals, they also produce a no-nonsense range of fixed-temperature units – the *LC18* (18W) and *LA12* (12W). These are suitable for general assembly work, hobby and student use. The LC18 and LA12 cost between about £12 and £16 depending on the type of flex (silicone rubber or standard) and the type of bit fitted. Low-voltage irons are available which may be operated from batteries or from Litesold power units.

The *ADAMIN Model 12* miniature Iron is of special interest. This is a tiny mains-operated 12 watt unit – possibly the smallest of its type in the world. It is useful for working in confined spaces where a larger 18W or 20W iron would normally be used. The price of the ADAMIN Model 12 varies between about £11 and £15 depending on the choice of flex and bit fitted.

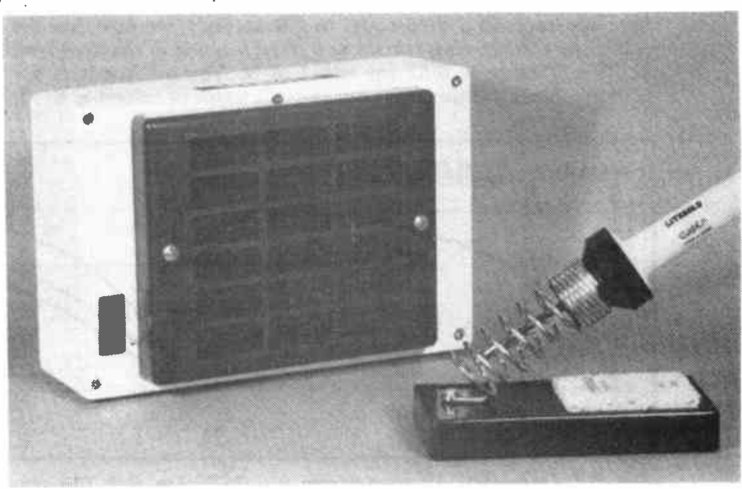
The *Cobra FX Soldering Station* provides fume extraction at source. A stainless steel extraction tube on the side of the iron is connected via silicone tubing to a vacuum pump and filter. The air containing the fumes is drawn through the tube and removed by the filter. The price of the Cobra FX with temperature readout is about £370 including VAT.

For those who want to remove fumes at lower cost but wish to continue using their present equipment, the *Solder Fume Captor* could be the answer. This is a free-standing unit containing a quiet axial fan and special replaceable filter. When it is placed close to the work the air around is sucked in and the harmful materials filtered out. The cost is about £50 which puts it within the reach of serious amateurs and anyone with breathing problems mentioned earlier.

Anyone buying a Litesold product is assured of technical back-up should the need arise. The company will be happy to answer any technical query about their products.

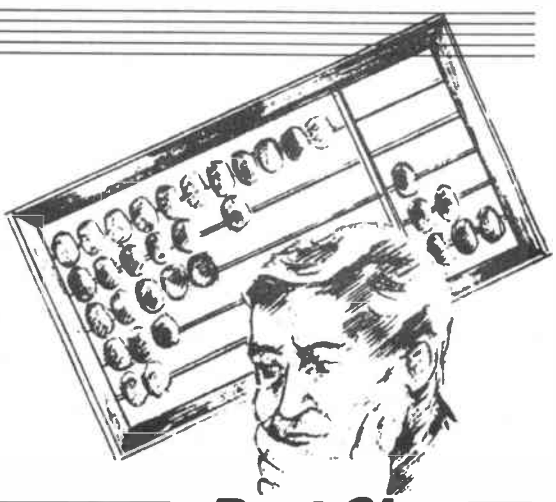
That's all for this month. Next time we shall look at Education Services and British companies supplying components to the hobbyist and to education.

Litesold Cobra soldering station.



Solder Fume Captor manufactured by Litesold.

Special Series



CALCULATION CORNER

Time Constants

STEVE KNIGHT

Part Six

This series is designed to help you make your way, at your own pace, through the often imagined fears of mathematics, as this is applied to electronic and electrical engineering matters.

THIS month we take a further look at the charging characteristics of a capacitor and find another interpretation of the time constant for a CR circuit.

MORE ON TIME CONSTANTS

Last month we made a note of the fact that if the initial charging rate of a capacitor C through a resistor R could be maintained, the time in which the capacitor would be fully charged would be the time constant of the circuit. Fig. 6.1 illustrates this. As this situation doesn't arise in practice (unless, that is, we do the charging in a certain way), you might think that a definition of time constant in this way has very little significant meaning.

This is not wholly true but we can get another and perhaps more meaningful interpretation of time constant if we consider again the true shape of the charging curve (the exponential curve) shown by the curved line of Fig. 6.1. The time for the charge to be *practically* completed (as against the theoretical infinite time) depends upon the values of C and R. If R is kept constant the initial charging current value remains the same but a longer time is needed to charge a larger capacitor. If C is kept constant the initial charging rate is reduced as R is increased and so a longer period is needed to charge the capacitor. Hence the time of charge increases with the increase in the values of both C and R.

The effect of increasing R from a low value R_1 to a high value R_3, with an intermediate value R_2 is shown in Fig. 6.2. The *final* voltage across C is, of course, unaffected and remains at V, the supply voltage, but as R is increased, the initial charging rate is decreased and the time constant clearly lengthens. The diagram now introduces us to the most important interpretation of time constant; the *product* of the circuit constants, C × R, is the circuit time constant. In a time equal to CR seconds, we find that the capacitor voltage *always rises to a fixed fraction of the final level V*. This fraction is 0·63 (or 63%) of V. The mathematics for proving this is a little above our present terms of reference but it involves only a relatively simple differential equation which some of you who are doing your A-levels may be familiar with already.

On the graph of Fig. 6.2, this fraction of the applied voltage has been marked and it is seen that the product CR remains at this level for all values of R. If instead of R, the capacitance is varied from a low value C_1 to a high value C_3 with an intermediate value C_2, the same sort of curves are obtained which show the effect of these changes, the respective time constants now being C_1R, C_2R and C_3R where the capacitor voltage has risen to the 0·63V level in all cases. This is shown in Fig. 6.3. The main difference from the previous case is that the initial rate of increase of the charging *current* is the same for all three conditions, since R is now considered constant.

An important thing to notice is that altering the applied voltage V does not affect the time constant of a particular circuit; it only affects the final *charge* on the capacitor.

COMPLETING THE CHARGE

In theory, as we have mentioned, the capacitor can never be completely charged, but in a time equal to 5CR seconds the voltage across C is within 1% of its final value and it is customary to take this period as the time in which the charge is completed.

Now follow the next few worked examples carefully as they illustrate the points we have just covered.

1. What is the time constant of a 10µF capacitor in series with a 270kΩ resistor?

In the formula T = CR seconds, C is expressed in farads and R in ohms. However, it is often more convenient to express C in µF and R in MΩ and the result remains in seconds since the "micro" (10^{-6}) and the mega (10^6) are self cancelling when they are multiplied. In this example then C = 10µF, R = 0·27MΩ.

Then T = CR = 10 × 0·27 = **2·7 seconds**

2. If the previous combination of C and R is connected to a 50V

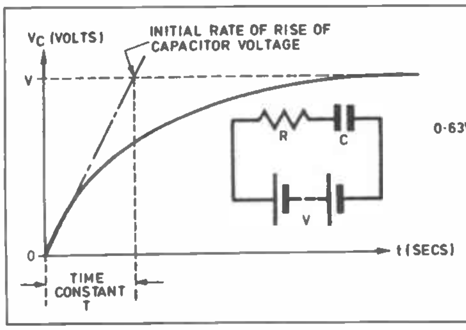


Fig. 6.1. One interpretation of the meaning of time constant.

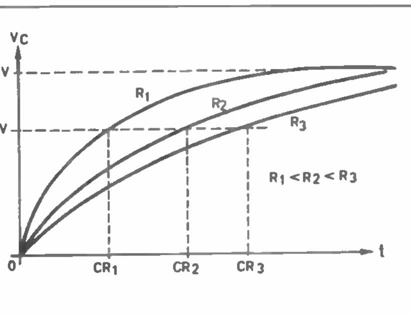


Fig. 6.2. The effect of increasing resistance R with C constant.

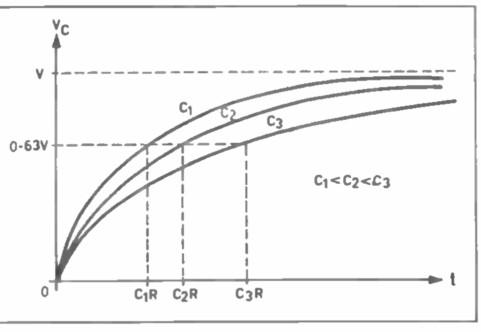


Fig. 6.3. The effect of increasing C with R constant

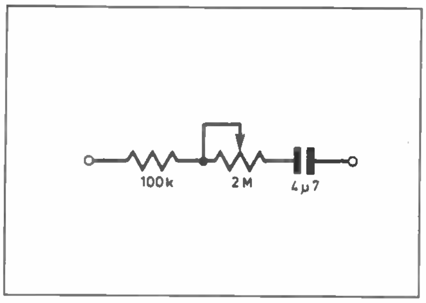


Fig. 6.4. A practical solution to a timer problem.

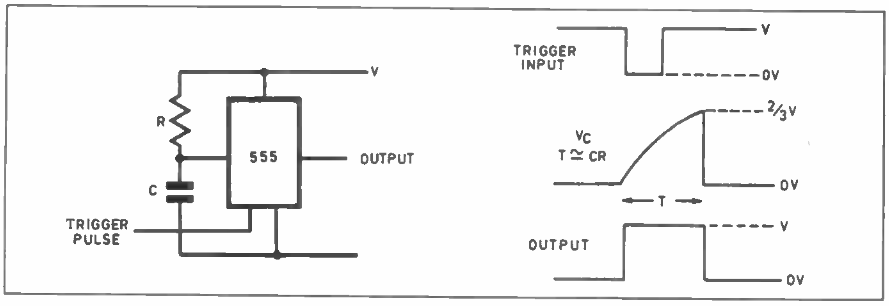


Fig. 6.5. How the 555 timer uses the charge of a capacitor to produce a known duration output pulse.

d.c. source, what will be the capacitor voltage after a time of 2·7 seconds?

Here 2·7 secs is the circuit time constant, so the capacitor voltage would, after that period, reach 63% of the applied voltage.

$$V_C = 0{\cdot}63 \times 50 \text{ volts}$$

$$= \mathbf{31{\cdot}6V}$$

Keep in mind that this particular level applies *only* to the period CR seconds. There are means of finding the capacitor voltage at any time during the charge but this is the one which remains constant at that percentage level.

3. An electronic system is to be controlled by a timer which depends upon the charging of a 4·7μF capacitor. If the circuit time constant is to be adjustable between 0·5 sec and 10 secs, find the limits of the value of a variable resistor needed in series with the capacitor.

We have T = CR secs, hence $R = \frac{T}{C}$ ohms

If we express T in secs and C in μF our answers will be given in MΩ. Then for T = 0·5 sec

$$R = \frac{0{\cdot}5}{4{\cdot}7}\,M\Omega = 0{\cdot}106M\Omega \text{ or } \mathbf{106k\Omega}$$

For T = 10 secs $R = \frac{10}{4{\cdot}7}\,M\Omega = \mathbf{2{\cdot}13M\Omega}$

We could, of course, have worked in farads and ohms; the solution to the first part would then have been, for T = 0·5 sec, $C = 4{\cdot}7 \times 10^{-6}F$:

$$R = \frac{0{\cdot}5}{4{\cdot}7 \times 10^{-6}} = \frac{0{\cdot}5 \times 10^6}{4{\cdot}7} = 0{\cdot}106 \times 10^6\Omega$$

$$= 0{\cdot}106M\Omega \text{ as before}$$

In a *practical* circuit where tolerances would have some effect, we could use a 2MΩ variable resistor in series with a 100kΩ resistor as our charging arrangement, as Fig. 6.4 illustrates.

TIMING DEVICES

Many timing devices are based on the charge of a capacitor through a resistor from a d.c. source. An example of a very accurate and versatile integrated circuit timing device is the popular NE555 chip. Fig. 6.5 shows a simplified circuit of the 555 in one of its forms of operation, with the appropriate waveforms relevant to the charging cycle.

A trigger pulse input initiates the charge of an external capacitor C through an external resistor R. When the voltage across C has risen to two-thirds of the applied voltage V, the timing period ends and the capacitor is discharged to zero volts. The output terminal provides a pulsed output whose duration is roughly equal to the CR time constant (actually 1·1CR), since the charge has risen to 0·66 of the final possible level.

THE DISCHARGE CYCLE

In Fig. 6.6 a fully charged capacitor C is abruptly switched to a resistor R; a current then flows through R until the capacitor is discharged. The initial discharge current is, as for the charging cycle, $I_0 = V/R$ and at this instant the *maximum* rate of decrease of the capacitor voltage occurs. As the voltage falls the discharge current falls and the rate of decrease follows an exponential curve as the graph of Fig. 6.7 shows. This curve has similar time constant properties and has the identical shape to that of the *current* fall during the charge cycle. The voltage across C will fall by 63% in a time equal to the time constant, that is, it falls to 0·37 of the initial voltage in that time.

4. A 0·22μF capacitor is charged to 50V before being connected to a 3·3kΩ resistor. What will be (a) the initial discharge current, (b) the circuit time constant, (c) the initial rate of decrease of the capacitor voltage?

(a) The initial discharge current $I_0 = \frac{V}{A} = \frac{50}{3300}$ A

$$= 0{\cdot}015A \text{ or } \mathbf{15mA}$$

(b) The time constant T = CR = 0·22 × 0.0033 where C is in μF and R is expressed in MΩ. Hence T = 0·00073 secs or **730μs**

(c) The rate of decrease of capacitor voltage is the slope or gradient of the initial discharge curve, that is, from Fig. 6.7, the initial rate of decrease of the voltage from 50V to zero would occur in a time equal to the time constant T if it went on at that rate uniformly. Hence

$$\text{initial rate of decrease} = \frac{V}{CR} \text{ volts/sec}$$

$$= \frac{50}{0.00073} = \mathbf{68{,}493\ volts/sec}$$

This may seem an astonishing rate of decrease but rates of many millions of volts per second are commonplace in such circuits. In reality the discharge is fully completed in about 5CR or 5 × 730μs = 3,650μs. When a discharge rate like this is being considered, you will sometimes find it prefixed with a negative sign to indicate a decrease.

5. In the circuit of Fig. 6.8, C = 8μF and R = 1·5MΩ. What is the potential across the points X-Y (a) before switch S is closed, (b) at the instant S is closed, (c) 12 seconds after S is closed?

(a) Before S is closed the capacitor is uncharged and no current flows in the circuit. Hence the p.d. across R is **zero**.

(b) At the instant S is closed the charge on C will still be zero and the whole of the applied voltage will appear across R; hence $V_R = \mathbf{50V}$

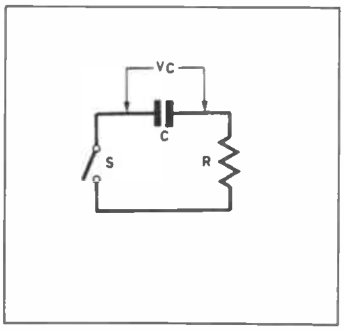


Fig. 6.6. Discharging C through R.

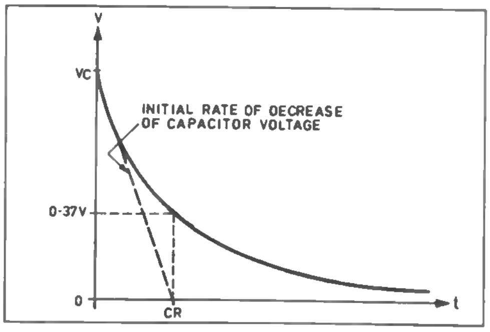


Fig. 6.7. The discharge curve of a capacitor through a resistor.

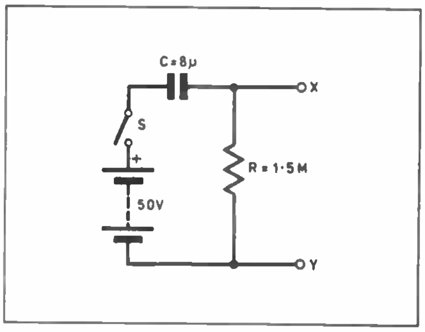


Fig. 6.8. Charging cycle problem.

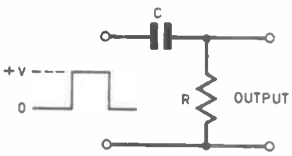


Fig. 6.9. A differentiator circuit.

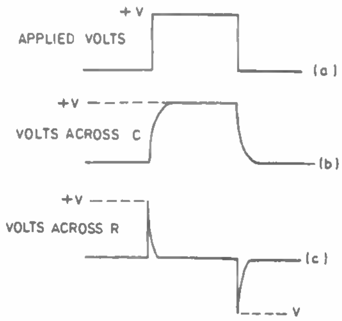


Fig. 6.10. Waveforms in the differentiator circuit.

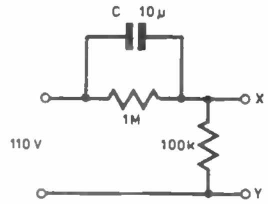


Fig. 6.11. Circuit for problem 4.

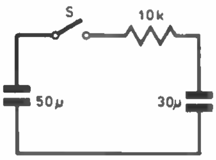


Fig. 6.12. Circuit for problem 7.

(c) The time constant of the circuit T = CR = 8 × 1·5 = 12 secs. Therefore 12 secs after S is closed the p.d. across C will have risen to 0·63 × 50 = 31·5V. Hence the voltage across R will be 50 − 31·5 = **18·5V** or, of course, 0·37 × 50 = 18·5V.

Now rework this problem with C and R interchanged. You'll find the answer at the end of the text.

GENERAL CHARGE TIME

If we know the C and R values of a charging circuit and the applied voltage V, there is a simple formula from which we can calculate the time taken for the capacitor voltage to reach *any* level of voltage. This is

$$t = CR \times \ln\left(\frac{V}{V - V_c}\right) \text{ seconds}$$

where CR is the time constant and $\left(\frac{V}{V - V_c}\right)$ is the Naperian (or natural) logarithm of the ratio given in the brackets. It is quite easy to evaluate this formula on your calculator. There are two "log" buttons on the calculator, one marked **log** and the other **ln**. The first of these will provide us with, the common (base 10) logarithm of a number; the second gives us the natural (base e) logarithm of a number, and this is the one we want in most natural phenomena work. The next example will show you how to use this formula.

6. How long does it take to charge a 3·3μF capacitor through a 220kΩ resistor from a 100V d.c. supply to a level of 75V?

Here V = 100V, V_c = 75V, CR = 3·3μF × 0·22MΩ

$$\text{Then } t = 3{\cdot}3 \times 0{\cdot}22 \times \ln\left(\frac{100}{100 - 75}\right) \text{ secs}$$

$$= 3{\cdot}3 \times 0{\cdot}22 \times \ln 4 \text{ secs}$$

$$= 3.3 \times 0.22 \times 1.386 \text{ secs}$$

You get the natural logarithm of 4 by pressing 4 and then the ln button. This gives you 1·386. The product can now be done in the ordinary way. This gives us a time of **1·006 secs.**

It is usual nowadays to find books using ln N to symbolize the natural logarithm of a number *N* (as calculators do), but in some books, particularly older editions, you may find it expressed as $\log_e N$. Never confuse this with $\log_{10} N$, which is the common logarithm of N.

THE DIFFERENTIATOR

Suppose instead of a steady d.c. supply, a rectangular pulse is applied to a series CR circuit and that the output waveform across R is considered. Fig. 6.9 shows the circuit. The input pulse has an abrupt rise from zero to +V volts, remains at this level for a short period; and then falls abruptly to zero again When the pulse is applied, the sudden change in the effectual supply voltage is transmitted instantly by the capacitor and appears across the resistor, Fig. 6.10(c). If now the time constant of C and R is very short relative to the pulse duration C will quickly charge to the level +V (Fig. 6.10(b)), and the voltage across R will likewise decay quickly to zero. This situation will then hold until the input falls to zero, when the falling edge is again transmitted instantly by the capacitor and appears as a *negative* drop of −V volts across R. C then discharges and the output returns to zero. Thus a succession of input pulses is converted into a succession of sharp positive and negative pulses.

Such a circuit as this is known as a *differentiator*. It has many applications in electronics, but at the same time its behaviour demonstrates to us that a short time-constant coupling does not faithfully reproduce the input waveform.

We can notice, however, that the voltage variation across C is closely equivalent to the input waveform.

What do you think the output would be like if the circuit time constant was very long relative to the pulse duration?

Now it's time for some consolidation on your part by having a go at this month's self-assessment problems. Answers next month as usual.

1. A photo-flash unit incorporates a 330μF capacitor which generates a discharge of 80 joules. To what voltage is the capacitor charged?
2. A 6·8μF capacitor is charged through a 330kΩ resistor from a constant d.c. supply. Find (a) the time constant, (b) the additional resistance needed to increase the time constant to 5 secs.
3. Find the time constants of the following combinations: (a) 47μF, 680kΩ, (b) 2·2μF, 15kΩ, (c) 3·3nF, 0·47MΩ, (d) 470μF, 4·7kΩ.
4. The circuit of Fig. 6.11 has been connected to the 110V d.c. supply for some time. Find (a) the potential across the points X-Y, (b) the voltage to which C is charged, (c) the charge in C, (d) the current in the 1MΩ resistor.
5. A 22μF capacitor is in series with a voltmeter of resistance 50kΩ. This circuit is switched suddenly across a 15V d.c. supply. Find, after a period of 1·1 secs: (a) the voltmeter reading, (b) the capacitor voltage. What is the value of the current when the voltmeter reads 10V?
6. How long does it take to charge a 0·5μF capacitor to 15V when it is fed from a 24V supply by way of a 2·2MΩ resistor?
7. In Fig. 6.12, the 50μF capacitor has an initial charge of 0·025C, whilst the 30μF capacitor is uncharged. What will be the initial current I_0 when switch S is closed? What then is the final charge on each capacitor and the p.d. across them?

The solution to the problem in the text is (a) 0V, (b) 0V, (c) 31·5V.

Last month's answers: 1. 22μF, 1.3μF; **2.** 3μF each; **3.** 200V, 50μF; **4.** Substitute Q/V for C in ½CV^2; **5.** Eight capacitors are needed: four groups in parallel, each group having two capacitors in series; **6.** 2·5V; **7.** 1·06mA, 23·5V, 4·7 secs.

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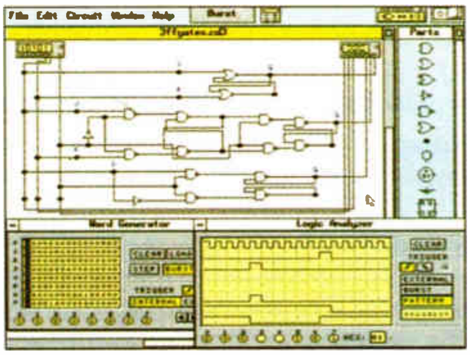

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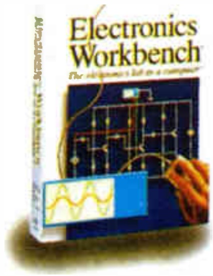

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Techniques

ACTUALLY DOING IT!

by Robert Penfold

ELECTRONICS tends to be regarded as a hi-tech business at the leading edge of modern technology. I suppose that to a large extent this is an accurate view of modern electronics, but it is also a fact that many components of yesteryear are still in everyday use. Indeed, many of these low-tech components are manufactured in larger numbers today than at any time in the past.

Moving coil loudspeakers are components that were in existence before most readers of this magazine were born. The purpose of the loudspeaker is to convert an audio frequency input signal into corresponding sounds. A moving coil loudspeaker consist basically of a metal chassis, a magnet, a coil of wire, and a paper or plastic diaphragm. Apart from "state of the art" hi-fi units, they are definitely in the low-tech category.

HOLE TRUTH

Miniature loudspeakers are used in many electronic projects, and they are perhaps slightly more awkward to deal with than most other components. An important point to bear in mind when dealing with any loudspeaker, large or small, is that the diaphragm is usually made from a rather flimsy material.

Most modern miniature loudspeakers have plastic diaphragms which are tougher than the paper types which were the norm a few years ago. Even so, all loudspeakers must be handled with due care as it is easy to accidentally poke a finger through the diaphragm. A sizable hole in the diaphragm might not render the loudspeaker unusable, but it will certainly not improve its performance either.

In component catalogues loudspeakers are usually listed as having a certain size and impedance. The size quoted is simply the physical size of the diaphragm. The impedance rating is an electrical one, and it is given in ohms.

Impedance is the a.c. equivalent of d.c. resistance, and with all the loudspeakers I have tested there has been little difference between the marked impedance and the d.c. resistance of the coil. The power rating of loudspeakers is often quoted in catalogues, and this is an important rating.

POWER

If a components list specifies a power rating for a loudspeaker it is important to use a component having a rating which is *no less* than the one quoted. Slightly exceeding a loudspeaker's power rating is unlikely to cause any damage, but the audio quality will almost certainly suffer.

Seriously overloading a loudspeaker will result in very poor sound quality, and could damage the loudspeaker. The coil could overheat and burn out, or the unit could literally rip itself apart.

In the interests of good sound quality and reliability it is advisable to always use a loudspeaker having an adequate power rating. It is acceptable to use a loudspeaker having a power rating which is much higher than is really necessary, provided its physical size is acceptable. In general, the higher the power rating of a loudspeaker, the larger its physical size. There is no point in using a loudspeaker having an excessive power rating if it results in a pocket radio the size of a shoe box!

The impedance figure is another important rating. Using (say) a 50 ohm loudspeaker instead of one having an impedance of 8 ohms is safe, but would give relative low output power. This could in turn produce inadequate volume levels.

Using a low impedance loudspeaker instead of a high impedance type is definitely not acceptable. This could easily result in damage to the loudspeaker or to the output stage of the circuit driving it. Even if no damage resulted, it would almost certainly give an extremely inefficient setup. With a battery powered circuit this would give greatly reduced battery life.

MIXED GRILLES

A loudspeaker is normally mounted behind a grille of some kind. Some constructors simply mount the component behind a hole in the front panel which is slightly smaller than the overall diameter of the loudspeaker. However, I would regard this as a very risky way of doing things, because it leaves the delicate diaphragm very vulnerable to physical damage. It is much better to have the diaphragm protected by some sort of grille.

The most simple type of grille is a matrix of holes drilled in the panel. This is a cheap but effective method, and is also one which gives good protection to the diaphragm. Fig.1 shows the grille design which I normally use. This is suitable for loudspeakers having diameters from about 50 millimetres to around 70 millimetres or so.

Drilling a grille such as this is one of those tasks which looks much easier than it is. The holes must be positioned with a fair degree of accuracy if the finished grille is to look reasonably neat. Mark the positions of the holes as accurately as possible, centre punch them as precisely as possible, and then drill small guide holes. To complete the grille drill out the guide holes to five millimetres in diameter. Provided due care is taken, a neat grille should be produced.

At one time a material called "expanded aluminium" was much used for speaker grilles. This seems to be less readily available than it was ten or twenty years ago, but it is still manufactured. I have not seen expanded aluminium on sale in do-it-yourself stores in recent years, but it can be obtained from some outlets that sell model making and general craft supplies. It is easily cut to size using an old pair of scissors, and it can be glued in place behind the panel cutout using an epoxy adhesive.

FRET

In the past it was possible to buy loudspeaker "fret", which was a material specifically designed for use as loudspeaker grilles. It was made from either plastic or aluminium, and was used much the same way as expanded aluminium. It might still be possible to obtain speaker fret, but on checking through a few catalogues I failed to find anything like this listed. If you require a grille material of this general type, there may be no option but to seek out some expanded aluminium.

A piece of loudspeaker cloth (as used for the fronts of the loudspeakers in hi-fi systems, etc.) looks quite neat when glued in place behind the panel cutout. It provides less physical protection than a metal grille, but it should still be adequate in this respect. Speaker grille cloths are to be found in some of the larger component catalogues, and should also be available from retailers who specialise in loudspeaker drive units and accessories.

One slight problem with grille cloths is that they are generally sold in quite large pieces. On the other hand, the cost should only be about £2 to £4 for a piece that may well be a life-long supply! It is probably best to choose a cloth having a relatively fine pattern, as a cloth of this type should look reasonably attractive when used in small pieces. Any general purpose

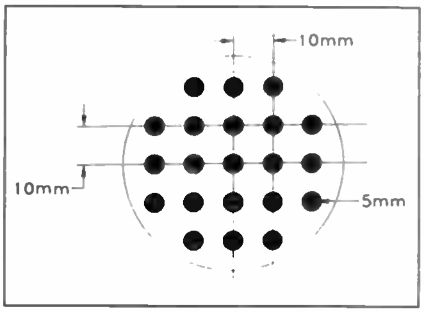


Fig. 1. Grille formed by drilling holes in the mounting panel.

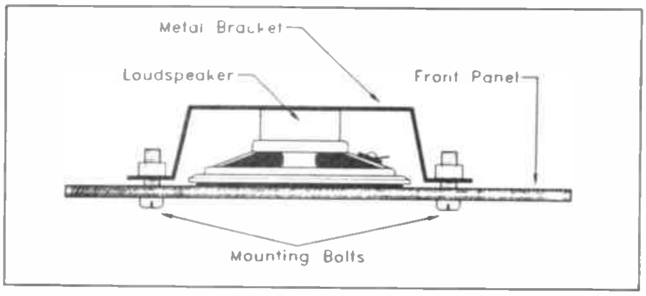


Fig. 2. Mounting a loudspeaker using a steel bracket.

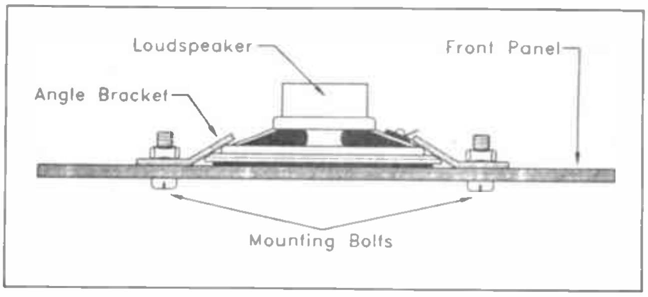


Fig. 3. Mounting a loudspeaker using small angle brackets.

adhesive should securely stick grille cloth to a metal or plastic panel.

MOUNTING TENSION

An unusual aspect of miniature loudspeakers is that they have no form of built-in mounting bracket. I have actually encountered a few that had provision for four mounting bolts, like full size units. Miniature loudspeakers of this type are something of a rarity though, and I have not encountered any for some years. Virtually all miniature loudspeakers are designed for fixing via some form of mounting clip or bracket.

For the home constructor the most simple method of mounting a loudspeaker is to glue it in place behind the grille. An epoxy adhesive or a general purpose clear type should hold the speaker firmly in place. This needs to be done quite carefully though, as it is not a good idea to get any of the adhesive smeared onto the diaphragm. Only apply the adhesive to the front rim of the loudspeaker using no more adhesive than is really necessary.

It is probably better to fix the loudspeaker in place using some form of mounting bracket if it is likely that unit will receive a lot of knocks, or be subjected to a fair amount of vibration. Fig. 2 shows a simple way of fixing a loudspeaker using a metal bracket. It is better to use thin steel rather than aluminium for the bracket. For this method of mounting to be successful it is essential for the bracket to maintain a reasonable amount of pressure on the rear of the loudspeaker. A fairly springy material such as steel will do this, but an easily formed metal such as aluminium soon buckles and releases its grip.

An alternative method which uses small angle brackets to hold the loudspeaker in position is shown in Fig. 3. Only two brackets are shown but in practice three or (preferably) four brackets should be used. Again, it is better to make the brackets from a fairly springy material such as thin steel, rather than use aluminium.

CERAMIC RESONATORS

In some applications ceramic resonators offer a practical alternative to moving coil loudspeakers. Ceramic resonators are not normally used for reproducing speech and music, but they are well suited to alarm applications. It is important to realise that they are very different to normal loudspeakers, and in most cases these two types of component are not interchangeable.

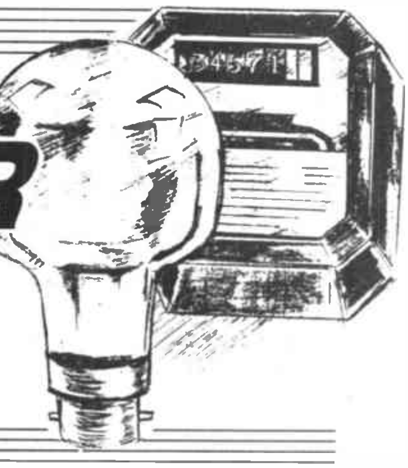
Ceramic resonators utilize the Piezo effect, and to the driver circuits they "look" rather like medium value capacitors. This makes them the electrical inverse of a normal loudspeaker, which has characteristics that are similar to a medium value inductor. Resonators have a major limitation in that they only provide good efficiency over a narrow range of frequencies, but over this range they have much higher efficiencies than any moving coil loudspeakers.

Using a moving coil loudspeaker instead of a resonator will not give good results because the available drive current will be inadequate. This produces very low volume levels, and there is a risk of the driver circuit being damaged. In some cases a resonator can be used successfully instead of a normal loudspeaker. This is dependent on a number of factors though, and it is probably best not to try it unless you know what you are doing.

Ceramic resonators usually have a moulded-in mounting plate which accepts two 8BA or metric M2 mounting screws. The mounting screws and bolts are not normally supplied with the resonator incidentally. The easiest way to mount a resonator is to bolt it on the front surface of the panel. It is then only necessary to drill two holes for the fixing screws, plus a third to permit the leadout wires to pass through to the inside of the case. I use the resonator itself as a sort of template when marking the positions of the three mounting holes on the front panel.

The alternative is to fit it on the rear surface of the panel, but it is then necessary to make a large round cutout to accommodate the body of the component. Provided it is done well this second method gives neater results, but you may not feel that it is worth the extra effort involved.

Constructional Project



MICROPROCESSOR SMARTSWITCH

BART TREPAK

See the light! Replace your light switch with this energy conscious touch switch – it has a mind of its own!

IN HIS last budget, one of the previous Chancellor's proposals (and one confirmed by the present encumbent) was the decision to levy VAT on domestic fuel – not, as some cynics would say, to help pay for Government spending – but as he said to help to save the environment by reducing the amount of energy we use. As most people do not think of the cost of energy when they switch on their heating or get into the car, these proposals should have as much effect on energy usage as lowering the price of shoes would have on encouraging people to walk more.

Be that as it may, the reason why we all use more and more energy is that it has become more convenient to do so. We could all go shopping by public transport and wait at the bus stop with heavy bags in the rain, but few would argue that it was more convenient than going by car. Similarly, in the good(?) old days, when warming our room meant cleaning out the grate on our hands and knees, going down to the cellar for more coal and then trying to kindle a flame with matches and bits of wood most people simply put on another jumper thereby saving energy.

It would need a good deal more than legislation to get people to return to these methods of saving energy. Today, when we are cold, a quick flick of a switch is all that is required to make the house warm. When we add to this the fact that most of the people doing the "flicking" are not the ones who pay the bills it is easy to see that some other strategy is needed if we are to persuade ourselves to use less energy.

BACK TO BASICS

Switching on the lights when we enter a room for example, is now almost a reflex action and one to which we do not normally give a second thought. Often the light is not even required and sometimes it is even left on when we leave the room which is, of course, very wasteful of energy. Children, (again those who have the least to do with paying the electricity bills) seem to be the worst offenders and it is not uncommon to enter a room in our house in broad daylight to find the lights on and the room unoccupied.

No doubt this problem did not occur in the days of oil lamps as putting the lights on then was much more of a chore. While not suggesting for one moment that we "get back to basics" and replace all our lights with oil lamps, the light switch itself could do with some redesign to make it more energy concious – hence the SMARTSWITCH.

Switches incorporating passive infra-red detectors (PIR) are available which sense if the room is occupied and switch the lights off if it is not, but these tend to be expensive and cannot always be sited in the most suitable position for detecting the people in the room. As PIR detectors are normally designed to respond to moving sources of heat, presumably the people in the room would need to move about for the system to work correctly.

To eliminate the possibility of the unit switching the lights off if insufficient movement is detected when there may still be someone in the room, a dimmer is usually incorporated to slowly fade the lights off over a period to enable the person to re-activate the switch by moving. The switch to be described does not use PIR sensors and is designed to replace a standard light switch. While it is as easy to use as a normal light switch, it should reduce energy consumption by switching on lights only when necessary and for no longer than required.

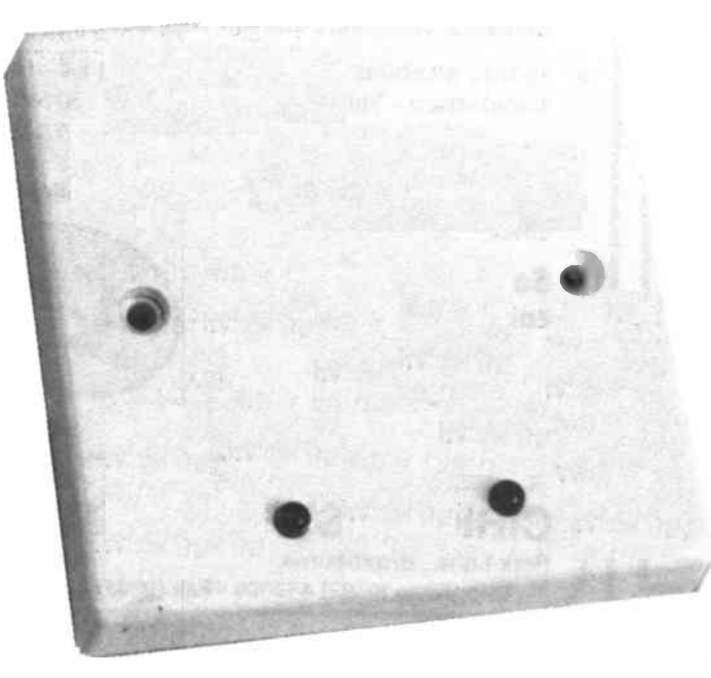
PHOTOCELL

The first, most obvious way of economising is to incorporate a photo detector which would prevent the light from being switched on when the ambient light level is too high and in this design a phototransistor is used to perform this task. A Sensitivity control is also included to vary the level at which the circuit determines whether or not it is too bright to switch on the lights.

To prevent the lights from being left on indefinitely, a timer could be included to switch the light off again after a preset time. This would need to be variable from say up to one minute for stairs and hallways to tens of minutes or more for other rooms.

There will obviously be situations where the light is required to be on for longer than any pre-set time and also times when the lights are required when the phototransistor would normally inhibit them. So provision must be made for this, but these two basic features would defeat those who feel they must at least attempt to switch on the lights when entering the room whether they are needed or not and also those who tend to leave them on.

Since a toggle switch would not be suitable for this application, a momentary type would be required to control the logic and a triac used to control the light.



Unfortunatley, momentary switches are not easily available in a style which would match existing electrical fittings. Since the days of building electronic projects in tobbaco tins are long gone and projects must not only do the business but look the business, a "touch switch" circuit has been incorporated enabling the unit to be built onto an electrical blanking plate.

The logic for the above switch could probably be designed around a couple of CMOS logic chips but as mentioned above, the basic concept must be modified to make a practical switch. First of all, you may want to stay in the room longer than the preset time or leave the lights on for some reason. This could be provided for by an override switch but would either involve the fitting of another wall box and switch in parallel with this one or fitting a separate toggle switch to our neat touch plate after all.

EXTRA LOGIC

Fitting another touch plate is not a good idea because this one may be activated by mistake and leave the light on indefinitely when this was not intended. The solution to this is to use the same touch plate with extra logic that would switch the timer on at the first touch and override it if the plate were touched again within a short period (say two seconds) leaving the light on permanently. To remind the user that the circuit is in the continuous mode, an l.e.d. has also been included.

The next problem with the simple solution is that you may enter a room intending to stay for only a short time and switch on the light accordingly, with one touch, but find that your task takes longer than you thought and longer than the preset period. The last thing you want is for the lights to go off without warning.

One way around this would be to have the lights dim slowly to off allowing you to re-activate the timer before they go off. The problem with dimming is that unless it is fairly fast or the light level drops appreciably it may not be immediately noticed. It also generates radio frequency interference so costly suppressor components have to be fitted to the circuit and since there is going to be little space left if we are to fit the unit into a standard wall box, a simpler method of warning the occupant of the room that the lights are about to go off is required.

The method adopted is to switch the lights on and off briefly, shortly before they are due to go off to enable the user to re-activate the circuit if required. This may sound dangerous in some circumstances but if the off periods are sufficiently short its effect should be no more than the loss of vision caused by blinking. The final circuit switches the lights off and on three times for approximately five mains cycles each time, ten seconds before the lights are due to turn off giving the occupant time to extend the on period or switch the light on permanately as required.

TOUCH CONTROL

The next thing is to decide how the user is to re-activate the timer when this is required. The obvious method and the one adopted here is to touch the plate again before the light goes out (but *after* it has flashed). Originally an additional sound operated switch was considered for this purpose consisting of a small electret microphone and an amplifier but this was felt to be an unnecessary complication and has not been included.

There may, of course, be situations when the light may be required even though the ambient light level as sensed by the phototransistor was "too high" which would normally prevent switching. This is catered for by switching the lamp on when the attempt to switch it on is made to acknowledge that the command has been recognised but then switching it off again if the light level is too high. Should the plate be touched again within two seconds, the light would be switched on for the preset period in spite of the high ambient light level, while a third touch would switch the light on permanantely (i.e. the same sequence of inputs as normal except that the first touch would in this case simply deactivate the light level sensor).

Finally, there must also be provision made to enable the lights to be switched off manually (by those who remember to do this) and this is done simply by touching the touch plate whenever the light is on. This will turn off the lights whether the switch is in its timed or continuous mode enabling the lights to be switched off in the normal way when leaving the room.

QUART IN A PINT POT

The number of monostables, bistables and gates required to implement this system would require more than a couple of 4000 series CMOS chips and it would be difficult to fit it all onto a 10cm x 10cm printed circuit board let alone on one which would fit into a standard wall switch box. At this point I remembered reading once, in the early days of microprocessors, in some sales literature by one of the big semiconductor manufacturers that they envisaged that one day, there would be at least one computer, not only in every house but in every room in the average house. I had always wondered how they could convince people to have one in the WC for example or what possible function it could perform there, but by fitting one into a lightswitch, we could have computers in the attic and the understairs cupboard as well!

Microprocessors are now so cheap, especially some of the single chip types that they can now be used to replace as few as three or four chips from the standard CMOS 4000 series and show a cost saving as well as performing more functions. A CMOS microcontroller, type PIC16C, was chosen because if we are to mount the unit in a wall box replacing the normal lightswitch, the total power consumption of the circuit must be very low so that the mains dropper components are small and fit into the box as well. Also since we are trying to save energy, it would be pointless to save the energy of a 60W to 100W light bulb by having a switch which consumed 15 to 20W in the mains dropper even when it was off!

As far as providing a low voltage (3V) supply for the circuit is concerned, a transformer is of course out of the question and a dropper resistor would get too hot in the confined space behind the switch so a capacitive dropper arrangement has been chosen which is quite feasible given the low current requirements of the circuit. The power supply circuit is in fact identical to that used in the *Whistle Switch* project published in the Feb. '94 issue and has the advantage that the supply is available even when the triac is on allowing it to be d.c. triggered (i.e. continuously) when it is on, thus avoiding radio interference.

Its only disadvantage is that since the main lamp current also flows through the Zener diode, the maximum load current is determined by this component rather than the triac. With the diode specified, this should not exceed 250W which should be sufficient for all but the most palacial of rooms.

ZERO CROSSING

Since we are using a microprocessor, we may as well make it work harder to provide another desirable feature to the switch – zero voltage switching. You may have noticed that whenever you switch the light on (or off) and a radio happens to be on nearby, a click is heard in the loudspeaker. This is due to the fact that a mechanical switch can be switched on at any point in the mains cycle and since the mains voltage is only at or near zero for two very short periods in each cycle, the chances are that the switch will open or close when there is a substantial voltage across it.

At the instant at which the switch closes therefore, the current will suddenly change from zero to a value determined by the mains voltage at that instant

Table 1: Time Delay Settings

S1	S2	S3	S4	Multiplier
0	0	0	0	X1
1	0	0	0	X1
0	1	0	0	X2
1	1	0	0	X3
0	0	1	0	X4
1	0	1	0	X5
0	1	1	0	X6
1	1	1	0	X7
0	0	0	1	X8
1	0	0	1	X9
0	1	0	1	X10
1	1	0	1	X11
0	0	1	1	X12
1	0	1	1	X13
0	1	1	1	X14
1	1	1	1	X15

S5	S6	Time Base
0	0	5 Secs
1	0	30 Secs
0	1	60 Secs
1	1	4 Mins

1 = SWITCH CLOSED

0 = SWITCH OPEN

EXAMPLE:–
Switch setting S1-S6:
0110 10
Time delay = 6 × 30 Secs
= 180 Secs.
or 3 mins.

and the resistance of the filament (ignoring any inductance in the wiring) and it is this sudden change in current which produces harmonics extending to many "megahertz" which are radiated and picked up by the radio. This is not a great problem as a light is only switched on or off infrequently and even in this switch, where the light can switch on and off a few times to indicate that it is about to turn off, it would not normally even be worth the extra few lines of code to add such a feature.

UNDER STRESS

This is not the only problem however. When the light is first switched on, the lamp filament is cold and has a relatively low resistance which is very much less than normal "hot" resistance.

Being a very thin wire, the filament heats up very quickly and in only a few half-cycles the resistance has increased to its normal value but before this happens, the current may have been up to ten times the rated value. This causes quite a stress on the filament and is the reason why light bulbs tend to blow when they are switched on rather than when they have been on for some time.

The maximum stress obviously occurs when the switch happens to close when the mains voltage is at its peak value and is progressively less at other points in the mains cycle. By switching the triac (and therefore the light) on when the mains is at *zero* or at least at a very low voltage, the filament has time to heat up while the mains voltage is increasing to its maximum and the inrush current is much reduced. This leads to a substantial increase in lamp life and is well worth the extra few lines of code, especially as no extra components are needed.

The circuit (Fig. 1) already has an input via resistor R5 which is the 50Hz squarewave appearing across the Zener diode D1 used for timing and this can be utilised to determine the zero crossing point of the mains. The processor is therefore programmed to detect the positive going transition of this waveform and when the output is required to be switched on, the switching is delayed until this occurs.

The situation is slightly complicated by the fact that due to the action of capacitor C1, this squarewave is 90 degrees out of phase with the mains voltage so switching on at this point would in fact make things worse by ensuring that the lamp was switched on at the mains peak. To overcome this, a further 5mS (quarter of a mains period) delay is introduced, which, being dependant on the clock frequency of IC1, is perhaps not as accurate as it could be but is good enough for this purpose and ensures that the lights are only switched on when the mains voltage is near the zero crossing point.

CIRCUIT DESCRIPTION

The full circuit diagram for the Smartswitch is shown in Fig. 1. The heart of the circuit is the microcontroller IC1 which contains all the elements of a computer (i.e. a central processing unit CPU, RAM, ROM, 12 programable input/output lines and other ancilliary circuits such as power on reset, clock oscillator etc.) and accepts inputs from the Touch Sensor built around transistor TR1 and the phototransistor light sensor TR2. The 3V square wave appearing across diode D1 is also fed to IC1 via resistor R5 and, as already stated, is used as a time base for the various timing operations required and also for deriving the mains zero crossing point.

Port B of the chip (pins 6 to 13) are programmed so that the four lower lines are outputs with B0, B1 and B2 paralleled to increase the current drive to the triac CSR1 and output B3 driving the indicator l.e.d. D4, while the four upper lines B4 to B7 are inputs. These are connected to a d.i.l. switch (S1 to S4) which programs the time delay multiplier. These together with the two switches (S5 and S6) connected to port A0 and A1, which set the time base, determine the time for which the switch will remain on in the momentary mode.

Table 1 shows the time bases obtained by the four possible settings of the two switches connected to A0 and A1. The switches which program the multiplier are binary coded giving a multiplication factor of x1 to x15 (0000 is read as 0001 giving a factor of x1) giving a range of time delays from five seconds to one hour.

The d.c. supply for the circuit is obtained from the a.c. voltage appearing across Zener diode D1 which is rectified by diode D2 and smoothed by capacitor C2. Resistor R1 and C1 form a low loss mains dropper, while R4 and C3 set the frequency of the on-chip oscillator.

FLOW CHART

Perhaps almost as important as the circuit diagram in this sort of project is the flow chart which shows the logical flow of the program. This is shown in Fig 2.

When the unit is first powered up, the controller (IC1) goes through an initialisation routine which defines all the I/O lines as either inputs or outputs, determines if the RTCC (Real Time Clock Counter) input is to respond to positive or negative transitions, and loads any registers with their initial states.

The program starts by reading the settings of switches S1 to S6 which determine the time delay and loads a register with appropriate values from a look-up table stored in the ROM. It then switches the light off and monitors the input to see if it has been touched (i.e. line A3 high) and depending on the result of this test continues executing the program as shown.

In practice, the actual program differs from the flowchart slightly in the way that the time delays are generated. Normally, time delays in microprocessor systems are generated by loading a counter with a suitable value and then decrementing the counter at regular intervals either from the internal clock or by an instruction in the program or from an external source such as the mains as used in this application.

When the counter reaches zero, the processor is interrupted and made to carry out some function e.g. blink the lights. In this application, the RTCC counter (Real Time Clock/Counter) is used with an internal prescaler which is loaded to ensure that the count reaches zero every 200mS and this is used to decrement other counters to give the required time delays. Because the PIC16C series microcontrollers do not have any interrupts, the RTCC counter would simply overrun zero and carry on counting and must therefore be interrogated each time it is incremented to see if it has reached zero and if it has, the appropriate action taken.

Since the microcontroller executes every instruction in about 5µS, and in this circuit the RTCC counter is incremented every 40mS, there is plenty of time to check if the register has reached zero as well as executing the rest of the program so that the absence of an interrupt is not a great problem but it does mean that the program must be written with this in mind. The program therefore spends most of the time in a loop checking to see if the RTCC counter has overflowed and if it has, the counter is reloaded and the rest of the program quickly executed and then

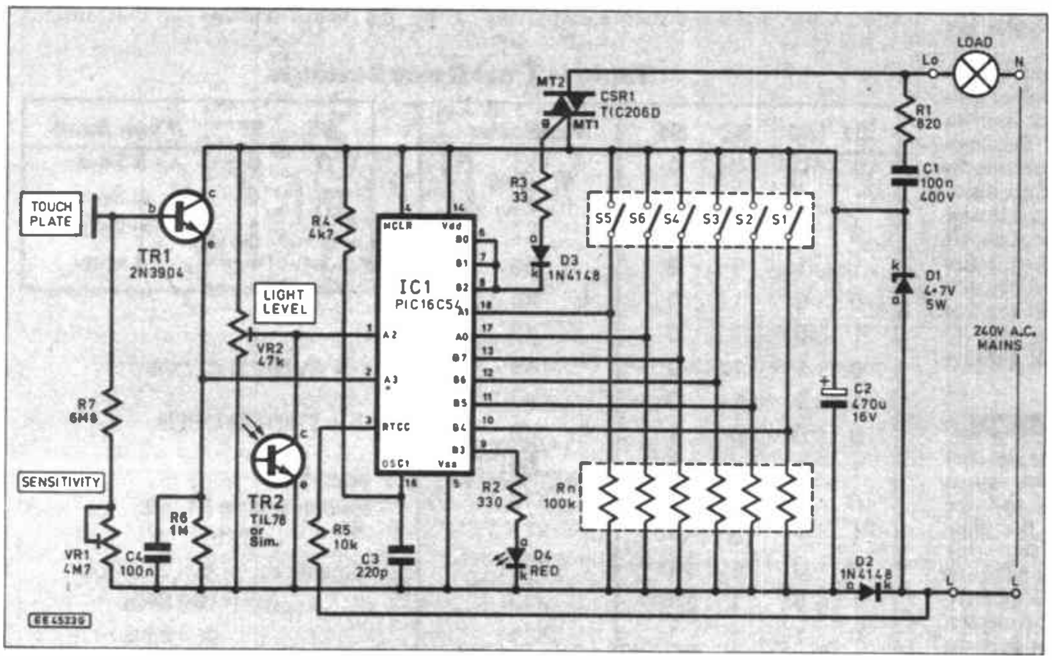


Fig. 1. Full circuit diagram for the Microprocessor Smartswitch.

returns to the loop to await the next RTCC overflow. This operation is in fact written as a subroutine which is called continuously, this is not apparent from the flow chart.

The listing for the program is not given as this would be of limited use as a special programmer is required for the device, but pre-programmed i.c.s are available (see *Shoptalk*).

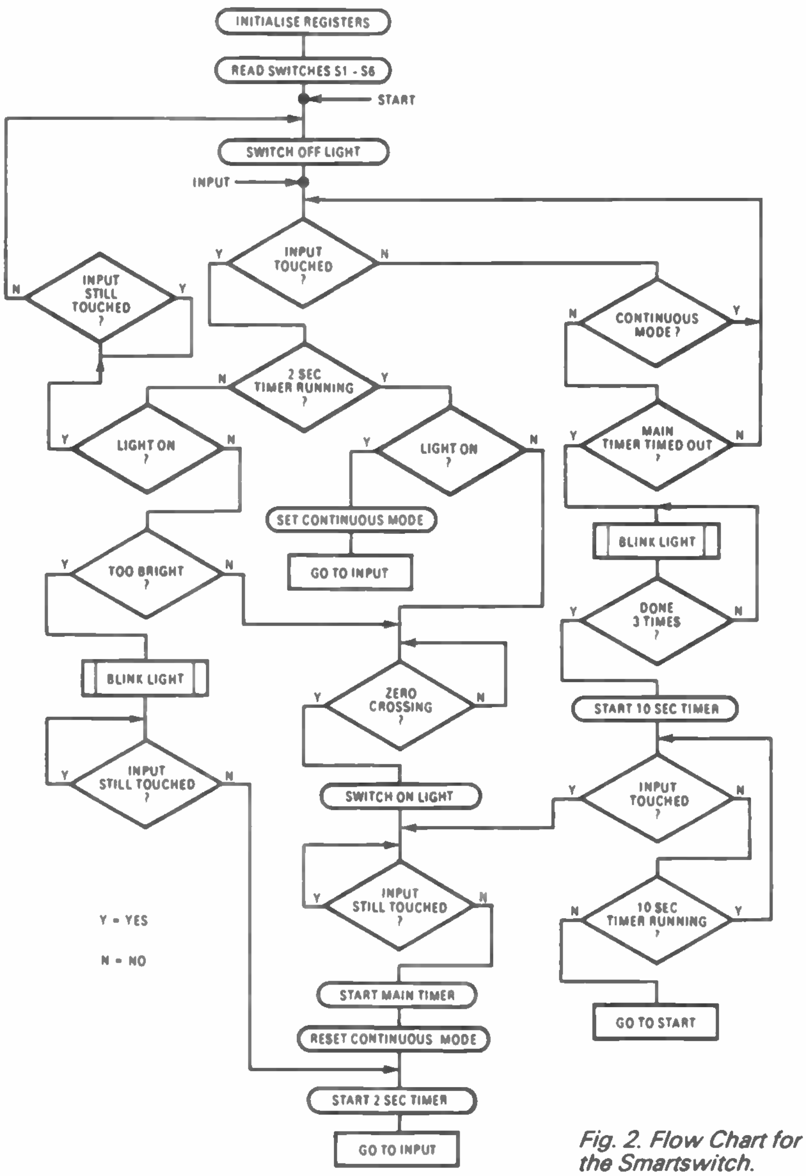


Fig. 2. Flow Chart for the Smartswitch.

CONSTRUCTION

The Smartswitch is built on a small printed circuit board (p.c.b.) which sits inside the lighting switch box. The component layout and full size copper foil master pattern is shown in Fig. 3. This p.c.b. is available from the *EPE PCB Service*, code 881.

Provided the printed circuit layout is used, there should be no difficulties in assembly. As usual, care must be taken to ensure that all the semiconductors and electrolytic capacitors are inserted the correct way around and it is stongly recommended that the i.c. (which is a CMOS device) is handled as little as possible and is not soldered directly to the printed circuit board but inserted into an i.c. socket.

If you are using a capacitor other than the one specified for C1 then make sure that this component is rated for ***240V a.c. operation.*** Failure to observe this precaution could easily destroy most of the components on the board.

Before soldering l.e.d. D4 and the phototransistor TR2 to the board, their leads should be preformed as shown in Fig. 4 so that they can protrude through the holes in the front plate. Note that the triac is mounted flat on the board so its leads must also be preformed as shown.

This should be done very carefully; paying particular attention to the polarity of these components so that repeated bending of the leads is avoided. The triac heatsink tab is connected internally to the centre lead of the device and should therefore not be allowed to touch any other component on the board or the metal wall box when the unit is fitted on the wall.

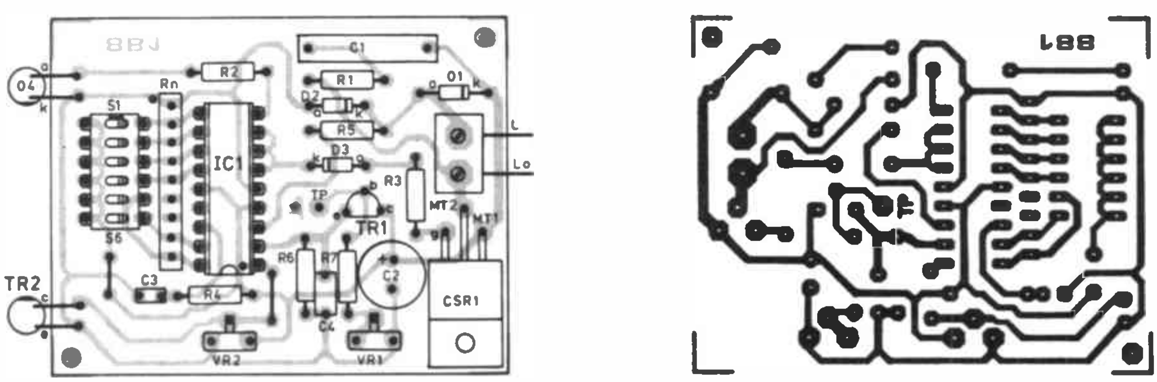
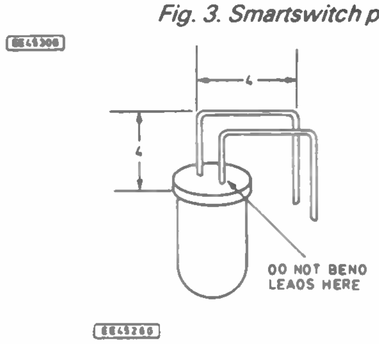


Fig. 3. Smartswitch printed circuit board component layout and full size copper foil master pattern.



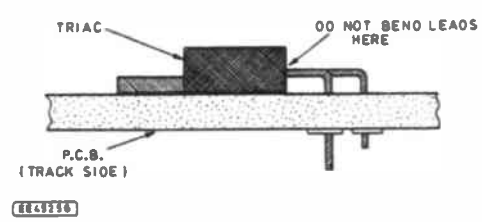


Fig. 4. Preforming the l.e.d., phototransistor (left) and triac (above) leads before mounting them on the p.c.b.

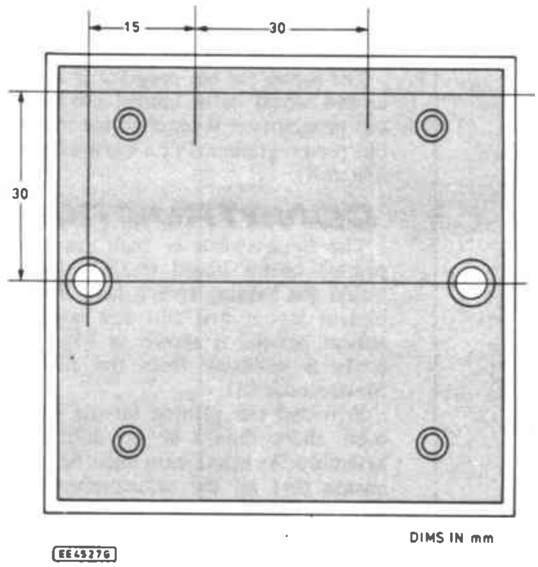


Fig. 5. Switch blanking plate drilling details.

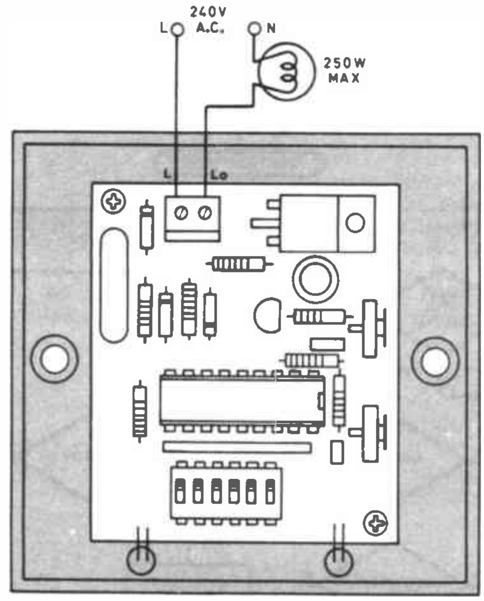


Fig. 7. Wiring to the mains supply and inserting a lamp (load) to test the "switch".

COMPONENTS

Resistors

R1	820
R2	330
R3	33
R4	4k7
R5	10k
R6	1M
R7	6M8
Rn	100k SIL 8-way resistor network

All 0·6W 1% metal film, except Rn

See SHOP TALK Page

Potentiometers

VR1	4M7 min. enclosed preset, vert.
VR2	47k min. enclosed preset, vert.

Capacitors

C1	100n polypropylene, 400V
C2	470µ radial elect. 16V
C3	220p min. polycarbonate
C4	100n disc ceramic

Semiconductors

D1	1N5337B 4·7V 5W Zener diode
D2, D3	1N4148 signal diode (2 off)
D4	3mm or 5mm red l.e.d.
TR1	2N3904 *npn* gen. purpose transistor
TR2	TIL78 *npn* phototransistor or similar
CSR1	TIC206D 400V 4A triac
IC1	PIC16C54 RC/P programmed microcontroller (see *Shoptalk*)

Miscellaneous

S1 to S6 6-way d.i.l. switch

Printed circuit board available from the *EPE PCB Service*, code 881; single switchbox blanking frontplate (see *Shoptalk*); 18-pin d.i.l. socket; 2-way p.c.b. mounting, mains rated, screw terminal block; aluminium foil, about 4cm square; insulating sleeving; solder etc.

Approx cost guidance only **£26**

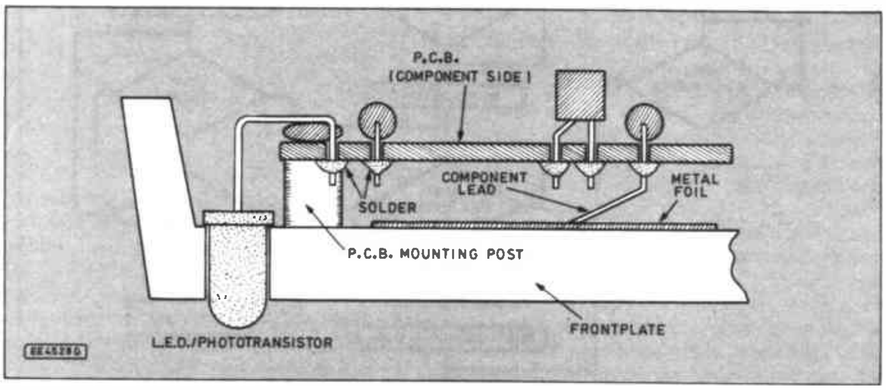


Fig. 6. Mounting the board and touch plate connection inside the switch plate.

The only other component worthy of mention is Rn which is a resistor network. This component has 9 pins and contains 8 x 10kohm resistors connected to a common line. As it is important to ensure that the common pin (which is normally marked with a dot) is connected to the circuit with the marked end nearest R2. Remember also to fit the two wire links at the positions shown in Fig. 3. These can be made from discarded resistor leads and need not be insulated.

When assembly of the board is complete, check it again carefully against the layout drawing and make sure that there are no solder splashes between tracks. If all is well, drill two 3mm or 5mm dia. holes in the plastic front panel in the positions shown for the l.e.d. and phototransistor in Fig. 5.

Next, attach a piece of aluminium foil (approx. 4cm x 4cm) to the back of the front plate between the two mounting holes to form the touch plate. Note that this circuit works by capacitance with the aluminium foil forming one plate while the users hand forms the other with the frontplate acting as the dielectric. If you do not have any self-adhesive aluminium foil, ordinary kitchen foil may be used and stuck using a suitable adhesive.

When the foil is firmly secured, clean the surface with emery paper to ensure a good contact. Solder a piece of discarded component lead to the printed circuit board at the point marked "TP" which will form the connection to the foil when the board is mounted on the front panel.

When this has been done, the assembled circuit board should be mounted and secured to the front panel using two self-tapping screws, see Fig. 6. The positions of l.e.d. D4 and phototransistor TR2 may be adjusted slightly to ensure that they line up with the holes in the front panel.

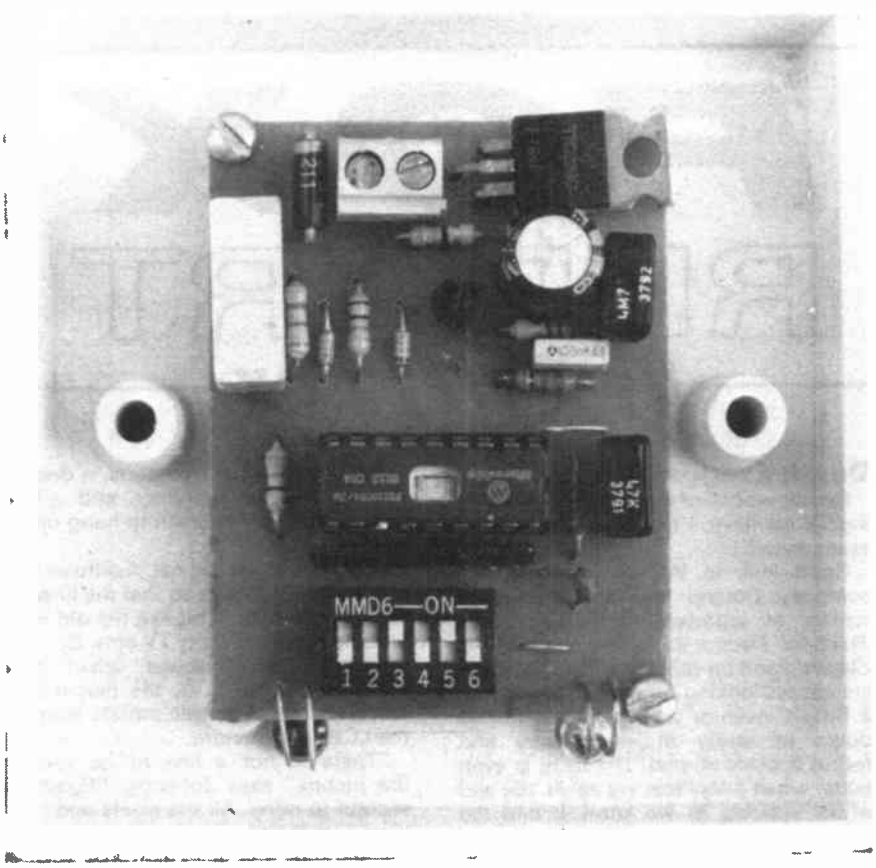
TESTING

Mains voltages are present on the p.c.b. and the finished unit should be carefully double-checked before wiring it in. Also, if possible, do not attempt to test the unit without first mounting it in a temporary fully enclosed plastic box, with holes drilled for leads and access to preset controls.

The routine programmed into the microcontroller (IC1) is written so that when the unit is first powered up, the controller sets up the input and output lines and then reads the d.i.l. switch settings after which it settles into a loop continually reading port A3 until it detects an input and acts accordingly. This means that the d.i.l. switches must be set *BEFORE* the circuit is powered up as any changes in the switch setting after the initialisation routine has been executed will be ignored. Thus to set or alter the time delay, the power MUST be switched OFF at the mains fuse box which is good from the point of view of safety.

REMEMBER THAT THE CIRCUIT OPERATES AT MAINS POTENTIAL AND MUST NOT BE CONNECTED TO EARTH. SWITCH OFF THE MAINS BEFORE FITTING OR MAKING ANY ALTERATIONS TO THE CIRCUIT AND USE AN INSULATED SCREWDRIVER WHEN ADJUSTING THE PRESETS. TOUCHING ANY PART OF THE CIRCUIT WHEN IT IS POWERED IS VERY DANGEROUS AND COULD REDUCE THE READERSHIP OF EVERYDAY WITH PRACTICAL ELECTRONICS BY ONE.

For initial testing, all d.i.l. switches should be set to off (which will give a time delay of five seconds) and presets VR1 and VR2 should be turned fully clockwise. The circuit is designed to replace a conventional lightswitch with the lamp in series with the switch and so, if testing is to be carried out "on the bench", remember to connect a lamp in series exactly as shown in Fig. 7. The polarity of the mains connections (i.e. Live L and Load Lo) is important and although no damage will occur if the connections are reversed, the unit will not function.



TOUCH PLATE SENSITIVITY

Now comes the tricky part and **extreme care must be taken in all the following operations.** Power up the circuit and while touching the centre of the plastic front plate with three or four fingers, adjust VR1 with an *insulated* screwdriver until the light switches on. This sets the sensitivity of the Touch Plate.

Remove your hand from the switch and the light should stay on for five seconds after which it should flash three times and remain on for a further 10 seconds before switching off (this time is preset and is not variable). Touch the plate again but this time touch it again after the lamp has flashed. Five seconds after you remove your hand, the light should flash again and eventualy, if the plate is not touched again, the lamp should go out after ten seconds.

With the lamp off touch the plate again and the light should switch on. Remove your hand and then touch the plate again (within two seconds) and the l.e.d. should switch on indicating that the lamp is now on permanantely. Wait for ten seconds or so to ensure that it is working correctly and then touch the plate again to switch the lamp off.

LIGHT LEVEL

Preset ctonrol VR2 selects the ambient Light Level at which the light should be disabled. This is more difficult to set up and should be done when the ambient light happens to be at the level required, or possibly adjusted over a period of time until the right level is selected and certainly with the switch mounted at the location where it is to be used.

Initially, when the ambient Light Level is high, VR2 should be adjusted so that when the plate is touched, the lamp flashes on and then goes off. A further touch (within two seconds) should cause the lamp to switch on and flash after five seconds while two further touches should cause the lamp to remain on permanantely (D4 on).

If these tests are successful, the unit should be switched off and the d.i.l. switches set for the time required. If the time delay required is say three minutes, switches S5/S6 could be set to 01 giving a time base of 60secs. and S4 to S1 (multiplier) set to 0011 or binary 3 (giving a switch setting reading from top to bottom with the board as shown in Fig 3 of 110001 where 1 = switch on and 0 = switch off).

Note that a three minute delay could also be achieved by setting S5/S6 to 30 seconds and the multiplier to 6 giving a switch setting of 011010. In this case, a delay of 3·5 minutes could also be selected by changing the multiplier to 7 (1110) while in the former case only integral minute delays are possible.

In all cases, the light will flash three times after the time delay set but will actually remain on for 10 seconds longer before finally switching off. Note that this 10 second period is preset internally and cannot be altered.

Finally, the "zero crossing" feature may be checked by operating the switch near to a radio tuned "off station" on the longwave band. This band is most affected by interference and if no clicks are heard when the light is switched on, this function can be assumed to be working.

IN USE

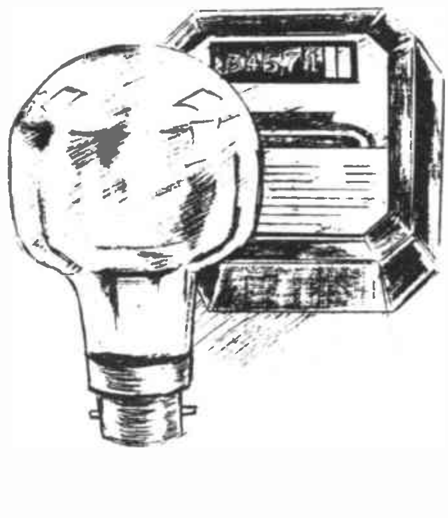
As mentioned, the Smartswitch has been designed to replace ordinary switches around the house and as such can be used with any tungsten filament lamp provided that the maximum rating of *250W is not exceeded.*

The use of this switch with fluorescent tubes is *not* recommended because of the length of time which they take to strike. This is also the case with the low energy lamps which are basically fluorescent lamps shaped like conventional lamps with a built in starter.

Although it may be used in any room, it should find most use in controlling the lights in locations which are visited only occasionally such as the WC, bathroom, garage, attic/cellar etc. where a light may be left on accidentally and go unnoticed for long periods of time. It is left to the user to decide the most appropriate time delay to set for each location which should, of course, be chosen so that lights are not left on for too long but long enough to avoid having to keep extending the time period when in use.

For example a period of one to two minutes for the switch in the garage would allow enough time to find your keys, do up your seat belt and drive out. On the odd occasion when you may have to unload the shopping for example it may be necessary to reactivate the switch perhaps once or twice while, on the even more infrequent occasions such as checking the oil or fluid levels or even servicing the engine, the continuous mode would be selected.

The longer delays available, would be more appropriate to the kitchen or lounge where should even longer stays be envisaged the switch could again be easily put into the continuous mode. □



FOX REPORT

by Barry Fox

Death Exaggerated?

Recent reports of the imminent death of the TV set have, I fear, once again been exaggerated.

Good luck to William Johnson, his company Durand and his Microsharp screen, as reported in *Everyday with Practical Electronics, The Independent, Observer* and on *Breakfast TV*. The media are always looking for a new story about a British inventor who has been turned down by stuffy British industry and found backers abroad. The story is even better when it foretells, yet again, the end of TV viewing as we know it and the beginning of a new age of flat screens to hang on the wall.

These stories have been splashed as news for more years than most people can remember, but we still keep watching TV on a cathode ray tube screen because the CRT is still the cheapest way of providing a bright, clear colour picture of reasonable size.

William Johnson is obviously a very good self-publicist. When I phoned to ask about his invention he faxed me an article (from *Virtual Reality News*) with the reassurance that it was "100% correct" and the result of "very thorough investigation" by the author. Although the article carries a note which "strictly forbids" reproduction "of any part" Mr Johnson assured me that the author would not mind my quoting from it. The only proviso, he said, was that I must quote verbatim from a statement "agreed by the Nashua Corporation and William Johnson" about the "the formation of a joint venture to manufacture and commercialise Microsharp technology".

I am happy to oblige on this verbatim quote, but I have to say that Nashua in the USA is rather less solid on all of this. Although the quote ties up with the Nashua agreement which Johnson later released, said Dan Junius PR Director for Nashua Corp in the USA: "The statement in *Virtual Reality News* goes beyond the reality of where this agreement is". The deal signed by Nashua is for an option to "determine whether to market".

Nashua will begin negotiating rights, with an announcement mid-year, if it decides to exercise the option. Firms like Nashua are swayed by technical evaluation, not bandwagon stories about making TV sets obsolete.

Depixillator

I asked William Johnson to answer a few of the questions which old-hand flat-screen watchers may be asking.

The system is in two parts, a depixillator in a video projector, and a high gain cinema-style screen to hang on the wall.

Depixillators are old hat. A diffuser filter fuzzes the TV picture so that the lines are no longer visible, a bit like the old spot-wobble system in early TV sets. On more modern video projectors, which push light through an LCD, the dexpixillator fuzzes the characteristic mosaic image of the LCD cell structure.

"There is not a line to be seen in the picture" says Johnson. "Quality is second to none. All the pixels and black matrix are removed".

I am sure this is true. If you fuzz an image you lose the fine detail that represents the picture lines, and LCD structure. The only trouble is that in life there is no free lunch. You also lose fine detail in the picture as well.

The screen, which hangs on the wall, reflects light from the projector, like any projection screen (other than a jet black screen which absorbs it all). High gain screens look very bright from head on, and a lot less bright from off-axis angles.

William Johnson, says his screen is "98% efficient" even at viewing angles of up to 75 degrees. So the projector can be mounted off axis. Surely there must be keystoning and defocussing effects when pictures are projected obliquely from the side?

Here I can only pass on William Johnson's reassurance. "It's quite remarkable. There is no misalignment, and no distortion".

Johnson says that he has his invention covered by patent applications, some of them granted. This should create an interesting situation because an inventor in the USA, Gene Dolgoff, and his company Projectavision, have a US patent on a depixillating projector. A close colleague of mine, who has seen Projectavision's latest prototype, says the picture is bright, with a very wide viewing angle. The brightness seems in practice to compensate for the loss of detail.

Philips Research

Philips has been working on flat screens for even longer than people have been predicting the end of the TV set. Much of the work has been done at Philips Research Laboratories at Redhill, in Surrey. PRL freely admits that the cost of producing large area LCDs has not come down to predicted levels, and the size of panels has not risen to match predictions, either.

In the USA, where people have big rooms, and really do want big screen, Philips has solved the problem with a new range of back projection TVs (using small CRTS) which are either built into a false wall or into furniture that backs against the wall. So all the viewer sees is a picture on the wall, with all the electronics hidden.

PRL is still working with LCDs, and since 1989 has been developing a new type of panel for portable PCs. This is now in production at the factory in Eindhoven which was originally built for the ill-fated "Megachip" memory project and was jointly re-fitted by Philips and Thomson to make LCDs.

Virtually all the LCD screens in today's portable PCs use backlit Active Matrix Thin Film Transistor technology. In 1989 PRL started looking for something which is easier to make, and gives a brighter picture. TFT screens have tiny semi-transparent transistors bonded to the glass plate over each pixel, to switch the current through the LCD material. Philips uses diodes instead of transistors.

Thin Film Diodes

Thin Film Diodes (TFDs) are made by sandwiching silicon-rich silicon nitride between tiny semi-transparent electrodes at each pixel. The diode has carefully controlled breakdown voltages. The electrodes are smaller than transistors so block less light. So the picture is around 10% brighter, with 256 grey scale levels.

The TF diodes are easier to make than TF transistors because alignment is not so critical; as long as the two halves of the electrode sandwich cover the filling, the diode works. The filling also has the remarkable ability to self-heal. If it is faulty in manufacture and passes too much current, its electrical resistance increases to reduce the current.

The TFD screen panel is to be sold as a plug-fit unit for PC manufacturers. I have seen a portable PC (unnamed) with TFD screen fitted by Philips researchers in place of its conventional TFT screen. The pictures (monochrome) are very bright with the 256 grey scale giving photographic reproduction. I was particularly impressed by the very black blacks. There was no noticeable smear on cursor motion.

Philips claims that the diodes are stable in bright light and heat and thus suitable for use in a projector. The same technology has been used to build a prototype HD colour LCD projection module, with over one million pixels; but so far only slide photographs of the result have been shown.

Constructional Project

ADVANCED TENS UNIT

ANDY FLIND

Research suggests that up to 70 per cent of "pain" victims get relief by using a TENS unit – If you can afford one!

Our advanced TENS has the additional facility of variable frequency and pulse width control – and it will still cost you a lot less than similar units used by the NHS!

FOR readers who missed last month's project, TENS stands for *"Transcutaneous Electrical Neural Stimulation"*, a technique employed for pain relief. No longer a curiosity, TENS instruments are widely used in both private practice and the public health service as a useful alternative to drugs for the treatment of pain.

The TENS unit described last month provided either a continuous 90Hz stream of output pulses or groups of eight of these pulses, repeating at 1·4Hz. Like similar commercial units this results in a minimum of controls for simple operation.

Although this is fine for many users, more complex units are frequently encountered and it was felt that some readers might like to try the extra features found on these for themselves. In addition to output pulse amplitude control, this design has variable frequency and pulse width. A fixed setting of 90Hz pulsed at 1·4Hz is also available, but in this mode the pulse width is still adjustable.

CIRCUIT DESCRIPTION

The full circuit diagram of the Advanced TENS Unit project appears in Fig. 1. As with last months' design, the high voltage required by the output is generated by the voltage multiplier circuit which can be seen in the upper part of the diagram. Two NAND gates, IC5a and IC5b, form an oscillator running at about 100kHz. Anti-phase outputs from this are buffered by gates IC5c and IC5d and transistors TR6 to TR9, to provide parallel drive through capacitors C8 to C23 to the diode chain D1 to D17.

Each stage of the chain adds almost twice the supply voltage, the only losses being the forward voltage drops of the diodes. The desired output is eighty volts, and sufficient stages are provided to ensure this will be maintained until the battery supply falls below six volts.

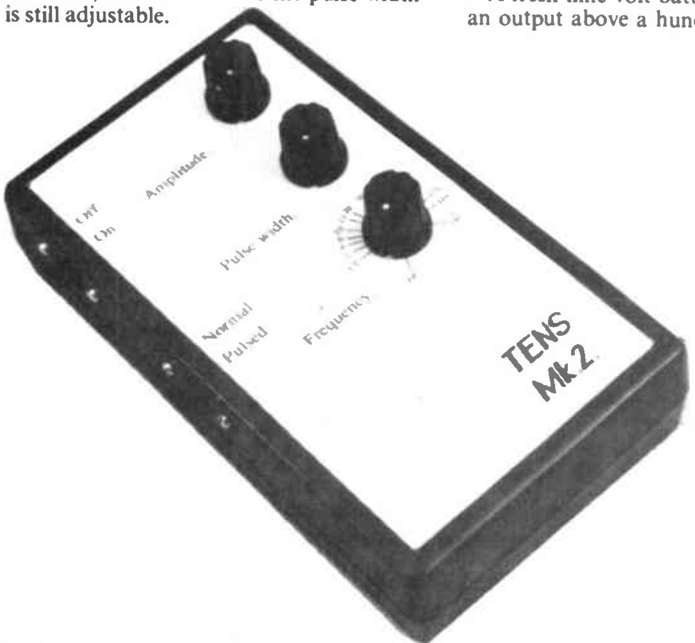
A fresh nine volt battery would result in an output above a hundred volts, but this is prevented by a simple regulator circuit. When the output exceeds 80V Zener diodes D18 and D19 begin to conduct and current from them turns on transistor TR5, which pulls one of the inputs to oscillator gate IC5a low, stopping the oscillator.

The multiplier output is therefore a constant eighty volts for supplies above six volts. Restriction of the output to this value permits construction with small, inexpensive capacitors and diodes, resulting in a very compact and efficient circuit.

PULSE GENERATOR

Whilst this part of the circuit is identical to last month's design, the pulse generator is completely different. At it's heart is an integrator IC1b, and a comparator IC2 which switches at one-third and two-thirds of the supply voltage.

The IC2 comparator output is fed back to IC1 integrator input, forming an oscillator. A potentiometer VR1 controls fre-



PLEASE NOTE

A TENS unit should NOT be used in the following circumstances:

By any person or persons with a Heart Pacemaker. Especially where the pacemaker is a "demand" type and might interpret the TENS pulses as signals from the heart.

Connections on the body where the TENS signal may pass across the heart, such as an electrode on each arm.

Siting the electrodes on the NECK, in the area of the "carotid arteries". Nerve centres here are connected with control of blood pressure and oxygen levels.

For obvious reasons the current should NOT be allowed to pass through the head. – Never use TENS for Headaches.

If you are in any doubt YOU must consult YOUR Doctor.

quency. Since the rate of change of the integrator's output depends upon the input voltage, the frequency is directly proportional to the attenuation of VR1.

Going into greater detail IC2, a 7555, is the CMOS version of the popular "555" timer chip. Connected as shown it acts as a latching voltage comparator with internal references of one-third and two-thirds of the supply. The output goes low, or negative when the input to pin 2 and pin 6 exceeds the upper reference, and goes high when the input falls below the lower one.

A feature of the CMOS 7555 is that the output voltage rises and falls all the way to both supply rails. In this circuit this makes the output frequency independent of battery supply voltage. The integrator output polarity is incorrect for driving the comparator so the unity-gain inverter IC1c corrects this.

ALL SQUARE

The final output required is 2Hz to 150Hz, a ratio of 75:1, with expanded control at the lower end of the range. A "log" law pot. would achieve the expansion but the "curves" of these vary between makes and are generally too steep for this circuit. Other non-linear types, such as square law pots. are not readily available to home constructors.

The solution chosen for this design is the dual (or stereo) linear potentiometer VR1, with the wiper of the first section supplying the top of the second. This produces something approaching a square law, not perfectly because of loading effects but adequate for the intended purpose.

Resistor R8 sets the minimum frequency. This resistor and two of the op-amp inputs are connected to a voltage of half the supply, provided by resistors R1 and R2 and buffered by IC1a. Switch S2a allows selection of a fixed resistor for 90Hz operation when the Pulsed mode of operation is chosen.

Although not shown in Fig. 1, IC1 contains a fourth op. amp. The non-inverting input of this is also connected to the half-supply rail with the inverting input and output shorted together to discourage spurious behaviour.

The oscillator runs at sixteen times the final output frequency. It's signal is taken from the "discharge" pin of IC2 with the aid of "pull-up" resistor R9, and applied to the "clock" input pin 10 of the CMOS 12-stage divider IC3.

The fourth output of IC3, pin 5, is differentiated by capacitor C5 and Pulse Width control VR3 together with resistor R12 to obtain output pulses of 40μS to 200μS from IC4c, whilst the other two inputs to this gate are positive. They will be positive when S2b is in the Normal position.

When S2b is set to Pulsed, the two inputs of IC4c will be controlled by IC4a, which combines divider outputs eight, nine and ten to produce pulses covering exactly eight cycles of the main output. This is used with the fixed 90Hz drive to produce 1·4Hz pulsed output.

The output from IC4c drives transistor TR1. When it is high, half-a-milliamp flows from TR1 collector (c) into TR2 base (b), turning it on so that the eighty volt supply appears across Amplitude control VR4 and resistor R15.

The signal from the wiper of VR4 is therefore pulses of four to eighty volts, which are buffered by transistors TR3 and TR4 to provide the final output. Blocking capacitor C6 prevents d.c. current flow,

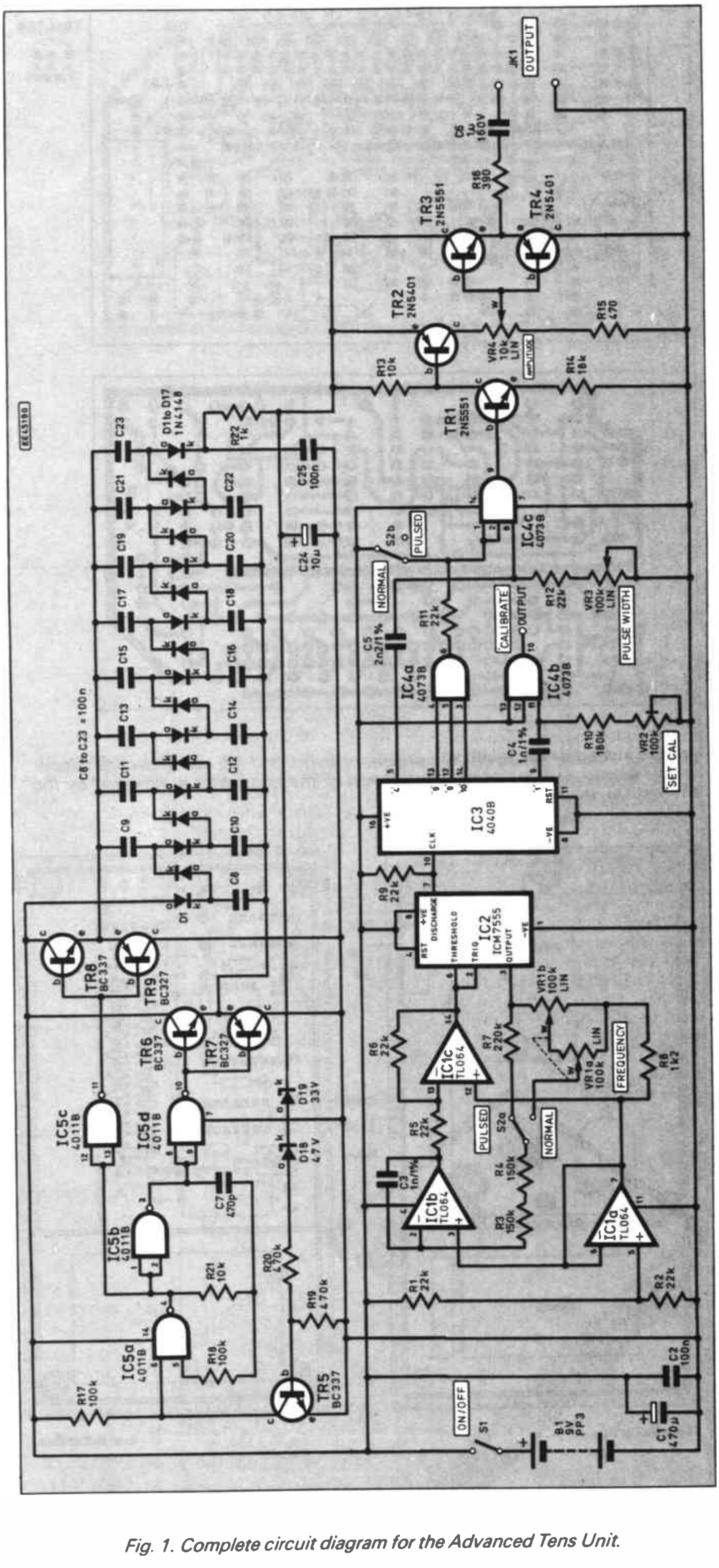


Fig. 1. Complete circuit diagram for the Advanced Tens Unit.

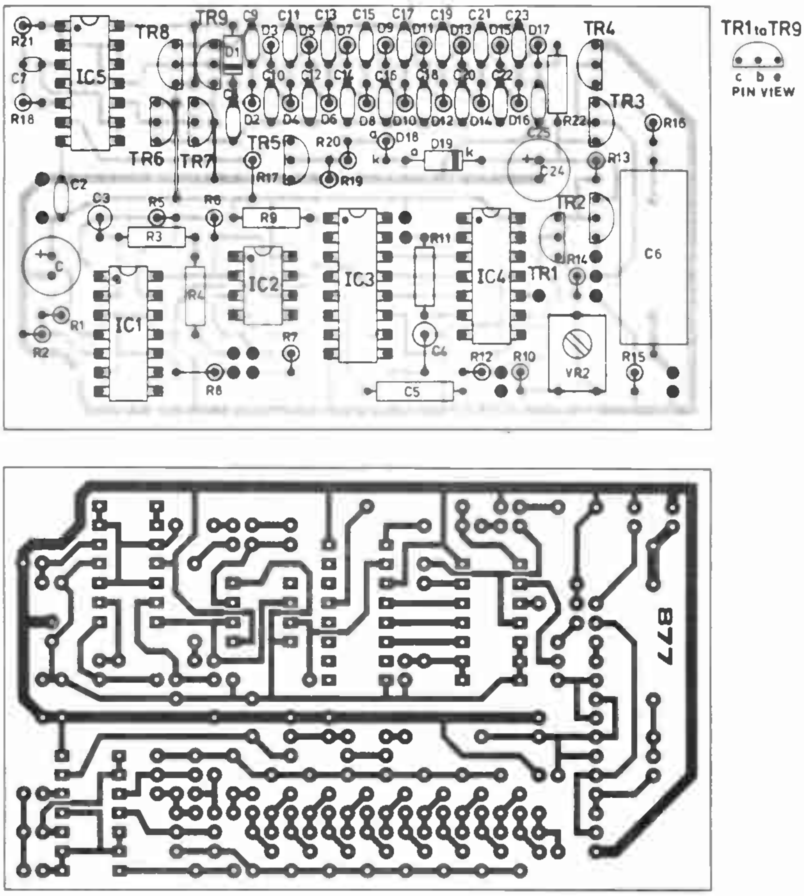


Fig. 2. Printed circuit board component layout and full size underside copper foil master pattern. Correct orientation of the transistors is indicated by the "flat" on their bodies.

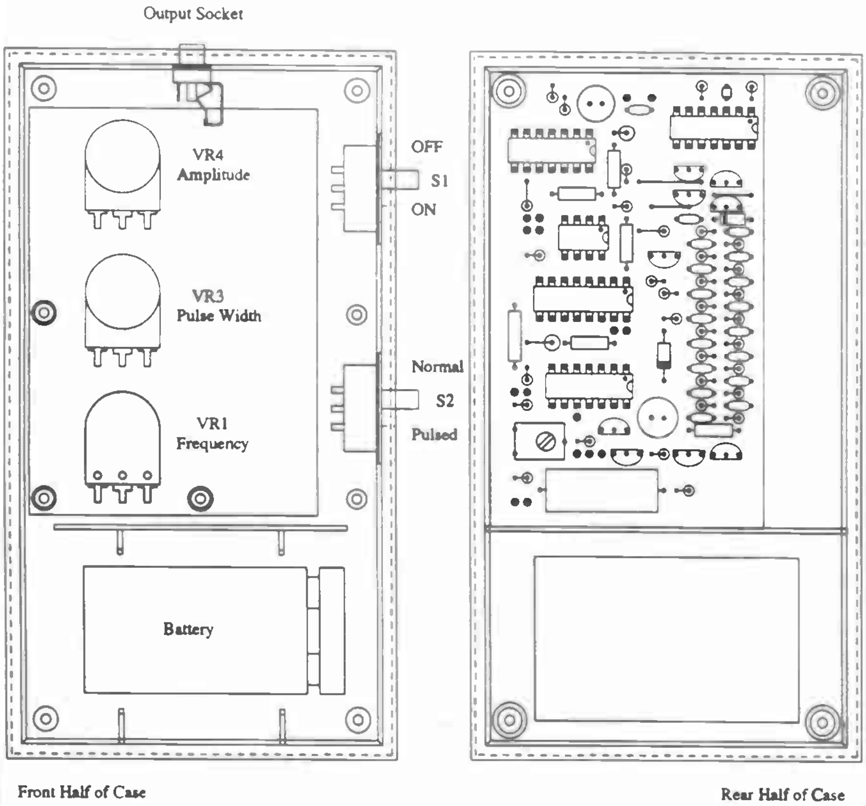


Fig. 4. Layout of components inside the two halves of the specifed case. Make sure that the connecting tags of the output socket do not touch the metal control mounting plate.

whilst resistor R16 gives protection in the event of accidental short circuit.

CALIBRATION

As the action of Frequency control VR1 is non-linear, a means of indication for calibrating it is useful. Not all constructors will have access to frequency meters or accurate 'scopes, so meter indication is preferred.

This is provided by IC4b with capacitor C4, resistor R10 and the preset VR2. It works by producing pulses of fixed length which can be averaged by a meter so that the reading displayed is directly proportional to output frequency.

In use, switch S2 is set to "Pulsed" where the frequency is within one or two percent of 90Hz and preset VR2 is adjusted for an indication of 0·9V. With S2 returned to Normal setting, the meter indicates output frequency for VR1 calibration.

The first divider output of IC3, pin 9, drives this circuit. As this runs at eight times the final frequency there should be little flicker on the meter, even when the output is just 2Hz. A minor disadvantage is that the supply voltage must remain constant for valid readings, so a good battery or a bench power supply should be used for calibration.

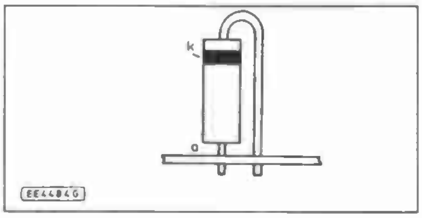


Fig. 3. Preforming the diode leads for mounting vertically on the p.c.b.

CONSTRUCTION

The advanced version of the TENS Unit is built on a small single-sided printed circuit board (p.c.b.) and the component layout and full size copper foil master pattern are shown in Fig. 2. This board is available from the *EPE PCB Service*, code 877.

The unit can be housed in a case of the constructor's choice, though the recommended box is a small black plastic item with a compartment for a PP3 battery. Much care has been taken to fit this project into it, so that it will be pocket sized. If this is used, the layout shown in Fig. 4 and the photographs should be followed to ensure everything will fit on final assembly.

The printed circuit board should be tried for fit before construction. A small piece will have to be removed from one corner to clear one of the case pillars.

Board assembly is straightforward, though the compact layout calls for care and a fine-tipped iron. As usual, physically low or small parts should be inserted first, starting with the three wire links. Positions of all components are shown in Fig. 2.

The multiplier capacitors should precede the vertically mounted diodes. All diodes except D1 and D19 are fitted vertically. For simplicity all have the marked cathode **(k)** end uppermost as shown in Fig. 3, including the other Zener, D18. Care should be taken to place them as shown. Care should also be taken when selecting transistors as four different types are used.

The i.c.s should not be fitted until testing takes place, low-profile d.i.l. sockets are recommended for them. A solder pin or short length of wire should be fitted to the "calibrate" point to allow later access. The output capacitor C6 is a 160V "working" polypropylene type, though a smaller and cheaper 100V polyester could be used. The p.c.b. will accept either.

CONTROLS

The rotary potentiometers (pots.) for the prototype model were screwed to an aluminium plate which was secured to the case with double-sided sticky tape. This prevents the nuts and threads projecting beyond the case so that small knobs will fit flush against the surface.

The pots. are miniature types, more compact than standard, especially the dual version. They could be screwed directly to the case to save effort, the choice is up to the constructor.

Dimensions for the mounting plate are shown in Fig. 5. It can be used as a template for cutting corresponding holes in the case. Two layers of double-sided sticky tape are needed to compensate for the thickness of the control securing nuts. TENS units sometimes have concealed or low-profile controls to prevent accidental operation during use, so some constructors might like to consider shortening the pot. shafts and slotting them for adjustment with, say, a small coin.

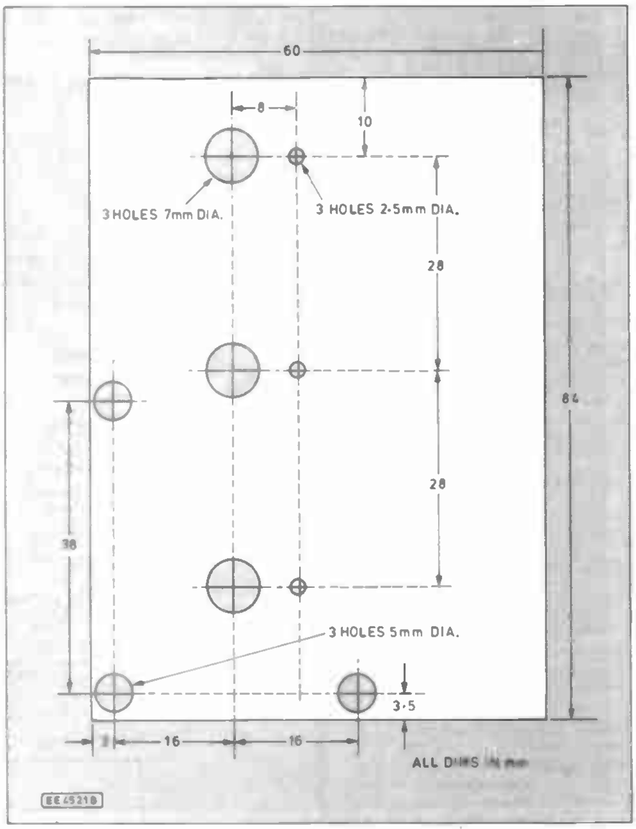
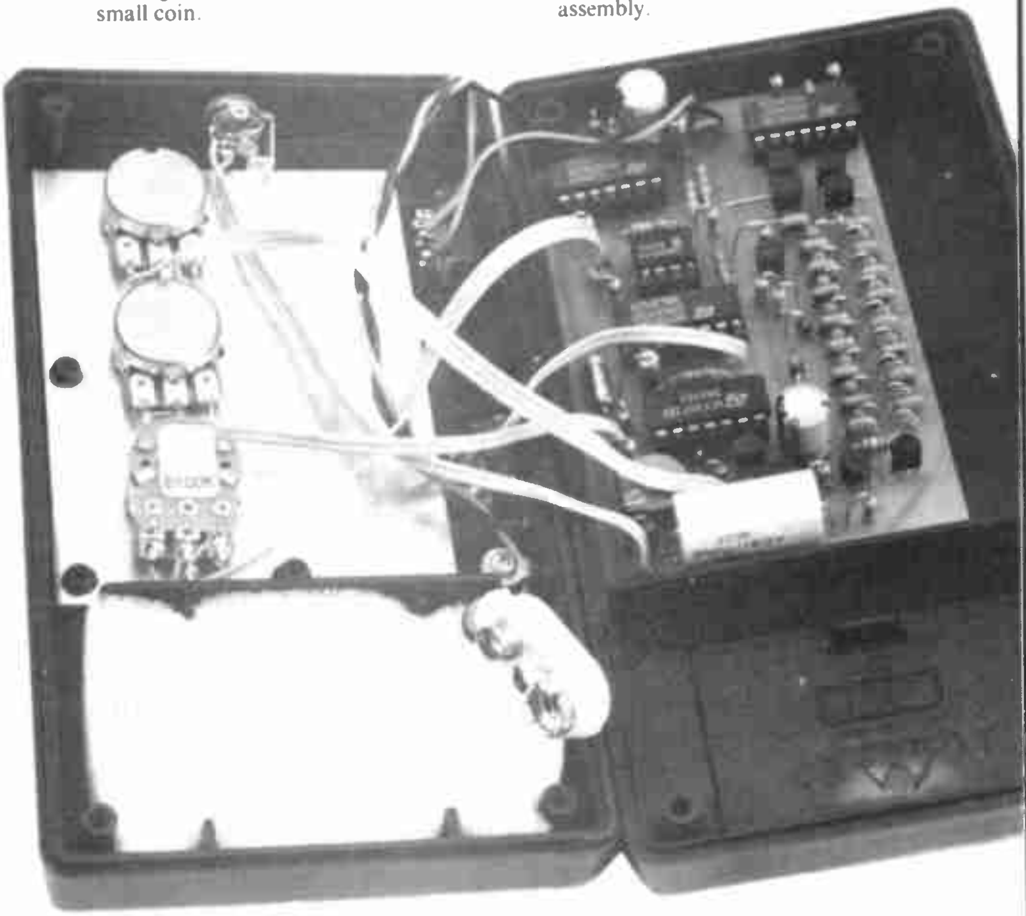


Fig. 5. Dimensions and drilling details for the mounting plate.

If the plate method of mounting is used, care should be taken when siting the output socket JK1 to avoid contact with it. The two slide switches S1 and S2, mounted in one side panel of the top-half of the case, should be placed down towards the front of the case to avoid fouling the p.c.b. on final assembly.



COMPONENTS

Resistors

R1, R2, R5, R6, R9, R11, R12	22k (7 off)
R3, R4	150k (2 off)
R7	220k
R8	1k2
R10	180k
R13, R21	10k (2 off)
R14	18k
R15	470
R16	390
R17, R18	100k (2 off)
R19, R20	470k (2 off)
R22	1k

All 0·6W 1% metal film.

See SHOP TALK Page

Potentiometers

VR1a, VR1b	100k dual min. rotary carbon, lin.
VR2	100k min. enclosed carbon preset, lin.
VR3	100k min. rotary carbon, lin.
VR4	10k min. rotary carbon, lin.

Capacitors

C1	470µ radial elect. 16V
C2, C8 to C23, C25	100n monolithic resin-dipped ceramic (18 off)
C3, C4	1n polystyrene, 1% (2 off)
C5	2n2 polystyrene, 1%
C6	1µ polypropylene, 160V
C7	470p monolithic resin-dipped ceramic
C24	10µ radial elect. 100V

Semiconductors

D1 to D17	1N4148 signal diode (17 off)
D18	47V 1·3W Zener diode
D19	33V 1·3W Zener diode
TR1, TR3	2N5551 *npn* high-voltage silicon (2 off)
TR2, TR4	2N5401 *pnp* high-voltage silicon (2 off)
TR5, TR6, TR8	BC337 *npn* silicon transistor (3 off)
TR7, TR9	BC327 *pnp* silicon transistor (2 off)
IC1	TL064 quad low-power op. amp.
IC2	ICM7555 CMOS timer
IC3	4040B CMOS 12-stage binary divider
IC4	4073B CMOS triple 3-input AND gate
IC5	4011B CMOS quad NAND gate

Miscellaneous

JK1	3·5mm mono jack socket and plug to match
B1	9V (PP3) battery, with clips
S1, S2	DPDT slide switch (2 off)

Printed circuit board available from the *EPE PCB Service*, code 887; plastic handheld case (with battery compartment), size 145mm x 80mm x 34mm; 8-pin d.i.l. socket; 14-pin d.i.l. (3 off); 16-pin d.i.l. socket; small piece of aluminium sheet – see text; multistrand connecting wire; solder etc.

Commercial electrodes – see Shoptalk page.

Approx cost guidance only **£28** *excluding electrodes*

All interconnections between the board and other components are shown in Fig. 6. Leads should be cut to length, stripped and fitted to the board before testing is commenced as they are short and therefore difficult to strip with one end already connected. As there are many connections in this small unit, the use of ribbon cable can help to keep things neat and tidy.

TESTING

Before testing is commenced, the group of four wires for switch S2a and Frequency control VR1 should be connected. A quick check for short circuits or other major problems should follow, by connecting power with none of the i.c.s in place.

Following a surge as C1 charges, the current drain should settle to about 0·2mA. If so, the supply should be disconnected for fitting of IC1 and IC2. When re-connected, the drain should be just over a milliamp, though it varies slightly with movement of VR1 and S2.

The voltage at IC1 pin 7 should be half the supply. Measured voltage at IC2 pin 3 should also be about half supply, though this is an average value as this pin should be oscillating with a 50 per cent duty cycle.

If these checks prove correct, IC3 can be inserted. The supply drain should still be just above a milliamp. If the average voltage at IC3 pin 5 is measured it should show half the supply voltage for most frequency settings, although if S2 is set to Normal and VR1 turned right down, it will be seen switching at about 2Hz. With S2 in Pulsed position, IC3 pin 14 should pulse at about 1·4Hz. The easy way to check this is to count fourteen pulses over ten seconds.

Connections to VR3 and S2b should be made before insertion of IC4. This raises the supply drain slightly. With switch S2 set to Pulsed, 1·4Hz pulses should be visible at IC4 pin 6. With a 9V supply, preset VR2 should be adjustable for an indicated 0·9 volts from the "calibrate" point on the p.c.b.

When subsequently switched to Normal, VR1 should give readings from just below 0·02V to just above 1·5V, these values corresponding directly to output frequency. In fact, a suitable DVM (digital volt meter) range will provide a digital readout in Hertz!

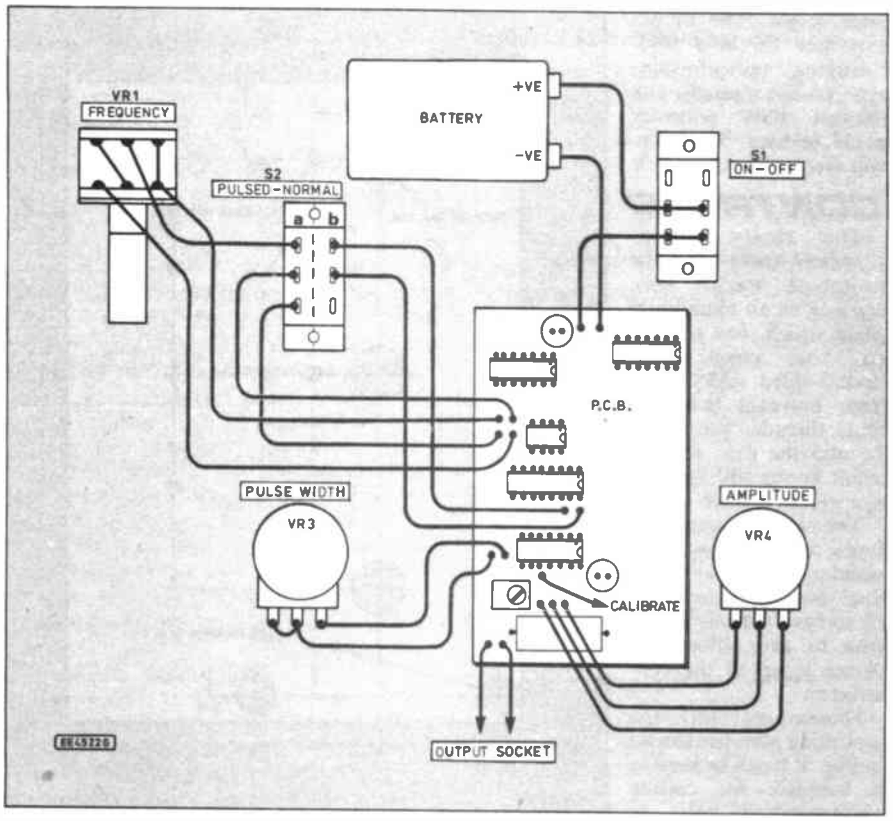


Fig. 6. Interwiring from the printed circuit board to off-board components.

The measured voltage at IC4 pin 9 will vary with positions of both control VR1 and VR3. The output here consists of narrow pulses of variable frequency and width, so altering either of these controls should produce some effect. With both turned right up, an average reading of 0·2V was obtained from the prototype.

Next, IC5 can now be fitted, raising the supply drain by a couple of milliamps. The high-voltage supply may be measured at the top of resistor R13, it should be about eighty volts.

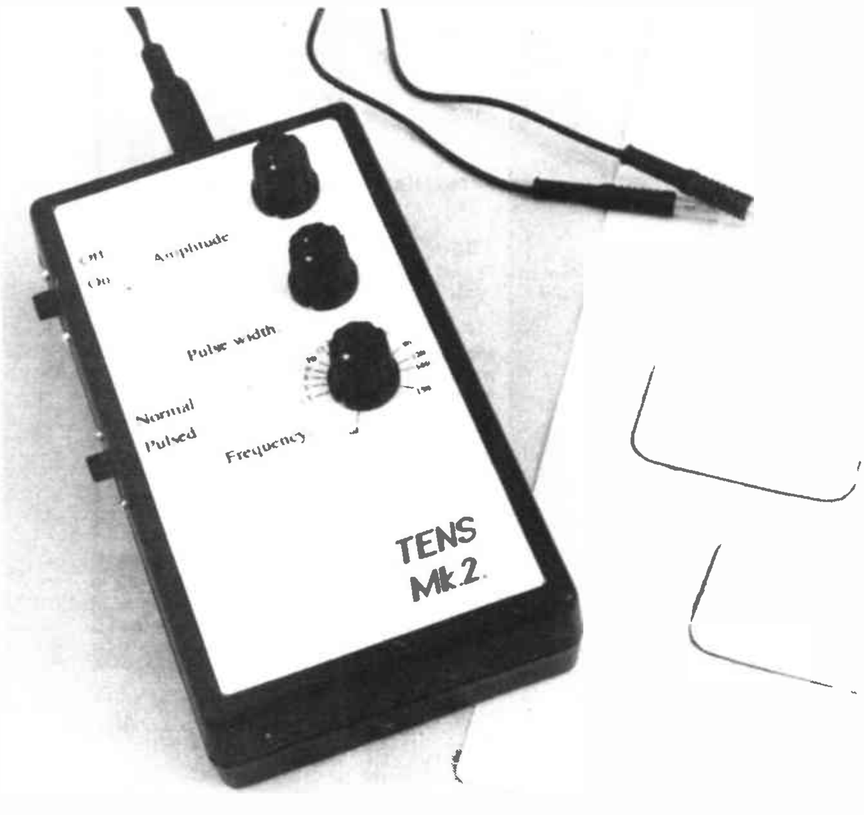
If problems are encountered here, it should be realised that during normal operation the oscillator is inhibited by the regulator most of the time. Regulator disabling is not recommended as it may result in capacitor damage, but an alternative is to reduce the supply voltage to five volts. The output will then be unable to reach it's full value, so the regulator will not operate and the oscillator and buffer stages will run continuously to simplify fault finding investigations.

The Amplitude control VR4 can now be wired to the p.c.b. This raises the supply drain to around five or six milliamps.

Despite the narrow pulsed nature of the output, a sensitive A.C. Meter should show a reading from the output leads if all three controls are turned right up with S2 is set to Normal. A value of about four volts was obtained from the prototype. Each control should be seen to reduce this when turned down. Where a 'scope is available the output pulses can be viewed, with maximum amplitude of about eighty volts, frequency 2Hz to 150Hz and width approximately 40µS to 200µS.

Providing the results of the various test readings are satisfactory, the completed p.c.b. can be secured in the rear case half with a large dollop of "Evo-Stik", "Bostik" or similar. If the unit has been assembled as shown, there should be adequate clearance between the various parts when the case halves are screwed together, although care should be taken to avoid trapping wiring.

Initially, a lead may be left connected to the "calibrate" point to aid the marking of VR1. It will be recalled that the supply voltage must remain constant during calibration.



ELECTRODES

Electrodes, as described last month, can be home-made with cotton-wool and salt water or a conductive gel such as "KY". The rule here is to avoid *direct* metallic contact with the skin and small contact areas, the contact area should be at least four square centimetres.

A good way to eliminate electrode problems is to purchase specially produced TENS electrodes from a retail supplier. These are re-useable, self-adhesive and are simply stuck in place like sticking plasters. A recommended supplier of these is: Spembley Medical Ltd., (see *Shoptalk*), who stock a range of different sizes and types.

A recommended electrode type for use with this machine is their "pack of four self-adhering "Pulsar" electrodes, size 45mm × 45mm". At the time of writing, Spembley state that they can supply these for a total of £7.76, including p&p and VAT.

A pair of leads terminated in a 3·5mm mono jack plug will be needed to connect the electrodes to the unit. Commercially produced electrodes usually have short leads fitted, terminating in 2mm sockets, so 2mm plugs may be used to connect to these.

IN OPERATION

In use, the electrodes are usually placed above or to either side of the source of pain. *It should be noted that TENS should NEVER be used by anyone with a heart pacemaker.* It is also wise to avoid placing electrodes where current will pass through the head or across the heart, and they should not be sited on the front of the neck where they may interfere with important nerve centres around the carotid sinus area.

Use of this unit will require some experiment compared with the simple version, described last month. A good procedure is to start with a frequency of around 90Hz and a pulse width about half-scale, then adjust the Amplitude control VR4 for a not-too-unpleasant tingling sensation.

Treatment should normally last twenty to thirty minutes, although longer sessions are acceptable if the need is felt for them. Pulsed operation may be preferable for longer sessions. Other settings may then be tried to discover those especially suited to the individual user.

Some people find low frequency settings, around two to six hertz, particularly beneficial. At these low settings, narrow pulse widths may also be found more comfortable with no loss of effect.

HOW IT WORKS

Some extra information regarding the way in which TENS may suppress pain has recently come to the author's attention. The stimulated release of natural opiate-like "endorphins" remains as one major theory, with at least one researcher suggesting that this effect is greater with lower pulse frequencies.

However, another widely accepted theory concerns the way in which nerves transmit pain. It has been suggested that there are pain "transmission gates" in the nervous system, which tend to be opened by signals from small, minor nerve fibres, and closed by signals from large, major nerve fibre bundles. This may explain why accident victims sometimes do not feel the pain of massive injuries for some time. It is suggested that TENS may stimulate these deeper, major nerve bundles, thus closing the appropriate pain gates, without itself causing any pain or damage.

Either way, most researchers have found that TENS produces significant results for around seventy percent of sufferers, and with this design, constructors can now try it for themselves for a minimal outlay. □

SHOP TALK
with David Barrington

EPE Microcontroller P.I. Treasure Hunter

A complete kit of parts to build the *EPE Microcontroller P.I. Treasure Hunter* is available from **Magenta Electronics** for the sum of £63.95 plus £3 carriage and packing. The kit includes the programmed microcontroller, all hardware and a headphone.

Magenta Electronics, Dept EPE 135 Hunter Street, Burton-on-Trent, Staffs. DE14 2ST. (☎ *0283 65435*). Kit code 847.

Microprocessor Smartswitch

Like the *Treasure Hunter* project, the *Microprocessor Smartswitch* also uses a special pre-programmed device which is only available from the designer. It is recommended that the specified switch plate (same source) be used as some standard types are not deep enough and can result in components touching the earthed metal wall box.

A ready-programmed PIC16C54 microprocessor chip and a single switchbox blanking plate are available – *Mail Order Only* – from **B. Trepak, Dept EPE, 20 The Avenue, London, W13 8PH** for the sum of £14.75, including postage, or £27 for two sets. Customers outside Europe are asked to add an extra £2 for postage.

The phototransistor can be the TIL78 or similar. The 4·7V 5W Zener diode used in the model is the 1N5337B and was purchased from **Electromail** (☎ *0536 204555*), code 283-132. When ordering the capacitors, make sure that C1 is rated for **240V a.c. operation** (usually listed as class X or Y).

L.E.D. Matrix Message Display and PC Interface

Of all the components needed to complete the *L.E.D. Matrix Message Display*, the pre-programmed 2756 EPROM is the one item that is a "special". A ready programmed 2756, together with a detailed operation manual, is available for the sum of £10 from the authors – *Mail Order Only* – by writing to them at **28 Blisworth Close, Yeading, Hayes, Middx. UB4 9RF.**

We understand that **Greenweld, 27D Park Road, Southampton, Hants, SO15 3UQ** (☎ *0703 236363*), are preparing kits, including p.c.b.s and programmed EPROM, and readers should contact them for details.

Advanced TENS Unit

All components needed to build the *Advanced TENS Unit* should be available from your local supplier or by mail order. It is most important that the recommended "working voltage" of 160V (polypropylene) or alternative 100V (polyster) output capacitor be used in this circuit, it must be a new unused one.

The small handheld case, to take the p.c.b., was purchased from **Maplin** and is their HH2 type, code ZB16S. Most of our advertisers should be able to offer a suitable plastic box.

Finally, a supplier of suitable 45mm square electrodes is: **Spembley Medical Ltd., Dept. EPE, Newbury Road, Andover, Hants, SP10 4DR.** The item required is a "pack of four self-adhesive *Pulsar* electrodes," size 45mm x 45mm. We understand that they can supply these for the sum of £7.76, including VAT and p&p.

Digital Water Meter

The liquid flow sensor module called for in the *Digital Water Meter* prototype model was purchased from **Electromail** (☎ *0536 204555*), code 257-133. The 4534 BCD counter i.c. (code 641-156), the 4-digit l.c.d. and handheld case were also purchased from the same source.

Circuit Surgery

For the Halogen Lamp Protector, the 3 Amp In-Rush Suppressor is supplied by **Electromail** (☎ *0536 204555*) Stock No. 210-702 priced 98p each exc. VAT, p&p – much cheaper than a new halogen bulb! The LM1830N Fluid Detector i.c. is more difficult to track down. It's available from Maplin (YY99H), or Farnell (☎ *0532 636311*).

PLEASE TAKE NOTE

MOSFET MkII Variable Bench Power Supply *(April '94)*
The type number for transistor TR3 should be ZTX605 and not 650 as shown on the circuit and in the comp list.

Prices and codes for all p.c.b.s used in this month's projects can be found on page 483.

REPORTING AMATEUR RADIO

Tony Smith G4FAI

PLENTY OF SPECTRUM?

Pressures on the radio spectrum, particularly in the USA, have resulted in the loss of amateur allocations to commercial organisations. When one considers the interest of governments in "selling" spectrum to the highest bidder it seems almost inevitable that at some time the non-commercial "parkland" of amateur radio, as it was described in one official report, will also be considered capable of raising extra revenue.

With this in mind, I was interested to read an article in *CQ Magazine*, January 1994, by Ray Kowalski, a lawyer specialising in telecommunications law. He suggests that technology is now available to develop broadband communications which could result in a spectrum glut!

The secret, he says, lies in the development of high-speed microprocessors coupled with digital signal processors, giving a capability to use vacant spectrum in the microwave region to support millions of wireless devices.

He refers to an article in *Forbes Magazine*, March 29, 1993. This contends that the narrowband FM model of radiocommunications, which is the basis for current commercial band planning and radio design, can now give way to a broadband model for which there is abundant spectrum. The theory has been around since 1948, it says, but only now has the technology caught up with it.

This could be good news for amateurs, but bad news for the legislators who hope to raise large sums from selling off spectrum.

WRC AGENDA

The International Telecommunication Union's first World Radiocommunication Conference held last November developed agendas for the WRCs to be held in 1995 and 1997.

According to a release from the ITU, WRC 95, among other things, is expected to simplify international radio regulation procedures, including new less complex processes for coordinating and registering radio frequency assignments. It will review the technical constraints associated with allocations and associated provisions for mobile satellite services (MSS) below 3GHz (which may bring pressure on UHF amateur allocations in that part of the spectrum) and review the use of h.f. bands newly allocated to broadcasting.

The provisional agenda for WRC 97 includes the examination of spurious emission issues, wind profiler radars, examination of the h.f. bands allocated to broadcasting, various satellite service matters, issues related to the implementation of the Global Maritime Distress and Safety System, and transmitting frequencies for stations in the Maritime Mobile Service.

The new biannual conferences are expected to speed up the work of the ITU. This means more work by national amateur radio societies to keep abreast of what is happening and to make appropriate representations whenever matters likely to affect amateurs are under discussion.

Just how they will manage to put up items affecting the amateur service themselves remains to be seen.

WICEN IN BUSHFIRES

Last month I mentioned briefly that WICEN (Wireless Institute Civil Emergency Network) members were active in providing support for firefighters during the bushfires in New South Wales in January.

Amateur Radio, journal of the Wireless Institute of Australia, reports that they assisted with communications in five different areas affected by the fires. In one area the State Emergency Services (SES) communications failed and WICEN was asked to completely take over communications for them.

As an example of the involvement of individual radio amateurs, Terry Ryeland VK2UX, President of the New South Wales Division of the WIA and a member of the Blue Mountains Volunteer Bushfire Brigade Communications Section, was on active duty at Katoomba Bushfire Communications Control Centre at various times over a period of almost three weeks.

Later in the month, he joined the thousands of volunteers who marched through Sydney in a parade to honour those who fought the fires.

YOUNG AMATEUR OF THE YEAR

Once again the search is on for an amateur radio enthusiast under 18 to qualify for the Young Amateur of the Year Award. Typical activities to be judged include DIY radio construction; radio operating; community service, such as emergency communications or helping the disabled in amateur radio activities; encouraging others to take up amateur radio; and appropriate school projects.

The £300 cash prize will be awarded by the Radiocommunications Agency for the most outstanding achievement between 1st August 1993 and 31st July 1994. The runner-up will receive £50, and both will be invited to visit the RA's Radio Monitoring Station at Baldock in Hertfordshire. Additional prizes will be awarded by the RSGB and in the past the radiocommunications industry has also provided prizes.

Applicants, who have not reached their 18th birthday by the closing date (31st July 1994), can enter themselves or be nominated by an adult sponsor. They need not hold an amateur radio licence. Requests for further information, applications or nominations should be addressed to Young Amateur of the Year Award 1994, Radio Society of Great Britain, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE.

ENCOURAGEMENT FOR NOVICES

As evidenced by the above Award, the Radiocommunications Agency recognises that amateur radio is an excellent training ground for those wishing to take up a scientific career. With this in mind, the UK amateur Novice licence was introduced to help youngsters get started in the hobby at a fairly basic level before going on for a full licence.

Today's young Novices can take heart, therefore, from the news that the two American scientists awarded the 1993 Nobel prize in Physics took the first steps towards their careers by becoming amateur radio operators when they were teenagers.

Dr Joseph Taylor obtained his amateur licence at the age of 13, and attributes his love of science to amateur radio. He is still a licensee, callsign K1JT, with the "JT" standing for "Joe Taylor". Although Dr Russell Hulse's licence has lapsed, he is again interested in amateur radio.

Joe Taylor, together with astronaut Linda Godwin, N5RAX, features in a new American Radio Relay League video public service announcement made to promote amateur radio in the US. *(W5YI Report)*.

AMATEUR RADIO IN EDUCATION

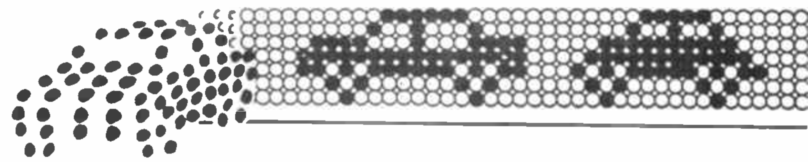
Launched at the last AGM of the Association for Science Education, STELAR (Science and Technology through Educational Links with Amateur Radio) is a group of educationalists aiming to promote amateur radio in education as a means of supporting good practice in the teaching of science and technology. To keep interested parties within the Education community in touch with future initiatives and activities it will publish a termly newsletter, *AMRED* (Amateur Radio in Education).

In their first major initiative, they have obtained substantial backing from Trio-Kenwood UK Ltd who are underwriting STELAR's first four-day course for 20 teachers from schools with no current amateur radio programme.

This will be at at Kenwood's UK headquarters in Watford, and includes local hotel accommodation, training for the Radio Amateur's Examination and "hands on" demonstrations of various aspects of the hobby at Kenwood's own permanent station.

STELAR would like to hear from any educational institutions having amateur radio activities which they have not already contacted. They would also like to hear from schools interested in taking up amateur radio as an educational activity. Please address all correspondence to the Chairman of STELAR, Richard Horton G3XWH, 7 Carlton Road, Harrogate, North Yorkshire HG2 8DD, and mention that you read about STELAR in EPE.

L.E.D. MATRIX MESSAGE DISPLAY UNIT



JULYAN ILETT and BRETT GOSSAGE

A versatile display unit with moving messages and graphics. A host of features include manually keyed or library messages plus an Interface Add-On for sending messages via your PC.

BY THE time you read this edition of *EPE*, we hope you have successfully completed the construction of the large Matrix board and the CPU board for the L.E.D. Matrix Message Display Unit. If you completed the task of wiring in the 448 l.e.d.s, without too many mishaps, the rest of work should be relatively easy; but now is not the time to become complacent and undo all the good work.

We conclude this month with the construction of the five-key keypad, testing and operating procedures. We also offer a neat Interface Add-On Unit for downloading messages from your personal computer.

CONSTRUCTION – Keypad

Construction of the Keypad board Fig. 12, requires no explanation, except perhaps for the various options that are available. The keypad p.c.b. was originally designed for right-handed use, but being completely symmetrical, makes left-handed operation equally possible.

If the left hand is used, switch S1 (on the left side of the keypad) corresponds to the little finger instead of the thumb. Alternatively, the five key connections can be reversed by cutting off the polarisation lug from the IDC socket and connecting it to the p.c.b. in reverse, although the character codes (shown in Fig. 14) will also be reversed.

Other designs of keypad may be employed that do not use the keypad p.c.b. Possibilities might include mounting five switches on the surface of a hemispherical enclosure, creating a sort of five button mouse, or perhaps along the finger positions of a bicycle handlebar grip. In both there cases, pairs of ribbon cable wires could be connected directly to the switch contacts thus eliminating the need for the keypad connector.

RIBBON CABLES

Fit the IDC sockets to both ends of the two ribbons cables using a small vice. Pin one of the IDC sockets is indicated by a small moulded arrow which should line up with the red stripe on the cable.

TESTING

Display Board

During construction of the Display p.c.b., a simple test of each of the l.e.d.s will already have been performed. Before commencing testing of the row and column switches, ensure that all the latch and buffer chips are removed from their sockets and that the voltage regulator IC21 is not fitted either.

Prepare a 6V power supply (four AA alkaline cells is ideal), and connect it to the p.c.b.'s power connector, making sure the positive and negative connections are the correct way round. A 6V supply is used during testing to ensure that the l.e.d.s are not damaged by constant illumination. Two pieces of wire should also be connected to the positive side of the supply which will be used to turn on combinations of row and column switches.

Attach the end of one of the wires to any one of the inputs (pins 1 to 9) of any one of the ULN2803A chips. The free end of the other wire can be used to turn on a row switch by touching it onto the cathode (k) of one of D1 to D7, at which point one of the l.e.d.s should light up. Any pair of row and column switches can be tested in this way, and it is quite possible to turn on more than one column switch at a time.

Following testing of the switch circuitry, the voltage regulator IC21 should be fitted

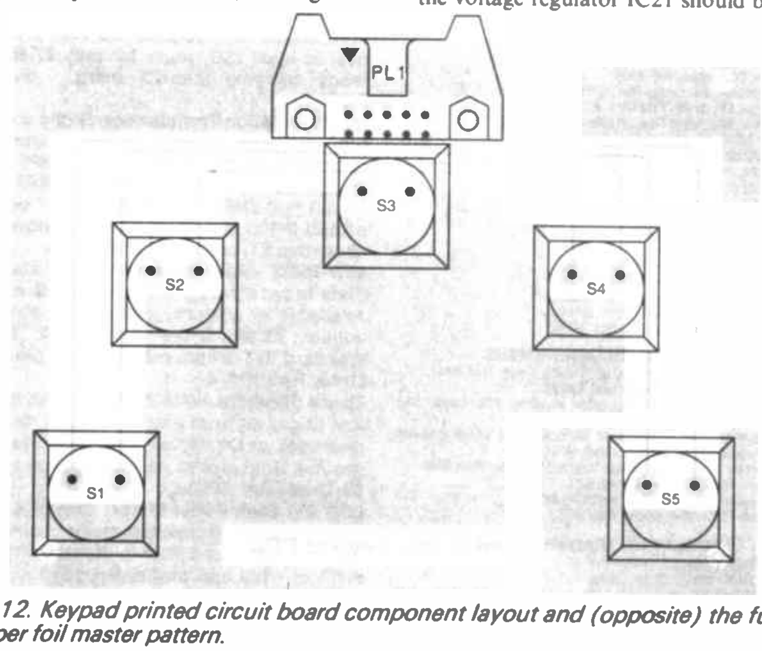
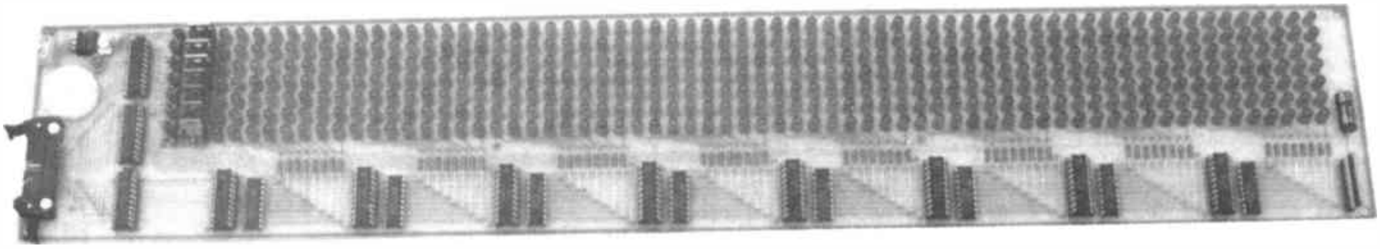


Fig. 12. Keypad printed circuit board component layout and (opposite) the full size copper foil master pattern.



and all the i.c.s. inserted into their sockets. Finally, connect a suitable power supply of between 8V and 12V to the display p.c.b.

At this point, a brief flash of light should be seen from some or all of the l.e.d.s and the piezo sounder WD1 should be heard to emit a continuous tone. The preset VR1 should be adjusted to produce the loudest tone possible from the sounder.

CPU Board

The CPU p.c.b. can be tested in the following way. With all of the i.c.s removed from their sockets, connect up a suitable power supply of between 8V and 12V. Make sure that 5V is present at all the appropriate pins of the i.c. sockets.

Switch the power off and insert all the i.c.s into their sockets. Switch on again and check that the reset circuit is functioning by pressing the Reset Switch S2. The Reset l.e.d. should light for about half a second and then go out. Check using an oscilloscope that a clean low going reset pulse is present at pin 26 of IC3.

With reference to the test waveforms Fig. 13, check that the 4MHz (250ns period) clock signal is present at pin 6 of IC3. The clock signal may not be very square, but check that it is stable.

The waveform at pin 20 of IC3 consists of eight equally spaced low going pulses, followed by three further pulses, the last of which moves around when the CPU is reset. All eight outputs of IC8 should appear to have the same waveform although they are displaced slightly in relation to one another.

Once all the tests have been performed, the three boards of the Message Display Unit can be connected together and power applied. At this point, the unit should display a start-up message, along with a short beep, providing a good indication that it is all working properly.

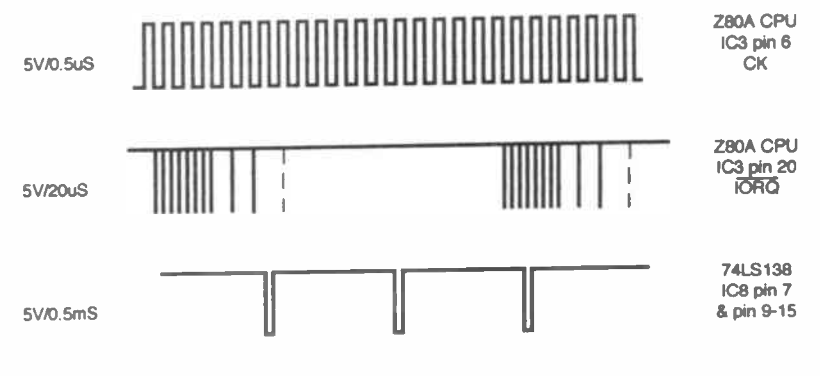
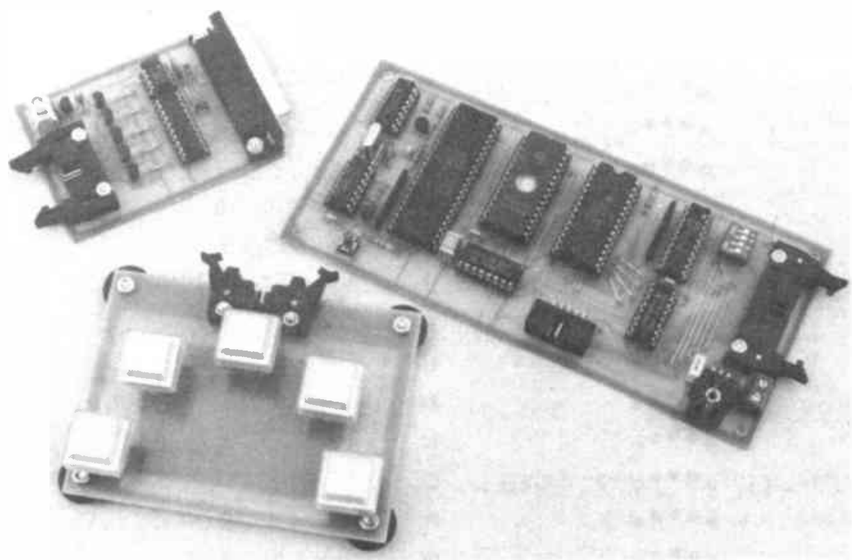
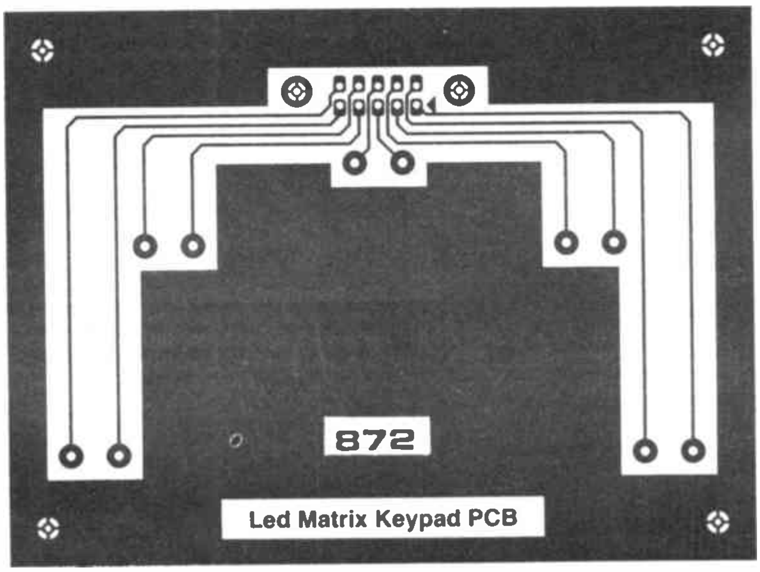


Fig. 13. Test waveforms for the CPU board.



The completed Computer Interface (top left), CPU board (above right) and the Keypad (above left).



COMPONENTS

KEYPAD

PL1	10-way R/A IDC plug
SK1, SK2	10-way IDC socket (2 off)
S1 to S5	Keyboard switch, with keytop switch caps (5 off)

Printed circuit board (set) available from the *EPE PCB Service*, code 872 (Keypad); small ABS plastic box, size to choice; 10-way ribbon cable, approx. three metres; M3 6mm bolt and nut (4 off); M2·5 12mm bolt and nut (2 off); solder, etc.

Approx cost guidance only **£8.50**

OPERATION

The five buttons on the remote Keypad allow 31 different codes to be sent to the CPU. This amounts to 26 codes for the "alhpa" characters plus SPACE and four command codes such as SHIFT. SHIFT allows a further 31 codes to be accessed, including numerals, punctuation, graphics and further commands, – see Fig. 14.

Messages can be keyed in directly, letter by letter from the keypad. A library of fixed messages (one of a set of four), can be accessed by a quick search method, or by keying the SEARCH code. A sounder beeps every time a combination of keys is pressed and then released, and provides various error condition sounds. See "Error codes".

Switching the unit on

When the unit is powered up, one of four start-up messages is momentarily displayed, dependent on the settings of the DIL switch S1 on the CPU p.c.b. This message consists of the words MATRIX, DISPLAY and then one of the four words shown in Table 1.

Table 1: DIL Switch Positions.

Switch 2	Switch 1	Message Library
Off	Off	General
Off	On	Retail
On	Off	Entertainment
On	On	Warnings

Entering a message

The diagrams in Fig. 14 show how to key in characters with either hand, using the specially shaped Keypad. You will be working "blind" i.e. what you are keying will NOT be displayed. However, you will hear a short "beep" with the entry of each character.

Displaying a message

When a message has been completely keyed in, it can be displayed by entering the DISPLAY code (See Fig. 14). The message will appear on the display, initially flashing on and off, although this can be altered by changing the display style.

Fig. 14. Keypad character allocations.

Keypad	Normal	Shift
○●●○○	A	1
○○●●●	B	2
●○●○○	C	3
●●●○○	D	4
○●○○○	E	5
●●●●○	F	6
○○○●●	G	7
●○○○●	H	8
●●○○○	I	9
●○○●●	J	0
●○○●○	K	'
●●○○●	L	<
○●●●●	M	>
○○●●○	N	&
○○●○○	O	-
●●●●●	P	£
○○●○●	Q	?
●●○●○	R	/
○○○●○	S	*
○●○●○	T	!
○○○○●	U	(
○●○○●	V	)
●●○●●	W	🚗/☎
●○●●●	X	🚢/🏠
●○●●○	Y	←/↑
●○●○●	Z	→/↓
●○○○○	Space	Link-Space
○●●●○	Clear	Backspace
○●●○●	Display	Display Style
●●●○●	Search	Multi-Search
○●○●●	Shift	Unshift

Clearing a message

To clear the display, simply enter the CLEAR command (see Fig 14), which, for convenience, is the middle three fingers. The display will go blank, but the original message can be re-displayed by entering the DISPLAY code again.

An important feature of the unit, is that a new message can be keyed in whilst the original message is still being displayed.

Searching for a message

There are two ways of searching for any of the built-in library messages. A single letter (A-Z) can be keyed, followed by the SEARCH code. This will display one of the first 26 messages in the selected library, along with its own display style. The chosen letter usually corresponds to a key word in the message and this is the quick search method.

Alternatively, a section of a known message, or string can be keyed, followed by the SEARCH code. This will access any of the messages in the selected library. For example, in the "Entertainment" message library 'V' SEARCH will call up '♡♡HAPPY VALENTINES DAY♡♡' and the same message can be accessed by keying 'VAL' SEARCH.

Error codes

A sounder has been included to assist with the keying of messages. There are essentially three sounds:-

i) Short beep – A character has been keyed.
ii) Single long beep – No message that matches the "String" has been found, or an incorrect character has been keyed in the chosen command.
iii) Two long beeps – More than one message matches the string of keyed characters. Here, you need to key in a longer SEARCH string, in order to call up a unique message.

The SHIFT key

There are only 31 possible codes accessible from the five keys, (A to Z, space, plus four command codes). Another 31 codes are accessed by keying SHIFT and then the selected code. The SHIFT must be used *before EACH* shifted character, and reverts to unshifted mode after the character is keyed in.

The range of new characters (See Fig. 14) allows for numerals, punctuation, some graphic characters, and more command codes. Again, a certain amount of practice is required to learn the codes, but the shifted characters will obviously be less frequently used than the unshifted set.

Display Style

Manually entered messages can be displayed in many features of the unit. On switch-on there is a default setting, which remains until it is overwritten by the user.

To change the display style, key in between one and six characters (using Space to leave any style unaffected) corresponding to the required change(s) shown in Table 2, and then key SHIFT

Table 2: – Display Style Options.

Char	1st Appear	2nd Disappear	3rd Hold Time	4th Once/Cont	5th Font	6th Word/Mess
A	Instant	Instant	Zero	Cont	Font 1	Word Breaks
B	Wipe	Wipe	Short	One Shot	Font 2	Message Scroll
C	Wipe from Centre	Wipe to Centre	Med		Font 3	
D	Wipe Stripe	Wipe Stripe	Long		Font 4	
E	Scroll Left	Scroll Left				
F	Scroll Right	Scroll Right				
G	Scroll Up	Scroll Up				
H	Scroll Down	Scroll Down				

Table 3: – Display Style Byte Details.

Byte and bits used	Bit Details
Byte 2 bits 7,6,5 (Appear type) & Byte 2 bits 4,3,2 (Disappear type)	000=Instant, 001=Wipe, 010=Centre Wipe, 011=Striped Wipe 100=Scroll Left, 101=Scroll Right, 110=Scroll Up, 111=Scroll Down
Byte 2 bits 1,0 (Hold duration)	00=Zero, 01=Short, 10=Medium, 11=Long
Byte 1 bit 1	0=Continuous, 1=One Shot
Byte 1 bits 7,6 (Font style)	00=Font 1, 01=Font 2, 10=Font 3, 11=Font 4
Byte 1 bit 0 (Long message handling)	0=Word Breaking, 1=Whole Message Scroll

DISPLAY. The new display style will become active on the next message.

The following sections refer to the columns in Table 2.

1st) Eight ways in which the message can ***Appear.***

2nd) Eight ways in which the message can ***Disappear.***

3rd) Four ***Hold Times*** – a delay between the above two sequences.

4th) A choice between whether the message is displayed only ***Once***, or whether it is ***continuously*** displayed.

5th) Four font selections. Here, one of four ***Fonts*** or character styles can be selected. (See Fig. 1 – last month).

6th) Two methods of handling long messages that will not fit on the display in their entirety. Either the message is broken into individual words, or it will default to a simple Scroll Left.

For example, to make the next message appear with the "Wipe" option, and disappear scrolling down, key in "BH" SHIFT DISPLAY. To change just the font selection to Font 3, key in four SPACE codes and then C SHIFT DISPLAY. Remember that all library messages have their own display styles that cannot be altered, although these will not interfere with the styles selected for manually entered messages.

Grouping messages

A group of library messages can be linked together and displayed in one long sequence by keying a string of characters and then keying SHIFT SEARCH. This string can be anything from 1 to 255 characters in length, but refers to the "quick search" messages in the selected library only. (See "Searching for a message").

Any of the messages can be displayed more than once by keying several of the appropriate letter. e.g. AABA or GCCCBCGG. This feature will continuously cycle through the selected messages, and can therefore be left run for long periods, until the CLEAR code is entered. Each selected message will be displayed only once, even if its display style is set to continuous.

MESSAGE LIBRARY MODIFICATION

Although the EPROM used in this project contains a variety of different messages, it is likely that some constructors will want to modify some of them or even create completely new message libraries of their own. The libraries have been positioned in the EPROM so that modification is made as easy as possible. They start at address 1000H and can extend as far as address 1FFFH.

The four libraries are not separated but are arranged in one long sequence, their individual start and end addresses being read by the CPU from a table located elsewhere in the EPROM which must be modified if the libraries are altered. Modification of the message libraries will of course require access to an EPROM programmer.

It may be helpful to examine the contents of the EPROM supplied as a guide. Each message in the library is constructed as shown below:

2 bytes of display style data,

n bytes of ASCII message characters (255 characters or less),

1 byte of value 0DH (carriage return).

Table 3 should be used to determine the values of the display style bytes. Bits 5, 4, 3 and 2 of byte 1 are not used and can be set to any value.

The table that holds the start and end addresses of the four message libraries is positioned in the EPROM between 0FFF0H and 0FFFH and is constructed as shown below:

0FF0H Library 1 start address low byte (note: always 00H)

0FF1H Library 1 start address high byte (note always 10H)

0FF2H Library 1 end address low byte

0FF3H Library 1 and address high byte

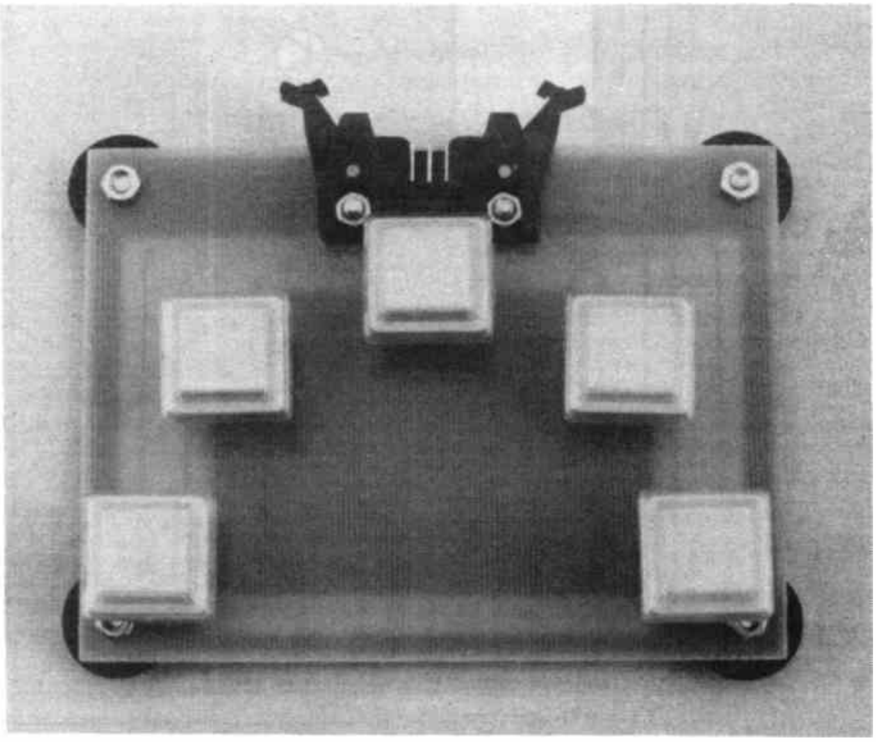
Addresses 0FF4H to 0FFFH store the addresses for Libraries 2, 3 and 4 in the same way. Note that the start address of one library will always be one greater than the end address of the previous library. For example, if Library 1 ends at address 173EH, then Library 2 will begin at address 173FH.

Ideally, each library should contain the following messages in the order shown:

i) A start-up message (displayed when the unit is switched on).

ii) 26 quick search messages (called up by characters A to Z).

iii) Additional messages (which must be called up using search strings).



L.E.D. MATRIX MESSAGE DISPLAY INTERFACE

An add-on to the Matrix Display Unit to allow easy downloading of messages from a personal computer.

Now you can add to the flexibility of your *L.E.D. Matrix Message Display Unit* by connecting this simple add-on project to the parallel port of your PC. With it, you can download messages using the QWERTY keyboard of your PC instead of the five-finger keypad. Either type in your message directly, or download a complete message from your own library, using a simple BASIC program which is supplied.

CIRCUIT DESCRIPTION

The circuit diagram of the PC Interface Add-On is shown in Fig. 15. The computer outputs a byte of data to the parallel port on execution of the 'LPRINT' command within the BASIC program (See "Software Description").

As only the five least significant bits of the byte are used, corresponding to the five fingers on the keypad, the data bits D5 to D7 are not connected. The lower five bits are fed into IC1 which is a CMOS latch with TTL compatible inputs, and the data is latched in via the $\overline{STROBE}$ signal on pin 1 of the parallel connector PL2.

This signal also triggers IC2, a CMOS 555 timer arranged in monostable mode, making the output on pin 3 go "high" which is used as the BUSY signal for the PC. After a fixed period of time determined by resistor R6 and capacitor C4, the timer chip output goes "low", allowing the program to send the next byte of data.

If however, your PC needs the $\overline{ACKNOWLEDGE}$ signal, this is derived from the BUSY signal via components R7, C5 and diode D1, which form a differentiator. These components need not be fitted under normal circumstances as most PC's can work with the BUSY signal alone.

This simple handshaking is necessary to prevent erroneous data being sent to the matrix display CPU, as different PC's run at different speeds. The outputs of IC1 are then fed into the base junctions of the five *npn* transistors TR1 to TR5, the collectors (c) of which are connected to the data lines of the keypad.

The same 12V power supply used to power the Main Display and CPU p.c.b.'s (last month) is also used to power IC1 and IC2 via connector SK1 and through a 5V low power regulator IC3. Three decoupling/smoothing capacitors C1 to C3 are included in the regulator circuit.

CONSTRUCTION

The PC Interface is built on a small printed circuit board and the topside component layout and full size copper foil master pattern are shown in Fig. 16. This board is available from the *EPE PCB Service*, code 880.

Assembling the p.c.b. is straight forward. There are no wire links, and relatively few components. The i.c.s can be mounted in

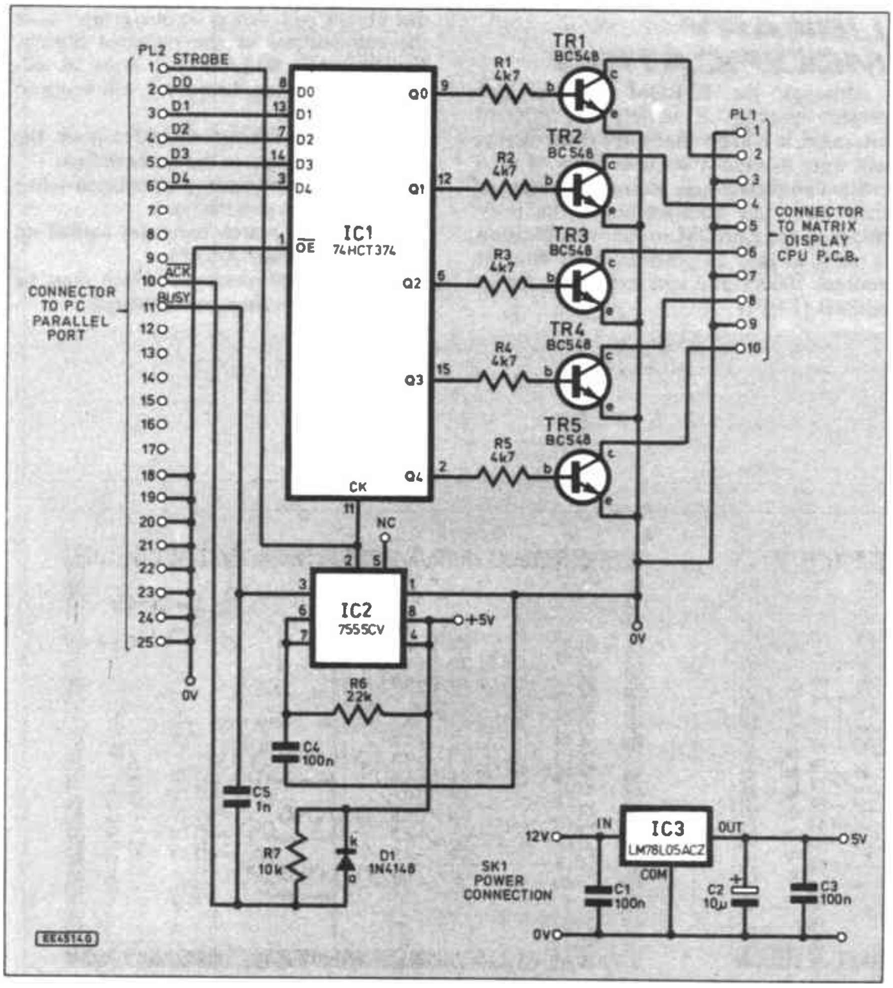


Fig. 15. Complete circuit diagram, including power supply voltage regulator, for the Computer Interface Add-On Unit.

COMPONENTS

PC INTERFACE

Resistors

R1 to R5	4k7 (5 off)
R6	22k
*R7	10k

All ⅛W 5% carbon film

Capacitors

C1, C3, C4	100n disc ceramic (3 off)
C2	10µ tantalum, 16V
*C5	1n disc ceramic

Semiconductors

*D1	1N4148 signal diode
TR1 to TR5	BC548 *npn* gen. purpose transistor (5 off)
IC1	74HCT374 octal D-type flip-flop
IC2	7555 CMOS timer
IC3	LM78L05ACZ +5V 100mA voltage regulator

Miscellaneous

SK1	2-way p.c.b. mounting power connector
PL1	10-way R/A IDC plug
PL2	25-way R/A D-type plug

Printed circuit board available from the *EPE PCB Service*, code 880; 8-pin d.i.l. socket; 20-pin d.i.l. socket; M2·5 12mm bolt (2 off); M2·5 nut (2 off); *M3 12mm bolt (2 off); *M3 nut (2 off); *M2·5 4mm countersunk bolt (2 off); *M2·5 nut (2 off); solder etc.

*Component marked with asterisk may not be required (see text).

Approx cost guidance only **£11**

sockets if required, as both are CMOS devices and can easily be damaged.

Do check that the two connectors PL1 and PL2 are secured to the p.c.b. firmly *BEFORE* soldering them in. The 25-way D-type connector supplied had two fastening pillars which hold the shell of the plug to the body.

If your PC also has pillars fitted on the socket, the two connectors will not mate, and so the pillars must be removed from the Interface connector. If these are removed, two short replacement bolts and nuts will be required to fasten the components of the connector together. The "snap-in" style fixings that connect the plug to the p.c.b., can also be removed and two more mounting bolts fitted to the p.c.b.

TESTING AND OPERATION

Testing should commence by first making sure that power to the Message Display Unit is switched off. Now, connect supply leads to the Interface p.c.b., via SK1, by tapping off a supply from either the Main Display p.c.b. or the CPU p.c.b., ensuring that the polarity is correct. Disconnect the keypad p.c.b. at the keypad end, and plug the ribbon cable into the Interface p.c.b. Connect the 25-way D-type plug to the corresponding socket of your PC (***Parallel Port only!***).

Switch on your PC and then switch on the supply to the Matrix Display Unit. (The boot-up message should come up as normal). Then run the BASIC program that you have keyed in (see opposite), and then select "A" (*Make sure your keyboard is in upper case*).

Now press a few alpha keys on the keyboard. The Matrix Display should respond by beeping with each character pressed, as with the five-finger keypad. If this is not the case, or if the PC locks up, remove the Interface p.c.b. from your computer and recheck supplies and connections.

If all is OK, key in the special CLEAR code from the PC (See Fig. 17), and then type in a test message and then the DISPLAY code. The message should now appear on the Matrix display. You can change the message display styles as with the five-finger keypad by keying in up to six characters, and then SHIFT DISPLAY.

By running part B of the BASIC program, you can download complete personalised messages in your own display styles, prepared by you at a stroke!

MATRIX DISPLAY INTERFACE – BASIC Program (Written in GW BASIC)

```
10 CLS:DIM A(65):DIM B$(5)
20 FOR T=0 TO 64:READ A(T):NEXT T
30 FOR T=0 TO 4:READ B$(T):NEXT T
40 CLS:PRINT "A - KEY IN A MESSAGE FROM THE KEYBOARD"
50 PRINT:PRINT "B - DOWNLOAD A MESSAGE FROM THE LIBRARY"
60 PRINT:PRINT "(Key selection A or B)"
70 A$=INKEY$
80 IF A$="A" THEN GOTO 110
90 IF A$="B" THEN GOTO 400
100 GOTO 70
110 CLS:PRINT "PLEASE KEY IN YOUR MESSAGE":PRINT
120 A$=INKEY$:IF LEN(A$)>0 THEN GOSUB 140
130 GOTO 120
140 B=ASC(A$):IF B<32 OR B>97 THEN GOTO 120
150 IF B=34 OR B=37 OR B=43 OR B=44 THEN GOTO 120
160 IF B=46 OR B=58 OR B=59 OR B=64 THEN GOTO 120
170 IF B=91 OR B=93 OR B=95 THEN GOTO 120
180 B=B-32:C=A(B)
190 IF B>31 AND B<64 THEN D=0 ELSE D=26
200 IF B=0 OR B=3 OR B=29 OR B=60 OR B=62 THEN D=0
210 IF B=62 THEN A$=" (SHIFT)"
220 IF B=3 THEN A$=" (SEARCH)"
230 IF B=60 THEN A$=" (CLEAR)"
240 IF B=29 THEN A$=" (DISPLAY)"
250 PRINT A$;:RESTORE
260 LPRINT CHR$(D);:LPRINT CHR$(0);
270 LPRINT CHR$(C);:LPRINT CHR$(0);
280 IF LEN(A$)>1 AND A$<>" (SHIFT)" THEN PRINT:PRINT
290 RETURN
300 DATA 01,10,00,23,31,00,12,09,16,18,08,00,00,04,00,11
310 DATA 25,06,28,05,07,02,15,24,17,03,00,00,19,22,30,20
320 DATA 00,06,28,05,07,02,15,24,17,03,25,09,19,30,12,04
330 DATA 31,20,11,08,10,16,18,27,29,45,21,00,14,00,26,00
340 DATA 31

400 CLS
410 INPUT "PLEASE ENTER YOUR MESSAGE NUMBER";A:PRINT
420 A=A-1:IF A<0 OR A>4 THEN GOTO 410
430 FOR T=1 TO LEN(B$(A))
440 A$=MID$(B$(A),T,1)
450 GOSUB 140
460 NEXT T
470 PRINT:PRINT:PRINT:GOTO 410
480 DATA "CCCAAA^=THIS IS MESSAGE 1="
490 DATA "GHDADA^=THIS IS MESSAGE 2="
500 DATA "BDBABA^=THIS IS MESSAGE 3="
510 DATA " EA CB^=THIS IS MESSAGE 4="
520 DATA "FFCABA^=THIS IS MESSAGE 5="
```

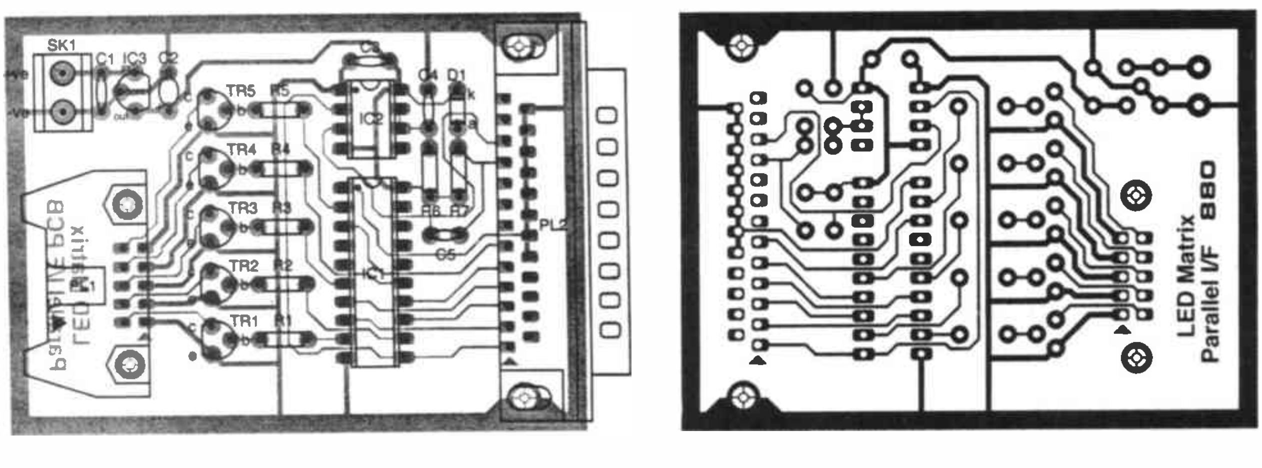
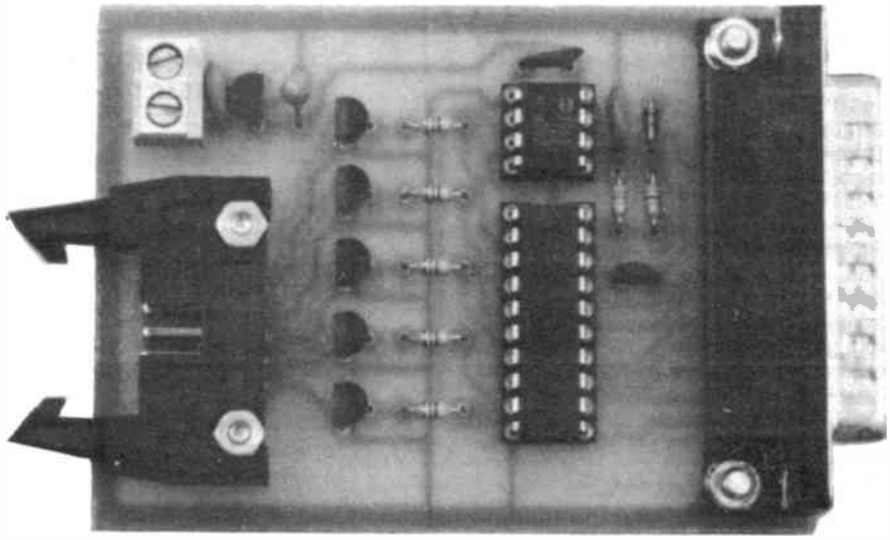


Fig. 16. Interface printed circuit board component layout and full size copper foil master pattern.

DISPLAY	=
CLEAR	/
SHIFT	^
SEARCH	#

Fig. 17. Command codes.



Layout of components on the completed Interface p.c.b.

SOFTWARE DESCRIPTION

Here is a simple description of the program. Those with better BASIC knowledge can alter functions themselves or even re-write the program completely, tailored to their own needs. Please note that there may be subtle differences between various PC keyboards (£ and $ characters may give incorrect codes).

Some characters are not used, as with the five-finger keypad, and so the program will ignore them. Command codes (SHIFT, SEARCH etc.) have been allocated keys that do not clash with any of the usable characters, and the SHIFT key on the keyboard does NOT act as the SHIFT code for the Matrix Display (See Fig. 17).

If you add to the message library, then change the higher value in line 30 and line 420 to one less than the total number of messages. Also change the size of the array B$ in line 10.

10	Two arrays – one for the 65 allowable characters, and the other is your own message library (Five test messages are included)
20-30	Read in the data
40-100	Boot-up prompt and program selection
120-130	Check to see if a key has been pressed
140	Conversion of pressed key to ASCII value and range checked for validity
150-170	Exclusion of unallowed keys
190	Activating the SHIFT code (=26)
200	Exclusion of SHIFT on special codes
210-240	Dressing of command codes
260-270	Outputting of bytes to parallel port
300-340	Character conversion data*
420	Checking invalid key entry
430-440	Selecting one character from within the message string for output
480-520	Messages – (The first 6 characters set up the display style)

*The eighth value from the end of the table corresponds to the 'Y' character. Normally this value would be 13, but it was found that the BASIC 'LPRINT' function interprets this as a 'Carriage return' code for a parallel printer, and subsequently sends a 'Line feed' code in addition to it.

To get around the problem, bit 5 of this particular byte was set high, adding a further 32 to the value, making 45. As already stated, bits D5 to D7 are not used by the matrix display as there are only five keys on the keypad, so this addition is ignored. □

INTERFACE

Robert Penfold

SOME time ago in an *Interface* article I mentioned that Texas Instruments had ceased manufacturing certain Hall Effect switches. In particular, the TL170C and TL172C were no longer to be produced. These were popular a sensors in computer controlled railway layouts, as well as in general robotics and a variety of specialised applications.

Keeping Track

As many readers will no doubt be aware, Hall Effect switches are semiconductor devices that are activated by a magnetic field. In a model train context they are used under or beside the track, and they detect a small bar magnet fitted inside the train. This enables the computer to keep track of the train, so that it can be controlled very precisely. The train can, for example, be brought accurately to a halt alongside a platform, or at the end of a siding.

A few readers wrote with suggestions for alternatives to the Texas devices, but some of these proved to be unobtainable, despite the fact they were still being advertised. Other devices were simply too expensive, or not really suitable for use with model railways or in similar applications. The only device I could find which was reasonably cheap and gave good results was the UGN3132U. Details of this device were given in the *Interface* article which appeared in the January 1994 issue of *Everyday With Practical Electronics.*

Although the UGN3132U is quite usable, it is less than ideal in that it is designed for bipolar operation. In other words, it is switched on by a north pole, and turned off by a south pole. If the magnet is applied to the other face of the component it is switched on by a south pole, and turned off by a north pole. For model railway and similar applications it is usually a straightforward non-latching on/off action that is required. With the right magnetic pole applied the device must switch on, and with the magnet removed again it should switch off again.

The Right Lines

No doubt there is an inexpensive and reasonably sensitive Hall Effect switch that provides the right action, but I have been unable to track one down. Reed relays provide an old fashioned byut still perfectly viable solution to the problem.

Another approach is to use a Hall Effect switch that is based on a low cost linear Hall Effect device. I have obtained good results using circuits based on the UGN3503U. This is a three terminal device which is very easy to use.

The UGN3503U is designed for operation on a standard five volt supply, and under standby conditions its output is at about half the supply potential. A magnetic field of one polarity produces and increase in the output voltage, and a magnetic field of the opposite polarity produces a decrease. There is a linear relationship between the strength of the magnetic field and the change in output voltage, but this is not really of any importance in the current context.

It is obviously quite simple to convert the changes in output voltage to a switching action, and it is basically just a matter of feeding the output signal into a voltage comparator circuit. Fig. 1 shows the circuit for a Hall Effect switch based on the UGN3503U.

An unusual feature of this circuit is that it will detect a magnetic field of either polarity, and it has a separate output for each polarity. This is potentially very useful, and in an up-market layout there could be two trains fitted with magnets set to give opposite polarities.

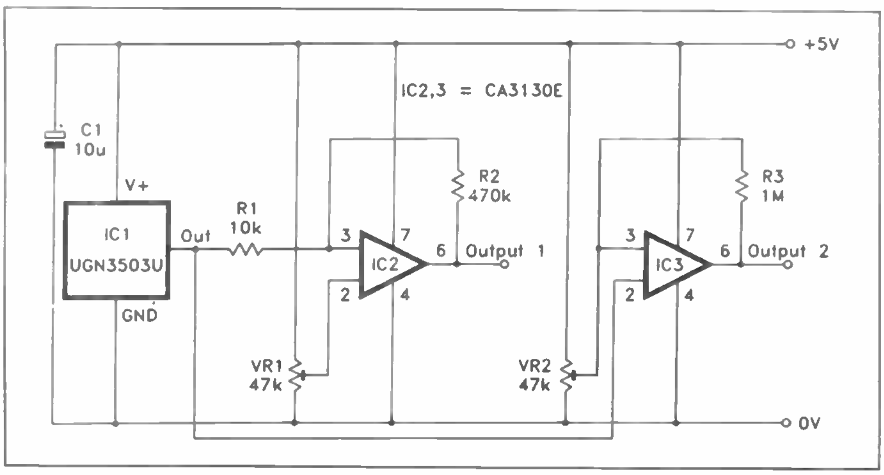


Fig. 1. Hall Effect switch based on the UGN3503U, will detect a magnetic field of either polarity.

The sensor would then have a different output for each train, making it possible for the computer to follow the progress of each train individually. Dual sensors of this type are also useful where direction sensing is required, but this is not normally needed in a model train application (where the computer is controlling the train's direction).

Circuit

The circuit is very straightforward, with a separate voltage comparator circuit to provide each output. These are both based on CA3130E operational amplifiers. The CA3130E is a good choice for an application of this type as it works well on a five volt supply with no latch-up problems. Also, its CMOS output stage will drive CMOS and most other forms of MOS logic input without any problems.

It will also drive most modern TTL inputs without any problems, but a buffer stage will probably be needed in order to drive genuine 74** series TTL inputs. The circuit will *not* work using most other operational amplifiers for IC2 and IC3.

Potentiometer VR1 is used to provide the reference voltage to the inverting input of IC2. VR1 is adjusted for a wiper voltage that is just high enough to take the output of IC2 low. The output of IC2 will then go high if a magnetic field sends the output of IC1 above its quiescent level. Resistor R2 provides a small amount of positive feedback which ensures that the output of IC2 triggers cleanly from one logic level to the other.

The reference voltage for IC3 is provided by VR2. This is set for a wiper voltage that is just low enough to take the output of IC3 low under standby conditions. The output of IC3 will then go high if the output voltage from IC1 reduces significantly. Resistor R3 provides positive feedback to ensure clean switching of IC3's output.

Single Output

If only a single output is required, simply omit IC3, VR2, and R3. Of course, with a single output the unit will only respond to a magnetic field of the right polarity. OR gating the outputs of IC2 and IC3 would give a switch that would respond to a field of either polarity, but it is probably not worthwhile doing this. In practice there is usually no difficulty in arranging things so that the sensor is

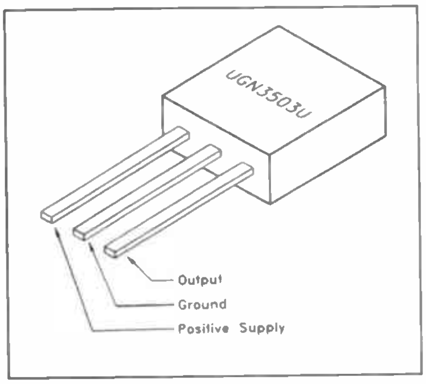


Fig. 2. Pin connections for the UGN30503U.

always presented with a field of the correct polarity. Use the "suck it and see" method to determine which end of the magnet activates the circuit.

The UGN3503U has a small flat plastic encapsulation. This does not have obvious top and bottom surfaces, which can make it difficult to decide which way round it should be connected! Fig. 2 should help to clarify matters. This shows the component oriented so that the surface having the type number is facing upwards.

Operating Range

The circuit provides quite a good operating range by magnetic switch standards. Using a Maplin "large" magnet a range of over 25 millimetres can be achieved. In practice it is probably best not to have VR1 and VR2 set for the greatest possible range, since only slight drift in the circuit would then be sufficient to send one of the outputs high under standby conditions. Backing off the presets very slightly should result in better reliability, and should still give a perfectly adequate operating range.

A small bar magnet will operate the circuit, but smaller magnets are generally less powerful, and will give greatly reduced operating range. The Maplin "small" bar magnet gives a maximum operating range of about 10 millimetres or so, which should be sufficient for most model train applications. Where possible it is better to use a larger magnet, even if only a short operating range is needed, because a more powerful magnet will give better reliability.

Pulses

It should be borne in mind that a sensor such as this only provides a brief pulse each time the train passes. Ideally the outputs of the unit would be monitored by edge sensitive inputs. These set a "flag" bit of a register within the interface chip when an input pulse is detected.

The "flags" are not reset until they have been read by the computer. If necessary they can be read a second or so after the sensor was activated. This eliminates the possibility of the short output pulses being missed.

If the outputs are not monitored via edge sensitive inputs it is essential to check them at a fairly high frequency (about a thousand times a second should suffice). Alternatively, use monostables to stretch the output pulses to about one second in duration. Checking a few times per second should then be sufficient to ensure that no pulses are overlooked.

Single Line

When experimenting with even quite rudimentary computer controlled model train layouts it is surprising how quickly you can use up all the available inputs and outputs of the computer's parallel ports. A few signals can occupy numerous output lines, especially if you use types which have three or four lights. Using one output line per signal light means that two signals could use up an entire eight bit output port.

It is actually quite easy to control a signal from a single output line. The circuit of Fig.3 is for a three colour (red - green - amber) signal that has a single input. The basic idea is to use an input pulse to move the signal from one state to the next. IC1 is a 4017BE divide by ten circuit and one-of-ten decoder. In this case only outputs "0" to "3" are actually used, and output "3" simply resets IC1 back to zero. In effect, IC1 therefore acts as a one-of-three decoder, with each output driving a signal l.e.d. (D1 to D3).

Components C1, R5, and D4 provide IC1 with a reset pulse at switch-on. This takes output "0" high, and switches on the green l.e.d. (D1). Sending an input pulse to IC1 results in output "1" going high and output "0" returning to the low state. This switches on the red l.e.d. (D2). A further input pulse takes output "2" high and output "1" low, so that D2 switches off and D3 switches on. This sets the signal to "amber". A further input pulse takes IC1 back to its original state with output "0" high, and only the green l.e.d. switched on. The circuit can be cycled through this green – red – amber – green sequence indefinitely.

Four States

The signals on my local railway line (the infamous Fenchurch Street line) seem to have four states. As a train passes a signal and progresses along the line the signal goes through a green – red – amber and amber – single amber – green sequence. The circuit of Fig. 4 is for a modified version of the signal which provides this sequence. IC1 is reset from output "4", so that it now provides a one-of-four action. Another orange (amber) l.e.d. is driven from output "3".

However, due to the gating provided by D5 to D7 this extra l.e.d. is switched on when output "2" or output "3" is high. This gives the required dual amber signal between the red and single amber signals.

In these circuits IC1 is used to directly drive the l.e.d.s with a current of a few milliamps. If necessary the l.e.d.s could be replaced with common emitter switching transistors. These could be used to drive l.e.d.s at higher currents, or to control miniature filament bulbs.

Software

Generating output pulses to control these signals is obviously very simple, but care needs to be taken when writing software for any form of serial control. The software is sequencing the signal through a set of predetermined states, and does not have direct control of the signal lights. The computer and the signal will soon get "out of sync." if due care is not taken when writing the software.

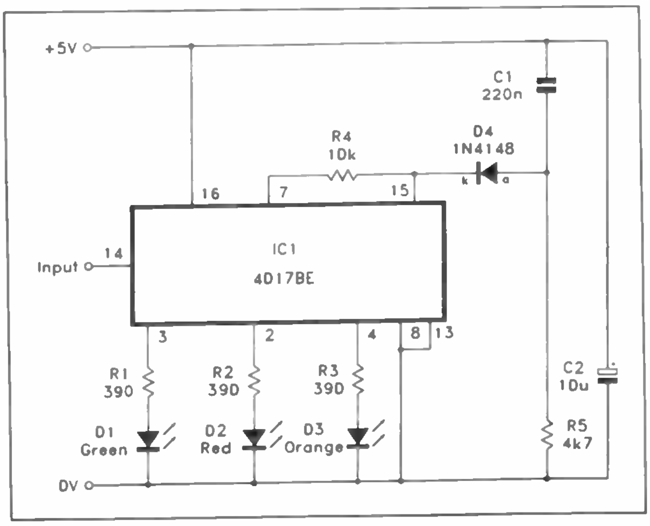


Fig. 3. A sequentially controlled three colour signal.

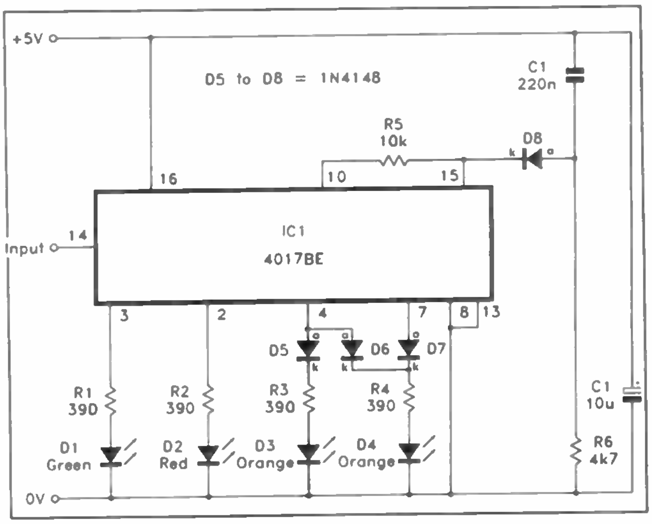


Fig. 4. Circuit diagram for the four state signal.

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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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See the first page of books – ELECTRONICS TEACH-IN No.5 – for full details.

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